

GREENHOUSE GAS EMISSIONS IN FINLAND
1990-2007

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

8 April 2009

PREFACE

Finland's National Inventory Report (NIR) under the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol (voluntary reporting in accordance with decision 15/CMP.1) contains the following parts:

- Part 1 Finland's national greenhouse gas emission inventory report (NIR) prepared using the reporting guidelines (UNFCCC 2006) and relevant parts of the Guidelines for the preparation of the information required under Article 7, paragraph 1 of the Kyoto Protocol. IPCC and other methods applied in the calculation of the emissions are described, as well as changes to the previous submission. Several summarising tables and graphs of the emission data and emission trends for the years 1990-2007 are included.
- Part 2 CRF (Common Reporting Format) data tables of Finland's greenhouse gas emissions for the years 1990-2007. The CFR tables are compiled with the latest UNFCCC CRF Reporter software (version 3.2.3).
- Part 3 SEF (Standard Electronic Tables) for reporting of Kyoto units (AAU, ERU, CER, t-CER, l-CER, RMU) in the registry 31.12.2008 and transfers of the units during the year 2008.

Since the submission of Finland's initial report under the Kyoto Protocol to the UNFCCC secretariat on 22 December 2006, only minor changes have occurred in the national system or registries. These and other information related to Article 7, paragraph 1 are presented in Annex 6. Information on emissions and removals related to Article 3, paragraphs 3 and 4, as well as on Article 3, paragraph 14 will be included in the inventory submissions from the year 2010 onwards.

The main methodological improvements and changes since the inventory submission in 2008 are listed in Chapter 10.

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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>

ES.2 Summary of trends in national emissions and removals

In 2007, Finland's greenhouse gas emissions totalled 78.3 Tg CO₂ eq. (million tonnes of CO₂ equivalent). The total emissions in 2007 were approximately 10% (~7.3 Tg) above 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 2006, the emissions decreased with approximately 2%.

A summary of the Finnish national emissions and removals for 1990-2007 is presented in Table ES.2_1.

Table ES.2_1. Finnish greenhouse gas emissions and removals in 1990-2007. The base year of the Kyoto Protocol is 1990 except for F-gases 1995.

Tg CO₂ equivalent	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Energy	54.7	54.6	53.2	52.5	54.4	59.7	56.3	62.0	60.3	57.2	56.6	54.6	59.9	62.5	70.0	65.9	54.3	65.6	63.6
Industrial Processes (excluding F-gases)	5.0	4.9	4.5	4.3	4.3	4.5	4.5	4.8	5.0	4.9	4.9	4.9	4.9	4.9	5.2	5.4	5.3	5.3	5.7
F-gases	0.10	0.09	0.07	0.04	0.03	0.04	0.10	0.15	0.24	0.30	0.40	0.58	0.73	0.53	0.71	0.73	0.89	0.80	0.93
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
Agriculture	7.1	7.1	6.7	6.2	6.2	6.2	6.3	6.2	6.2	6.1	5.9	6.0	5.9	5.8	5.7	5.6	5.6	5.6	5.5
Waste	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.8	3.8	3.6	3.5	3.3	3.2	3.0	2.8	2.7	2.5	2.5	2.4
TOTAL	71.0	70.9	68.7	67.2	69.2	74.6	71.2	77.1	75.7	72.1	71.5	69.5	74.7	76.8	84.5	80.5	68.7	79.9	78.3
Land-Use Change and Forestry	NA	-17.8	-31.5	-26.2	-24.1	-17.3	-16.6	-25.7	-19.7	-16.6	-18.5	-18.4	-21.5	-22.5	-22.5	-23.3	-28.3	-32.2	-25.3

(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 primary energy in 2007 was lowered by warmer weather than in the year before as well as the increased use of hydro power and imported electricity. The biggest reduction was seen in the consumption of coal (which includes hard coal, coke, blast furnace gas and coke oven gas), which decreased by 12 per cent. Consumption of peat increased by 9 per cent and the production volume of hydro power was 24 per cent higher than in the year before and 9 per cent higher than the average in the past decade. The availability of hydropower in the Nordic countries was better this year than in the year before. Increases were seen both in import from the Nordic countries and in export to them. Import, however, increased clearly more, which caused the small net export to the Nordic countries in 2006 to turn into net import in 2007 (Energy Statistics 2008).

Emissions in the Industrial Processes sector show a growing trend, which is largely consistent with the economic trend. 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 1990-2007 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.A), 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 2007 is presented in Figure ES.3_1.

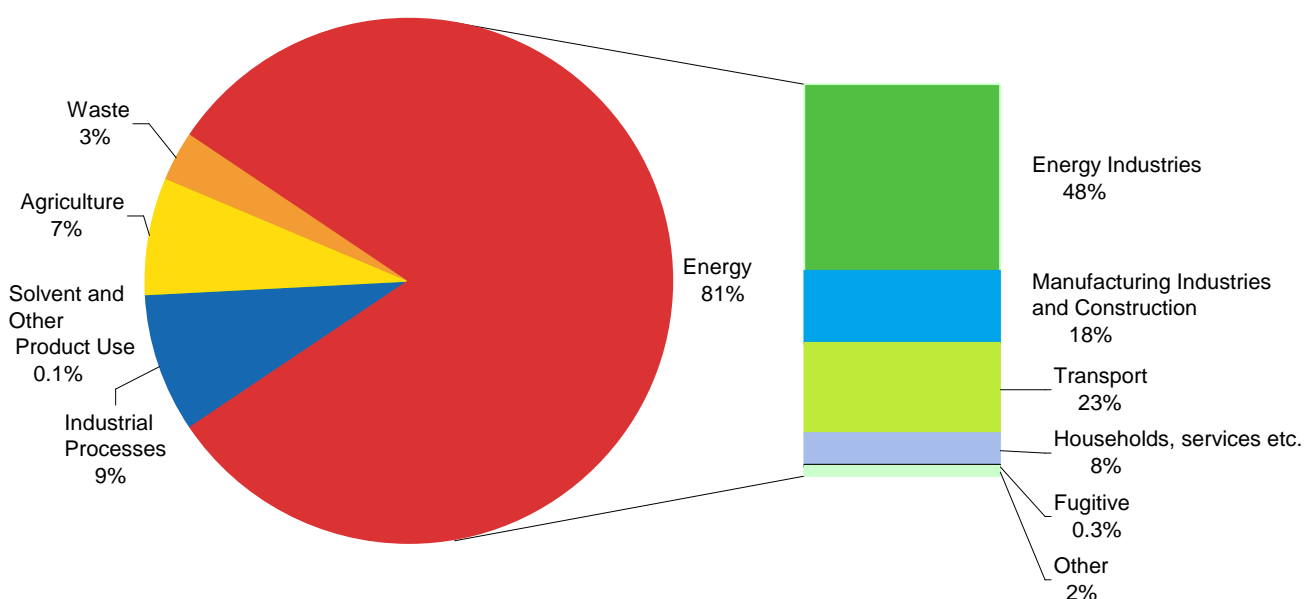


Figure ES.3_1. The composition of Finnish greenhouse gas emissions in 2007 (LULUCF sector excluded). Due to independent rounding the sums do not add up.

The energy sector is the most significant source of greenhouse gas emissions in Finland with an around 81% share of the total emissions in 2007. 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 2007 only by 1% 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 9% of total greenhouse gas emissions in Finland in 2007, being the second largest source of greenhouse gas emissions. Emissions from the process industry have increased by about 34% (~1.7 Tg CO₂ eq.) since 1990, but their share from the total greenhouse gas emissions has remained relatively constant (6 to 9 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 2007 agricultural emissions accounted for approximately 7% (5.5 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 22% 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% (2.4 Tg CO₂ eq.) of total Finnish greenhouse gas emissions in 2007. 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 over 39% 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.

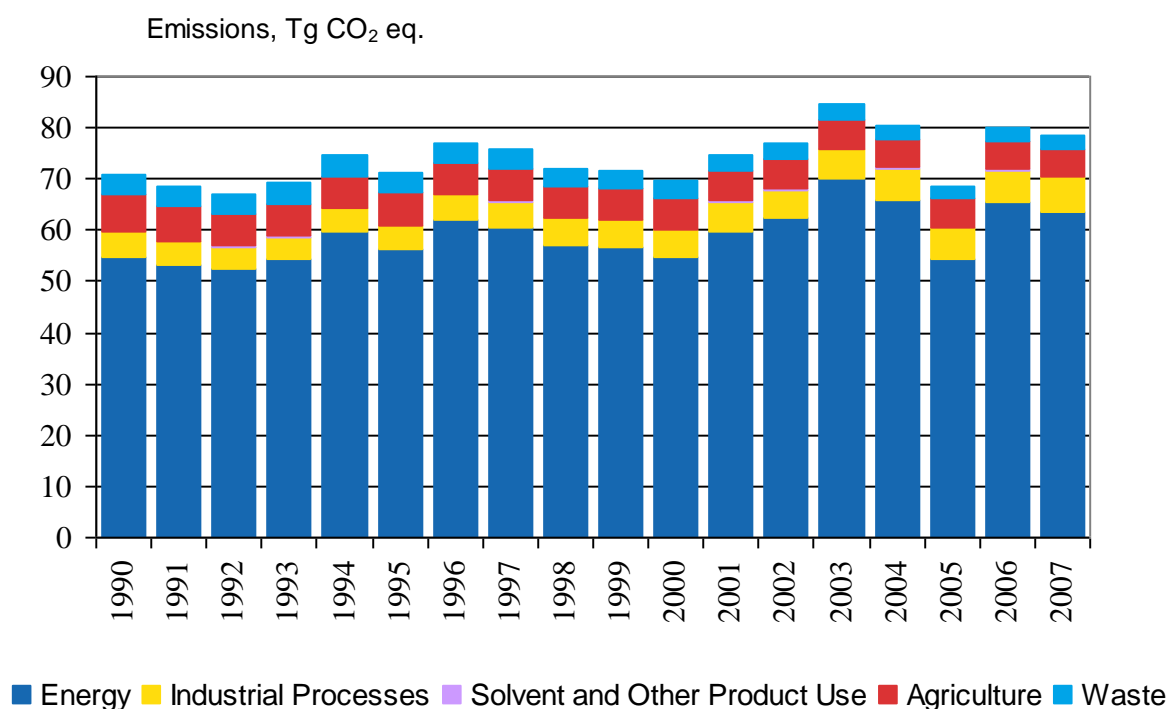


Figure ES.3_2. Greenhouse gas emissions in Finland in 1990-2007 by reporting sector (Tg CO₂ eq.).

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 other sectors during 1990-2007 (Figure ES.3_3). 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% (Metinfo).

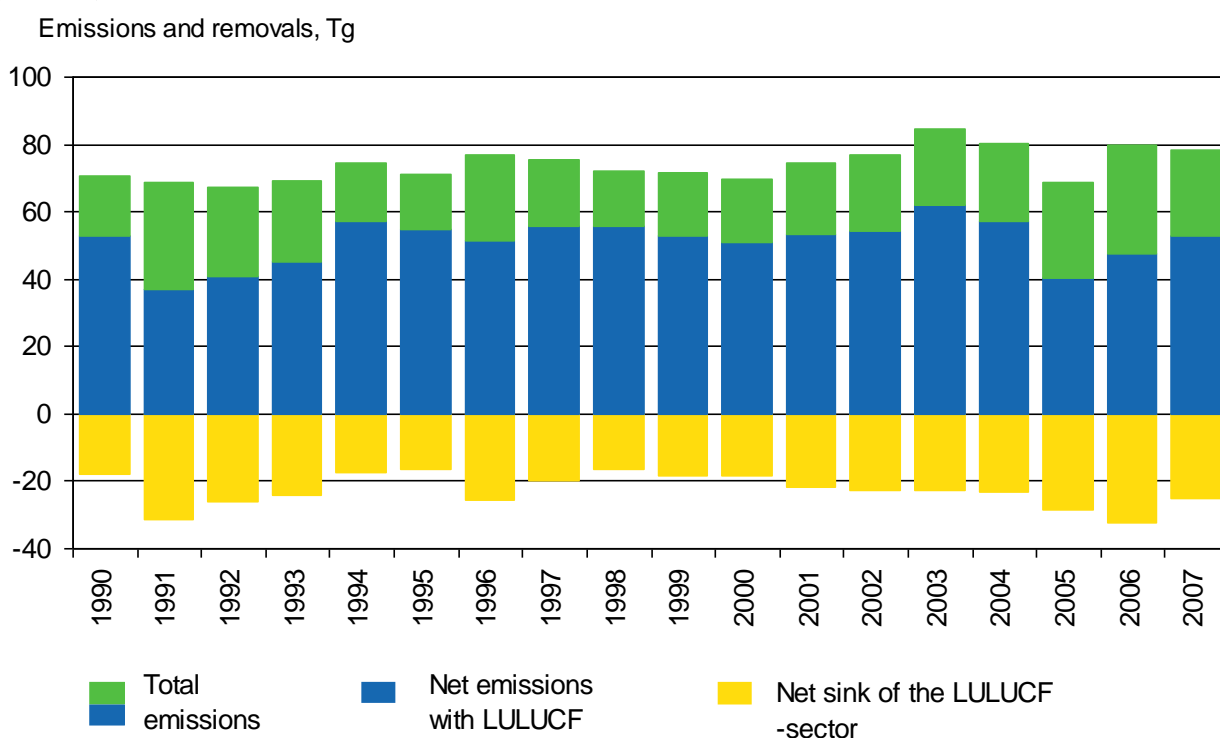


Figure ES.3_3. Net CO₂ equivalent emissions of greenhouse gases in 1990-2007 (emissions plus removals). Emissions are positive and removals negative quantities.

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 2009 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).

CO₂ emissions (so-called indirect CO₂ emissions) resulting from atmospheric oxidation of CH₄ and NMVOC emissions from fossil 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 other sources, such as fossil fuel combustion, these emissions are included in the methodology to estimate the "direct" 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 (CO, NO_x and NMVOCs) and SO₂ (actually SO_x 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 2007. Full time series of the emissions and removals from 1990 to 2007 are included in the submission.

The structure of this NIR follows the UNFCCC reporting guidelines on annual inventories (UNFCCC 2006). 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 2007. 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. 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. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in Annex 4. Annex 5 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 6 includes the supplementary information required under Article 7, paragraph 1.

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 (Ilmastomuutoksen 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.

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)*

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.

- *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 have been described in the Annex 6.

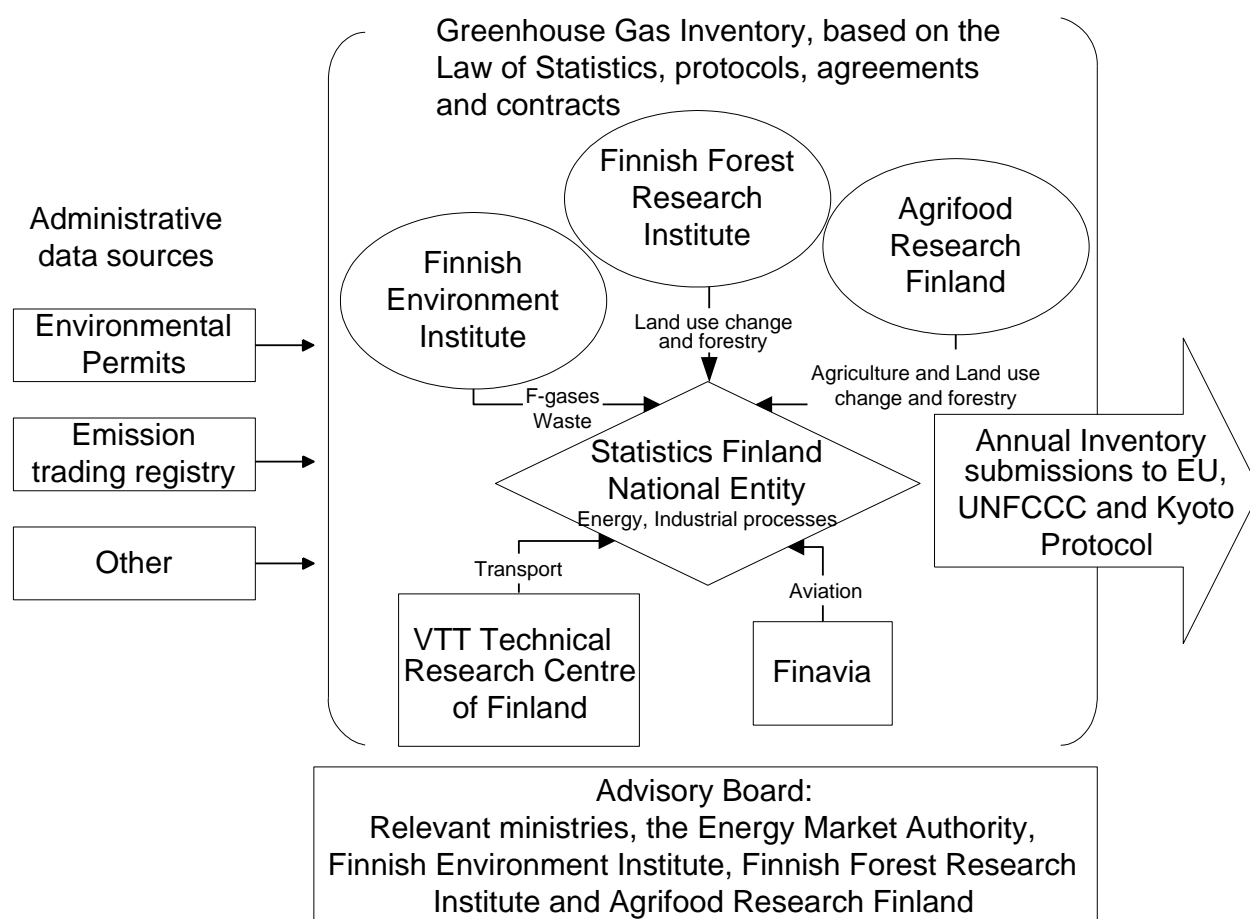


Figure 1.2_1. The National System for the Greenhouse Gas Inventory in Finland.

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

Reporting protocols	Responsible organisations
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 2009.

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 2009.

1.2.2 National Registry

The description for the national registry for initial report under the Kyoto Protocol was provided to UNFCCC secretariat as part of Finland's initial report under the Kyoto Protocol (an updated description can be downloaded at <http://stat.fi/greenhousegases>). The registry was connected to the international transaction log (ITL) of the UNFCCC secretariat in October 2008. Changes in the national registry in 2008 are addressed in Annex 6.

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 Annex 6.

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 2009 submission contains estimates for the calendar year 2007.

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 in the 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 2008 (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	Energy Statistics (Statistics Finland) Individual companies
2. (I) Industrial processes	Industrial statistics database VAHTI system Individual production plants Energy Market Authority (ETS emission data)
2. (II) Industrial processes (F-gases)	Surveys of the Finnish Environment Institute
3. Solvents and other product use	VAHTI system ULTIKA, 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 13 regional environment centres 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 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 EU ETS has modified its rules for its second trading period 2008–2012.

1.5 Brief description of the key categories

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 127 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) is then used to select 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.

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 - liquid fuels	CO ₂	Yes	Level (1990, 2007), trend	..
1.A. Fuel Combustion - solid fuels	CO ₂	Yes	Level (1990, 2007), trend	..
1.A. Fuel Combustion - gaseous fuels	CO ₂	Yes	trend	..
1.A. Fuel Combustion - other fuels	CO ₂	Yes	Level (1990, 2007), trend	..
1.A 3b. Road Transportation - gasoline - cars with catalytic converters	N ₂ O	Yes	Level (2007), trend	..
1.A 3b. Road Transportation - gasoline - cars without catalytic converters	N ₂ O	Yes	Level (1990)	..
1.A 4. Other Sectors - biomass	CH ₄	Yes	Level (1990, 2007)	..
1.A 5. Other - other fuels (mostly indirect N ₂ O from NO _x)	N ₂ O	Yes	Level (1990, 2007)	..
2.B 2. Nitric Acid Production	N ₂ O	Yes	Level (1990, 2007), trend	..
2.C 1. Iron and Steel production	CO ₂	Yes	Level (1990, 2007)	..
2.F 1. Refrigeration and Air Conditioning Equipment	HFCs	Yes	Level (2007)	..
4.A. Enteric fermentation	CH ₄	Yes	Level (1990, 2007)	..
4.B. Manure management	N ₂ O	Yes	Level (1990, 2007)	..
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N ₂ O	Yes	Level (1990, 2007), trend	..
4.D. Agricultural soils: indirect emissions	N ₂ O	Yes	Level (1990, 2007), trend	..
5.A 1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO ₂	Yes	Level (1990, 2007), trend	..
5.A 1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO ₂	Yes	Level (1990, 2007), trend	..
5.A 1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO ₂	Yes	Level (1990, 2007), trend	..
5.A 1. Forest Land remaining Forest Land - net carbon stock change in dead organic matter	CO ₂	Yes	Level (1990, 2007)	..
5.B 1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO ₂	Yes	Level (2007), trend	..
5.B 1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO ₂	Yes	Level (1990, 2007), trend	..
5.C 1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO ₂	Yes	Level (1990, 2007), trend	..
6.A. Solid Waste disposal on Land	CH ₄	Yes	Level (1990, 2007), trend	..
6.B 2 Domestic and Commercial Wastewater - densely populated areas	N ₂ O	Yes	Level (1990, 2007)	..

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 quality management system is an integrated part of the national system. It ensures that the greenhouse gas inventories and reporting are of high quality and meet the criteria of transparency, consistency, comparability, completeness, accuracy and timeliness set for the annual inventories of greenhouse gases.

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. Statistics Finland compiles and approves the inventory and submits it to the UNFCCC Secretariat and to the European Commission. 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://stat.fi/greenhousegases>) supports the GHG inventory quality management. The expert organisations contributing to the production of emission or removal estimates are responsible for the quality of their own inventory calculations.

The objective of Finland's GHG inventory system is to produce high-quality GHG inventories. In the context of GHG inventories, high quality provides that both the structures of the national system (i.e. all institutional, legal and procedural arrangements) for estimating GHG emissions and removals and the inventory submissions (i.e. outputs, products) comply with the requirements, principles and elements rising from the UNFCCC, Kyoto Protocol, IPCC guidelines and EU GHG monitoring mechanism.

The quality co-ordinator steers and facilitates the quality assurance and quality control (QA/QC) process, and experts of all calculation sectors implement and document the QA/QC procedures. The inventory working group, which consists of participants from all institutes participating in the inventory preparation, has been established to advance communication between the inventory unit and the expert organisations in charge of the different sectors. 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).

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 calculation archive the primary data used, internal documentation of calculations 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 describes at a general level how the inventory is produced by the national system. The quality of the output is ensured by the inventory experts in the course of compilation and reporting, which consist of four main stages: planning, preparation, evaluation and improvement (Fig. 1.6_1). The quality control and quality assurance elements are integrated into the production system of the inventory; each stage of the inventory includes the 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.

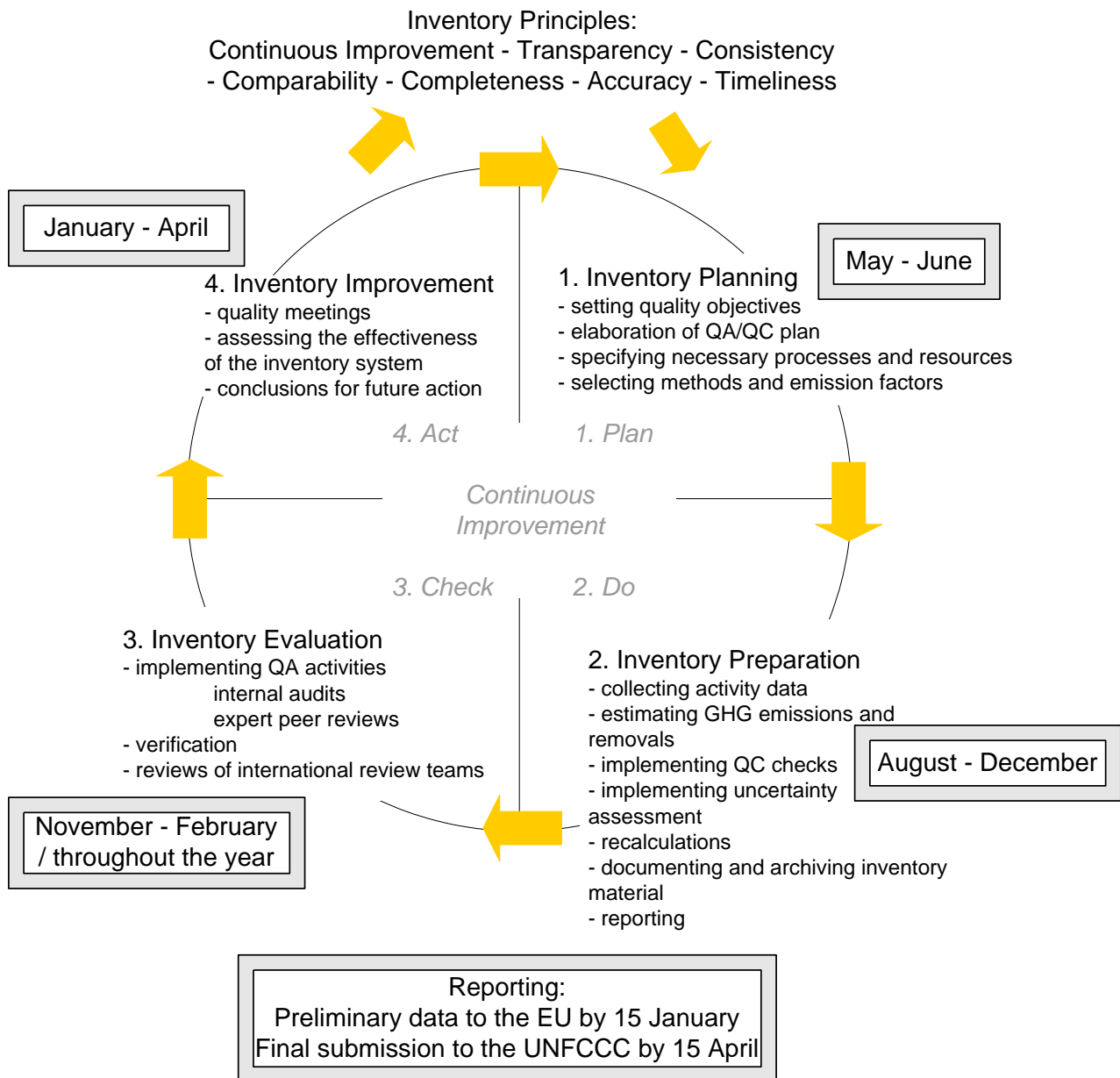


Figure 1.6_1. Inventory process.

1.6.3 QA/QC process

In addition to the above-mentioned inventory process, the quality assurance and quality control process (QA/QC process) has been identified and described to clarify the logic of quality management. The QA/QC process is a sub-process for the inventory process and the two proceed simultaneously (Fig. 1.6_2).

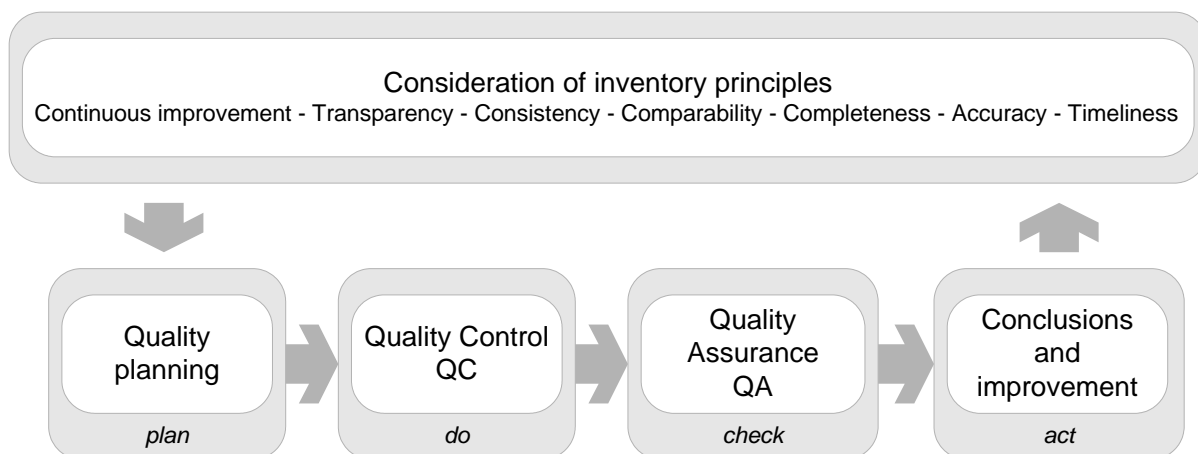


Figure 1.6_2. QA/QC process of the inventory.

Inventory principles - the framework for quality

The starting point for accomplishing a high-quality GHG inventory is consideration of the expectations and requirements directed at the inventory. The inventory principles defined in the UNFCCC and IPCC guidelines, that is, transparency, consistency, comparability, completeness, accuracy and timeliness, are dimensions of quality for the inventory and form the set of criteria for assessing the output produced by the national inventory system. In addition, the principle of continuous improvement is included.

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 concrete expressions about the standard that is aimed at in the inventory preparation with regard to the inventory principles. The objectives' aim is to be appropriate and realistic while taking account of 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 2007 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 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 over nor under 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 recipient (EU / UNFCCC) within the set time.

The quality objectives and the planned general QC and QA procedures regarding all calculation sectors are recorded as the QA/QC plan. The QA/QC plan is a checklist that specifies the actions, the schedules for the actions and the responsibilities to attain the quality objectives and to provide confidence in the Finnish national system's capability and performance to realise and 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 in use in the 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 data, identification of errors and deficiencies and documentation and archiving of inventory data and quality control actions. In addition to general QC checks, 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 QC activities directed to the Member States submissions under the European Community GHG Monitoring Mechanism (e.g. completeness checks, consistency checks) produce valuable information on errors and deficiencies that is taken into account before Finland's final annual inventory submission 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 to the finalised inventory. The inventory 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.

QA actions differ from one another in their viewpoints and timings. The actions include basic reviews of the draft report, quality meetings, internal audits, peer reviews, UNFCCC reviews of inventories and data verifications.

A basic review of the draft GHG emission and removal estimates and the draft report takes place before the initial submission to the EU (in November to December) and again before the final submissions to the EU

and UNFCCC (January to March) by the inventory working group, the inventory unit and the advisory board.

The bilateral quality meetings are first-party audits that are held between the inventory unit and the expert organisations annually before the final submission to the UNFCCC in April. For the 2007 inventory, the quality meetings have been held from January to February 2009. In the quality meetings special attention is paid to the implementation of the general QA/QC plan for the inventory. The UNFCCC review feedback and other accumulated information on the quality of the inventory are discussed at the meetings. The draft NIR is gone through to ensure the quality of the reporting. Inventory development needs and projects that require additional resources are identified and included in the inventory improvement plan to be considered by the advisory board of the inventory. In addition, the conditions (resources, schedules, procedures, support needs) for the inventory work are discussed.

There will be internal audits in place from 2009 onwards. In internal audits representatives of the inventory unit visit the expert organisations to evaluate how effectively the actual activity and the results attained in the specific calculation sectors comply with the requirements. The internal audits are directed at topical or otherwise important factors (e.g. implementation of general and source-specific QC checks, QA and verification procedures, internal documentation or archiving). Internal audits provide an in-depth analysis of the respective procedures taken to develop the inventory, and of the documentation available. Internal audits also contribute to learning and sharing of knowledge and good practices among the actors in the national system.

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. In the improvement stage of the QA/QC process, conclusions are made on the basis of the realised QA/QC measures and their results. The main findings of the bilateral quality meetings and conclusions of the inventory quality and improvement needs are 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 sector (except F-gases, 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 Chemical Divisions archives for confidential material. Responses of two most recent inventory years are archived in the office of sectoral expert before moving them into the Chemical Divisions archive.
2. Additionally, part of the survey questionnaires, official letters and 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 Environmental Management Division 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). Environmental Management Division'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 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

Agriculture

Back-up copies of the files used in the inventory calculations for agricultural emissions including CO₂ emissions from cropland and grasslands (LULUCF categories) are stored in a specific folder in the server maintained by the information services of MTT Agrifood Research Finland during the inventory process. Back-up copies from the server are stored six months by the information services. After inventory compilation the calculation results are archived in specific folders in computers of the inventory compilers 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 two main sources of information in the LULUCF sector are the national forest inventory data (NFI) and the official statistics on forestry for which Metla is the responsible organisation. The NFI data and methods are described in NFI reports (Tomppo et al. 2001, Tomppo et al. 1998, in Finnish), and by Tomppo (2006) and Heikkinen (2006). The statistics on forestry are published annually in the Finnish Statistical Yearbook of Forestry. Forestry statistics are also available on the website www.metla.fi/metinfo/tilasto. At the moment data, descriptions of data compilation and quality documentations are only in Finnish. The documentation of fellings and drain is on the website www.metla.fi/metinfo/tilasto/laatu/poistuma.htm. The activity data for the emissions from controlled burning biomass, area of prescribed burnings, bases also on the statistics. The data compilation method, reliability and consistency are described on the website www.metla.fi/metinfo/tilasto/laatu/mhmp.htm and the definition for the term prescribed burning is on the site www.metla.fi/metinfo/tilasto/laatu/mhmppterm.htm.

The Association of Finnish Peat Industry and the Vahti system (see Annex 2) (areas for peat extraction) and the company Yara Suomi Oy (volume of nitrogen fertilisers) are other data sources.

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. The original NFI data are stored as ASCII text files in the UNIX operating system. The reported results are also stored in CRF Reporter database files and MS Excel files in the network drives and CDs. Paper copies of referred articles and literature are archived in the same place at Metla. Digitising of articles which are published only as paper copies and other paper material has been started.

This description applies to

- reported land areas
- carbon stock change in living biomass on forest land
- carbon stock change in dead organic matter on forest land
- carbon stock change in soils on forest land
- greenhouse gas emissions from peat extraction areas
- greenhouse gases from biomass burning
- direct N₂O emissions from forest fertilisation
- harvested wood products.

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 5.

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 5, 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 list of key categories is the subject of further scrutiny. From this list, one or more categories are selected annually. These categories are 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. Following Tier 1 QC checks the list was amended with several minor emission categories. 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 current 127 categories provide a complete set of uncertainty estimates for the inventory. The emissions total of the analyses corresponds to the emissions total of the CRF tables (compare table 6.1 in Annex 5 to CRF table “Summary 2” for 1990 and 2007).

The uncertainty analysis suggests that the inventory level is accurate within $\pm 23\%$. Moreover, the analysis suggests that the emission trend between 1990 and 2007 is accurate within 15%-points; in other words the trend is $(0 \pm 15)\%$. Both uncertainty estimates include the sinks of IPCC sector 5: land use, land-use change and forestry.

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 4.

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 2007 Finland's greenhouse gas emissions totalled 78.3 Tg CO₂ (million tonnes of CO₂ equivalent). The emissions increased by 10% (7.3 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 2007 were 2% 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 1990-2007 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.

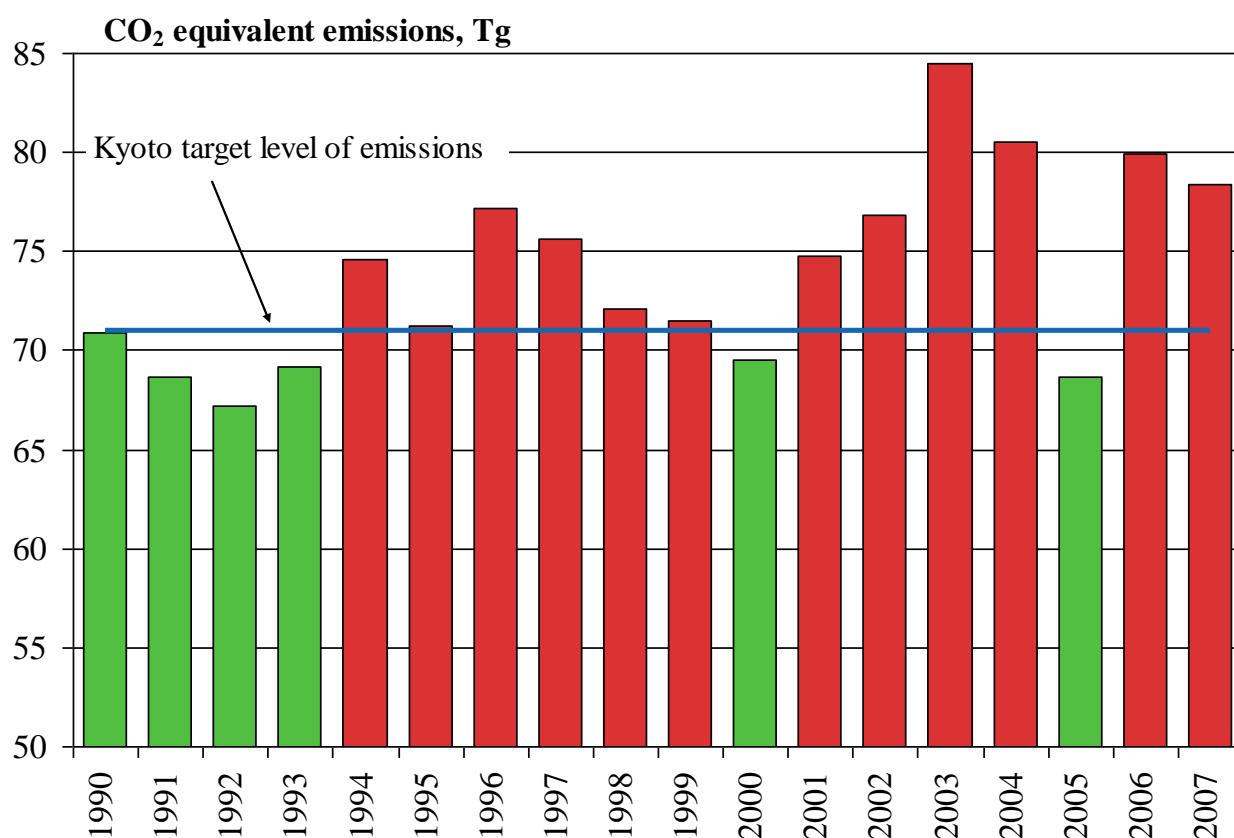


Figure 2.1_1. CO₂ equivalent emissions and the emission target of the Kyoto Protocol (Tg CO₂ eq.).

Table 2.1_1. Total greenhouse gas emissions in Tg CO₂ eq. and indexed 1990-2007 (index 1990=100).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO ₂ without LULUCF	56.6	55.0	54.2	56.1	61.4	57.9	63.9	62.4	59.2	58.7	56.7	62.0	64.4	72.0	68.1	56.3	67.7	66.1
CO ₂ with LULUCF	38.7	23.4	27.8	31.7	43.9	41.1	37.9	42.5	42.4	39.9	38.1	40.2	41.7	49.3	44.6	27.8	35.3	40.6
CH ₄ without LULUCF	6.30	6.28	6.25	6.27	6.24	6.10	6.03	5.96	5.77	5.65	5.43	5.29	5.09	4.90	4.73	4.51	4.57	4.44
CH ₄ with LULUCF	6.41	6.38	6.36	6.38	6.35	6.21	6.15	6.08	5.89	5.77	5.56	5.42	5.22	5.02	4.86	4.64	4.71	4.57
N ₂ O without LULUCF	7.85	7.27	6.72	6.84	6.95	7.15	7.11	7.08	6.91	6.80	6.85	6.77	6.81	6.91	6.91	6.95	6.85	6.86
N ₂ O with LULUCF	7.94	7.35	6.79	6.91	7.03	7.23	7.19	7.16	7.00	6.89	6.93	6.85	6.90	7.00	7.00	7.04	6.95	6.96
HFCs	0.000	0.000	0.000	0.000	0.007	0.029	0.077	0.168	0.245	0.319	0.50	0.66	0.46	0.65	0.70	0.86	0.75	0.90
PFCs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.02	0.02	0.01	0.01	0.01	0.01	0.02	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	0.04	0.02	0.02	0.04	0.02
Total Emissions	70.9	68.7	67.2	69.2	74.6	71.2	77.1	75.7	72.1	71.5	69.5	74.7	76.8	84.5	80.5	68.7	79.9	78.3
Total Emissions With LULUCF	53.1	37.1	41.0	45.1	57.4	54.7	51.4	56.0	55.5	53.0	51.1	53.2	54.3	62.0	57.2	40.4	47.7	53.1
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Index (1990=100)																		
CO ₂ without LULUCF	100	97.2	95.7	99.0	108.5	102.2	112.8	110.2	104.5	103.6	100.1	109.4	113.7	127.2	120.3	99.5	119.6	116.8
CH ₄ without LULUCF	100	99.7	99.2	99.5	99.0	96.8	95.7	94.6	91.5	89.6	86.2	83.9	80.8	77.7	75.0	71.5	72.5	70.5
N ₂ O without LULUCF	100	92.6	85.5	87.2	88.5	91.1	90.6	90.1	88.0	86.6	87.2	86.2	86.7	88.0	88.0	88.5	87.3	87.4
Total (group of three)	100	96.9	94.9	97.7	105.4	100.5	108.8	106.6	101.5	100.5	97.5	104.6	107.8	118.4	112.7	95.8	111.8	109.4
F-gases	100	71.4	39.0	35.8	44.0	103.7	158.4	258.2	316.1	421.9	609.4	774.8	559.0	750.1	773.2	945.5	850.6	989.6
Total (without LULUCF)	100	96.9	94.8	97.7	105.3	100.5	108.9	106.8	101.8	100.9	98.1	105.5	108.4	119.3	113.6	96.9	112.8	110.6

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 increased 10 Tg (i.e. 17%) since 1990. Around 93% 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 30% 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 13%, which has been occasioned mostly by the reduced nitrogen fertilisation of agricultural fields.

The development of emissions of the three main greenhouse gases in 1990-2007 (CO₂, CH₄ and N₂O) relative to the 1990 level is presented in Figure 2.2_1.

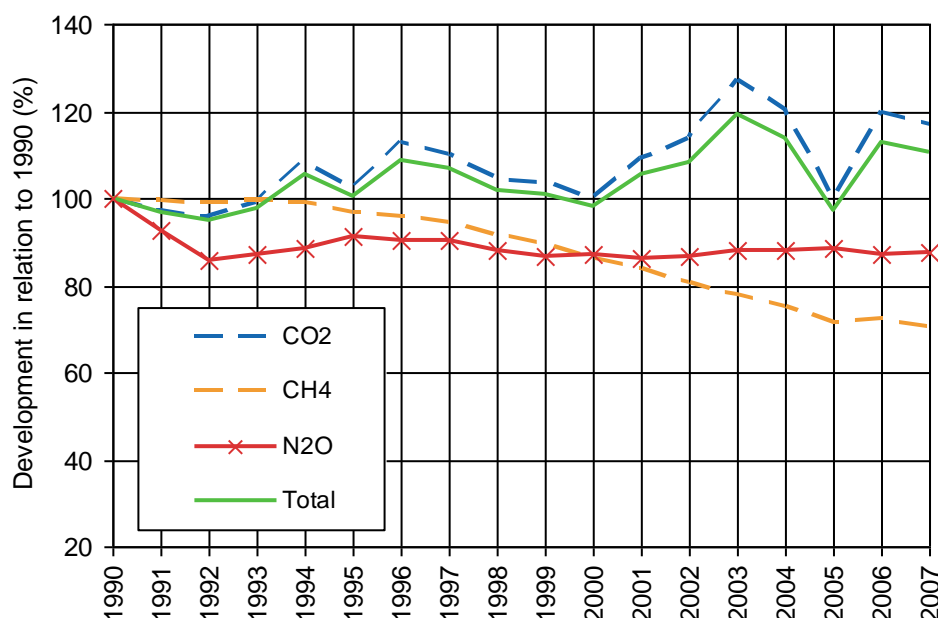


Figure 2.2_1. Relative development of CO₂, CH₄ and N₂O without the LULUCF sector in 1990-2007 relative to the 1990 level (%).

The emissions of F-gases have increased over nine-fold during 1990-2007. A key driver behind the trend has been 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 1990-2007 is presented by gas category.

Table 2.2_1. Actual emissions of HFCs, PFCs and SF₆ in 1990-2007 (CO₂ equivalent Gg).

Year	HFCs	PFCs	SF₆	Total F-gases
1990	0.02	0.07	94.4	94.5
1991	0.05	0.08	67.3	67.5
1992	0.10	0.09	36.6	36.8
1993	0.10	0.10	33.6	33.8
1994	6.52	0.12	34.9	41.5
1995	29.33	0.14	68.5	98.0
1996	77.3	0.16	72.2	149.7
1997	167.8	0.18	76.0	243.9
1998	245.2	0.21	53.2	298.6
1999	318.6	27.97	52.0	398.5
2000	501.7	22.46	51.5	575.7
2001	656.9	20.06	55.0	732.0
2002	463.4	13.37	51.3	528.1
2003	652.1	14.85	41.7	708.6
2004	695.1	12.23	23.2	730.5
2005	863.8	9.88	19.6	893.2
2006	747.7	15.43	40.4	803.5
2007	903.9	8.40	22.6	934.9

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 2007 the energy sector's emissions were 17% over the 1990 level. The total energy consumption decreased in 2007 only approximately 2% compared with the previous year, totalling 35.0 Mtoe. Total consumption of primary energy was lowered by warmer weather than in 2006 as well as the increased use of hydro power and imported electricity.

Energy industries (mainly electricity and district heating production) caused approximately 48% of the total emissions in the energy sector in 2007. Emissions from the energy industries were 60% higher in 2007 than in 1990.

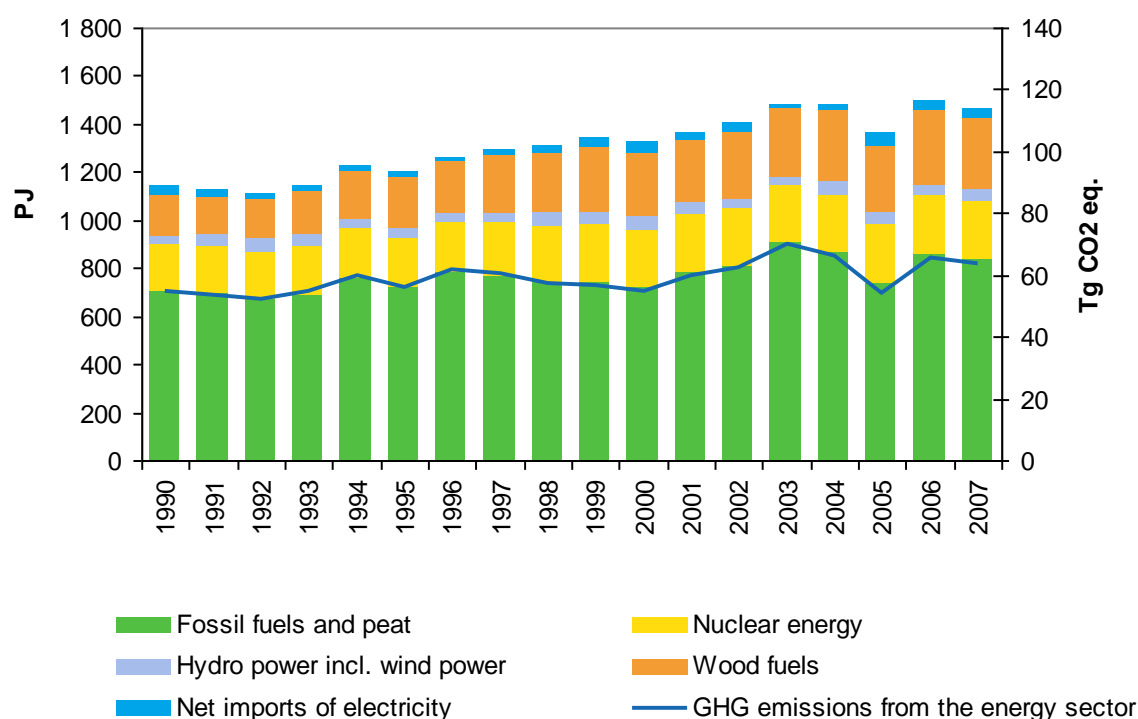


Figure 2.3_1. Development of total energy consumption by energy source (PJ) and the energy sector's greenhouse gas emissions (Tg CO₂ eq) in Finland in 1990-2007 (GHG Inventory and Energy Statistics, Yearbook 2008).

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
1. Energy	54.6	53.2	52.5	54.4	59.7	56.3	62.0	60.3	57.2	56.6	54.6	59.9	62.5	70.0	65.9	54.3	65.6	63.6
A Fuel combustion total	54.3	52.9	52.2	54.1	59.5	56.0	61.8	60.1	57.0	56.4	54.5	59.7	62.4	69.8	65.7	54.1	65.5	63.4
CO ₂																		
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	21.6	32.5	30.4
2. Manufacturing Industries and Construction	13.2	12.7	12.2	12.3	12.6	12.0	11.9	12.1	11.7	11.7	11.7	11.3	11.0	11.3	11.4	11.1	11.4	11.2
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
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	5.4	5.3	5.1	5.0	4.9
5. Other	1.19	1.02	1.03	1.03	1.14	1.20	1.22	1.13	1.38	1.23	1.27	1.26	1.26	1.35	1.16	1.09	1.13	1.02
CH ₄	0.307	0.301	0.299	0.297	0.299	0.297	0.304	0.303	0.302	0.296	0.285	0.293	0.299	0.300	0.291	0.280	0.285	0.276
N ₂ O	1.00	0.99	1.00	1.05	1.10	1.08	1.15	1.19	1.20	1.23	1.22	1.30	1.36	1.44	1.45	1.37	1.49	1.49
B Fugitive fuel emissions	0.23	0.25	0.28	0.34	0.25	0.25	0.24	0.27	0.22	0.19	0.18	0.19	0.18	0.18	0.17	0.19	0.17	0.19
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	0.14
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
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
2. Industrial Processes	5.0	4.6	4.3	4.3	4.6	4.6	4.9	5.2	5.2	5.3	5.5	5.6	5.4	5.9	6.2	6.2	6.1	6.7
CO ₂	3.2	3.1	3.0	2.9	3.1	3.0	3.3	3.5	3.5	3.6	3.5	3.6	3.5	3.8	3.9	3.7	3.8	4.2
CH ₄	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
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
HFCs	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.17	0.25	0.32	0.50	0.66	0.46	0.65	0.70	0.86	0.75	0.90
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
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	0.04	0.02	0.02	0.04	0.02
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
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
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

IPCC Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
4. Agriculture	7.1	6.7	6.2	6.2	6.2	6.3	6.2	6.2	6.1	5.9	6.0	5.9	5.8	5.7	5.6	5.6	5.6	5.5
CH ₄																		
A. Enteric Fermentation	1.93	1.85	1.79	1.79	1.79	1.69	1.70	1.73	1.69	1.66	1.66	1.64	1.64	1.62	1.59	1.58	1.58	1.56
B. Manure Management	0.23	0.22	0.22	0.22	0.23	0.25	0.25	0.26	0.26	0.26	0.26	0.25	0.26	0.27	0.27	0.28	0.28	0.28
N ₂ O																		
B. Manure Management	0.66	0.61	0.58	0.57	0.57	0.57	0.58	0.60	0.59	0.56	0.56	0.53	0.53	0.52	0.51	0.51	0.51	0.50
D. Agricultural Soils	4.30	4.00	3.62	3.65	3.63	3.82	3.69	3.62	3.53	3.44	3.49	3.43	3.39	3.34	3.25	3.23	3.21	3.19
F. 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	0.001
5. Land-Use Change and Forestry	-17.8	-31.5	-26.2	-24.1	-17.3	-16.6	-25.7	-19.7	-16.6	-18.5	-18.4	-21.5	-22.5	-22.5	-23.3	-28.3	-32.2	-25.3
CO ₂	-18.0	-31.7	-26.4	-24.3	-17.5	-16.7	-25.9	-19.9	-16.8	-18.7	-18.6	-21.7	-22.7	-22.7	-23.5	-28.5	-32.4	-25.5
CH ₄	0.102	0.101	0.107	0.107	0.112	0.113	0.117	0.121	0.123	0.126	0.127	0.129	0.127	0.126	0.134	0.133	0.133	0.130
N ₂ O	0.085	0.080	0.071	0.067	0.077	0.073	0.076	0.084	0.086	0.083	0.085	0.086	0.086	0.085	0.092	0.090	0.097	0.094
6. Waste	3.98	4.02	4.04	4.04	3.98	3.93	3.85	3.75	3.60	3.52	3.32	3.19	2.98	2.80	2.67	2.46	2.52	2.43
CH ₄	3.82	3.86	3.88	3.88	3.83	3.77	3.68	3.59	3.44	3.37	3.16	3.03	2.82	2.64	2.50	2.29	2.35	2.26
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	0.157	0.161	0.162	0.165	0.163	0.169
7. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
National Total Emissions with LULUCF	53.1	37.1	41.0	45.1	57.4	54.7	51.4	56.0	55.5	53.0	51.1	53.2	54.3	62.0	57.2	40.4	47.7	53.1
NATIONAL TOTAL EMISSIONS	70.9	68.7	67.2	69.2	74.6	71.2	77.1	75.7	72.1	71.5	69.5	74.7	76.8	84.5	80.5	68.7	79.9	78.3

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 1.48 million terajoules (TJ) in 2007. The decrease from 2006 amounted to nearly two per cent. The biggest reduction was seen in the consumption of coal (which includes hard coal, coke, blast furnace gas and coke oven gas), which decreased by 12 per cent. The consumption of natural gas, wood fuels and oil decreased as well. Consumption of peat increased by 9 per cent and the production volume of hydro power was 24 per cent higher than in the year before and 9 per cent higher than the average in the past decade. Net imports of electricity were 10 per cent higher than in 2006. The share of renewable energy of total energy consumption stayed nearly on level with the year before (Energy Statistics 2008).

The use of fuels in the production of electricity and heat decreased by 5 per cent in 2007. Electricity production with renewable energy sources grew by 25 per cent in 2007, as production of hydro power, which has been decreasing in the past few years, started to increase. Electricity produced with wood fuels decreased by 16 per cent and that produced with black liquor from the forest industry by 3 per cent. The volume of electricity produced with wind power and other renewable energy sources was some 20 per cent higher than in the year before. Production of nuclear power grew by 2 per cent. Electricity produced with Nordic hydro power was amply available for import, so the production of domestic condensing power decreased by 18 per cent. The volume of electricity generated with combined heat and power production decreased by 3 per cent (Statistics Finland, 2008).

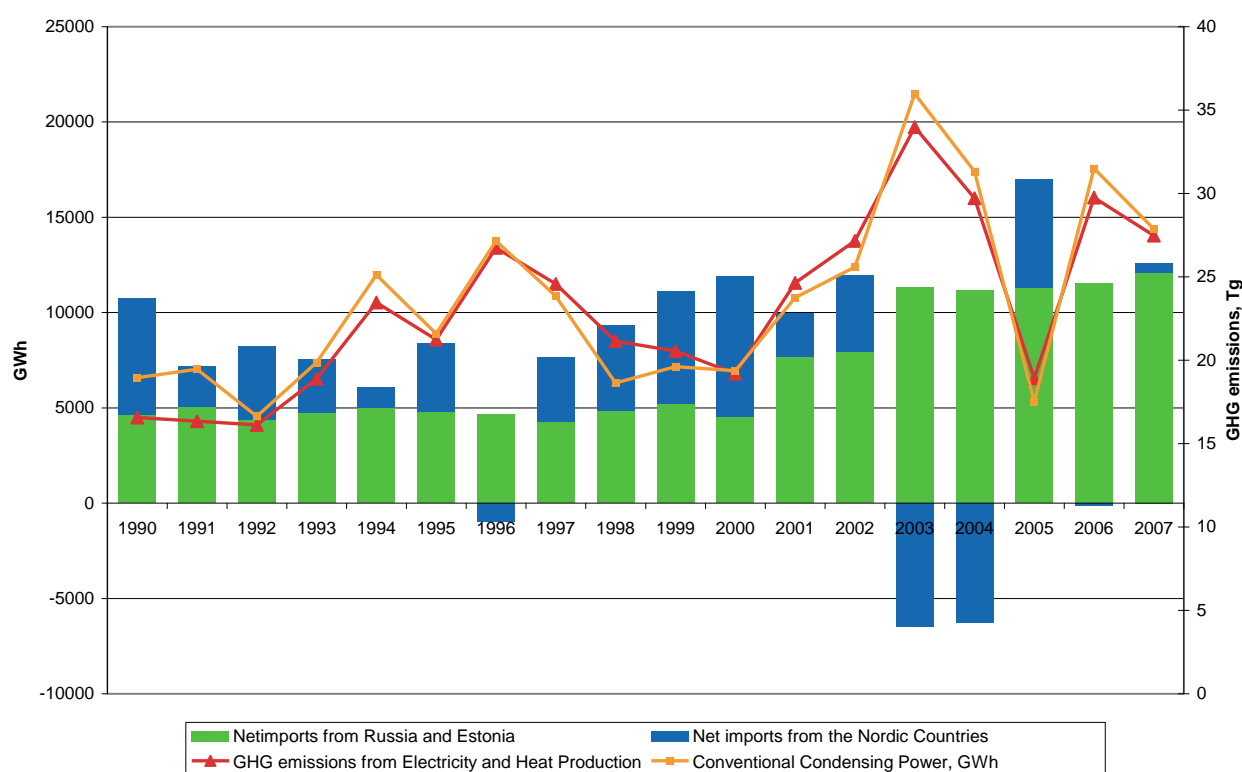


Figure 2.3_2. Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity from the Nordic Countries and Russia and Estonia and production of conventional condensing power for 1990-2007 (Energy Statistics, Yearbook 2008).

Manufacturing industries and construction produce much energy themselves. Their share of the energy-related emissions was around 18% in 2007. Emissions from manufacturing industries and construction have declined by 14% since 1990. The main reason behind this trend is increased use of biofuels in the forest industry.

Emissions in the transport sector have grown by around 15% 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 fifth in 2007.

Emissions from the residential sector have decreased by 28% and from commercial sectors by over 44% 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 1990-2007 by IPCC source sector.

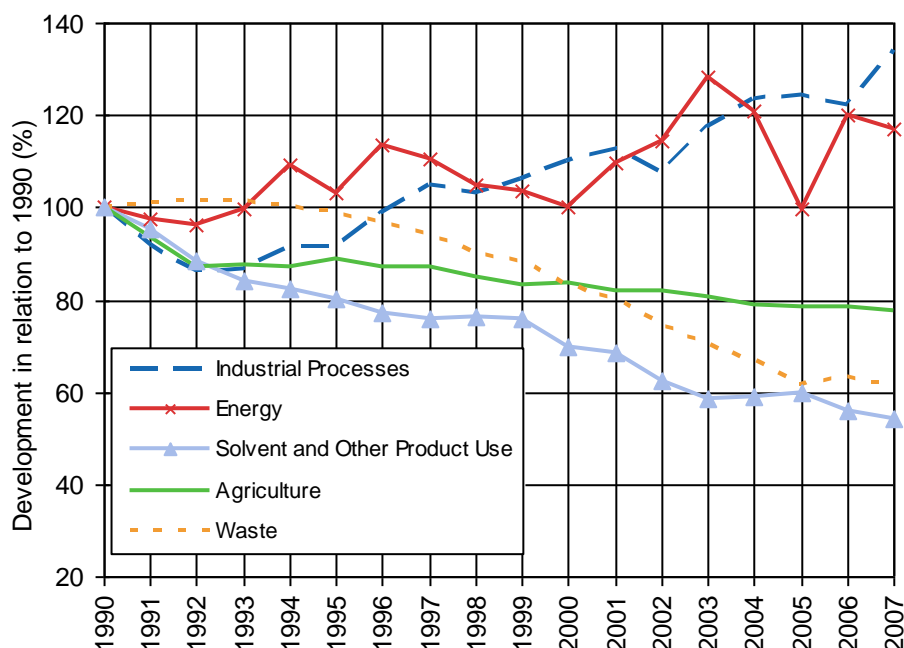


Figure 2.3_3. Relative development of greenhouse gas emissions by main source category relative to the 1990 level (1990=100%).

Emissions of industrial processes have increased by 34% from 1990 to 2007. 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 1990-2007 CO₂ emissions have increased 1.0 Tg and methane emissions 0.04 Tg CO₂ eq. Nitrous oxide emissions have decreased 0.2 Tg CO₂ eq. and emissions of all F-gases have increased 0.8 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 22% (1.6 Tg CO₂ eq.) over the period 1990-2007. 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 32% 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 ten-fold methane emissions compared with solid storage or pasture. Nitrous oxide emissions from manure management are larger 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 26% compared with the 1990 level. The decrease has resulted mainly from lower use of synthetic fertilisers and a decrease in the area under cultivation of organic soils. The drop in agricultural emissions in 1992 (Figure 2.3_3) 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 1.6 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 20% to 50% of the annual emissions from other sectors during 1990-2007. 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% (Metinfo). This is main reason for decrease in net sink of LULUCF sector in 2007.

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.

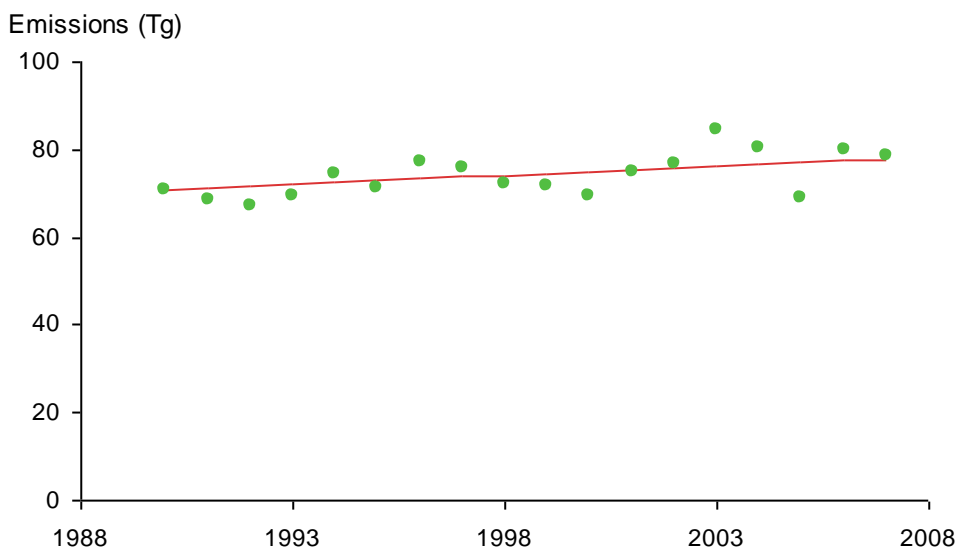


Figure 2.3_4. One possible description of a trend behind the data. The fitted line corresponds to an addition of 0.4 Tg CO₂ eq. to the level each year, starting from 1990.

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.

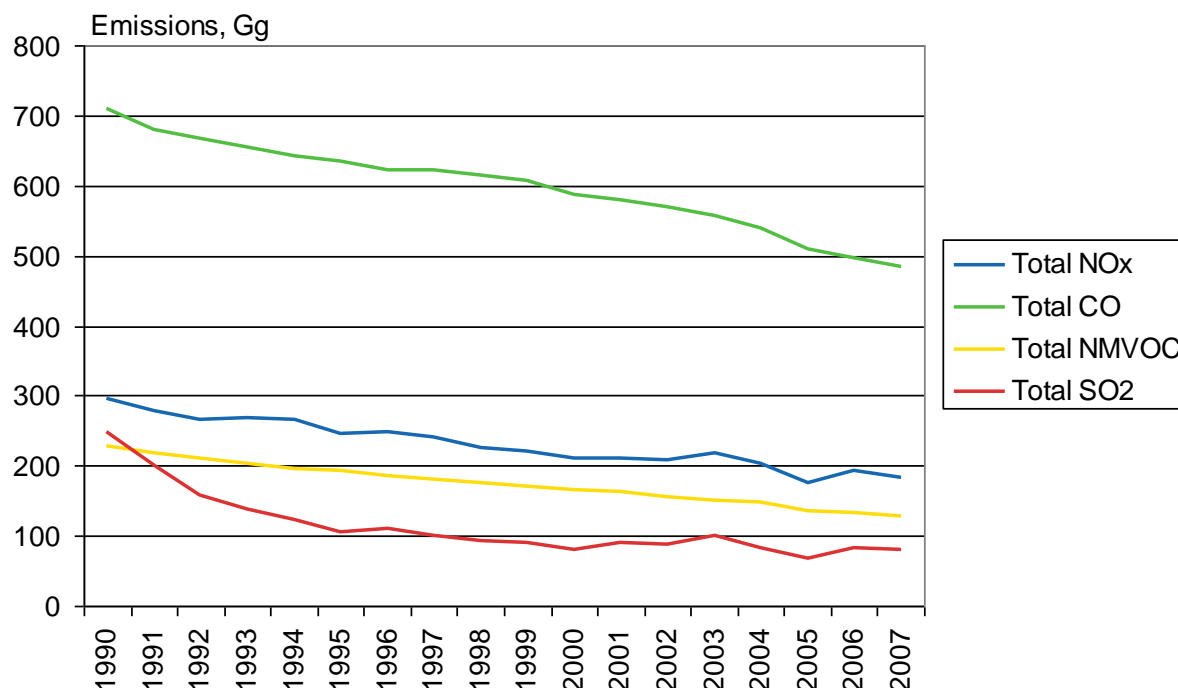


Figure 2.4_1. Indirect greenhouse gas and sulphur dioxide emissions in 1990-2007, Gg.

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 38% and they were 183 Gg in 2007. The biggest decrease, 56%, 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 2007. Energy industries as well as manufacturing industries and construction generated 27% and 23% of the emissions, respectively.

Carbon monoxide (CO) emissions, total 487 Gg, originated almost exclusively in the energy sector, where transport generated 63% and other sectors (including small scale combustion in the residential energy sector as well as off-road machinery in forestry, agriculture and fishery) 24% of the total emissions. Total carbon monoxide emissions have decreased by 32% 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 128 Gg in 2007. In all, 70% of the total emissions were generated in the energy sector, 21% originated from solvent and other product use and 8% from industrial processes. Total NMVOC emissions have decreased by 44% from 1990 to 2007, the greatest decline has taken place in industrial sector, where emissions decreased by 53%.

The **sulphur dioxide (SO₂)** emissions totalled 82 Gg out of which 81% originated in the energy sector, where energy industries generated 52% of the total emissions and manufacturing industries and construction 20%. Sulphur dioxide emissions have totally decreased 67% 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 1990–2007.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total nitrogen oxides	295	277	266	268	267	245	248	240	225	220	211	211	208	217	203	175	193	183
- energy	294	277	265	267	266	244	247	239	224	219	209	210	207	216	202	174	191	182
- industry	0.9	0.6	0.9	0.7	0.8	1.1	0.9	0.9	1.0	1.0	1.0	0.9	0.9	1.1	1.0	1.3	1.3	1.1
- agriculture and LULUCF	0.11	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.04	0.04	0.05	0.04	0.02	0.03	0.04	0.03
Total carbon monoxides	710	680	668	654	642	634	623	621	616	607	587	579	570	557	539	509	497	487
- energy	706	679	667	653	641	632	622	620	615	607	586	578	568	556	538	508	496	486
- 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
- LULUCF	1.7	0.7	1.2	0.5	1.0	0.8	0.6	0.8	0.3	0.8	0.4	1.0	1.1	0.8	0.2	0.6	0.9	0.4
Total NMVOCs	229	217	210	202	197	192	185	180	176	171	165	162	156	151	147	136	133	128
- energy	153	147	146	142	139	138	134	131	129	125	119	117	114	111	106	99	95	90
- industry	22.6	20.6	19.7	19.0	18.3	17.2	16.3	14.9	12.6	11.9	11.9	11.7	11.0	10.8	11.3	9.5	9.9	10.6
- solvent use	52.9	49.3	43.4	40.2	38.4	36.7	34.5	33.5	33.8	33.2	32.7	32.9	30.8	29.2	29.5	27.2	27.6	27.6
- waste	0.54	0.53	0.52	0.53	0.54	0.54	0.53	0.52	0.51	0.52	0.51	0.49	0.52	0.51	0.51	0.49	0.51	0.52
Total sulphur oxides	249	202	158	138	123	105	110	101	93	91	81	90	88	101	83	68	84	82
- energy	187	154	125	111	99	83	90	82	74	72	65	75	74	87	71	54	68	67
- industry	62	47	33	27	24	21	20	18	19	19	16	15	15	14	12	14	16	15

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 2007, the sector contributed 81% to total national emissions, totalling 63.6 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.

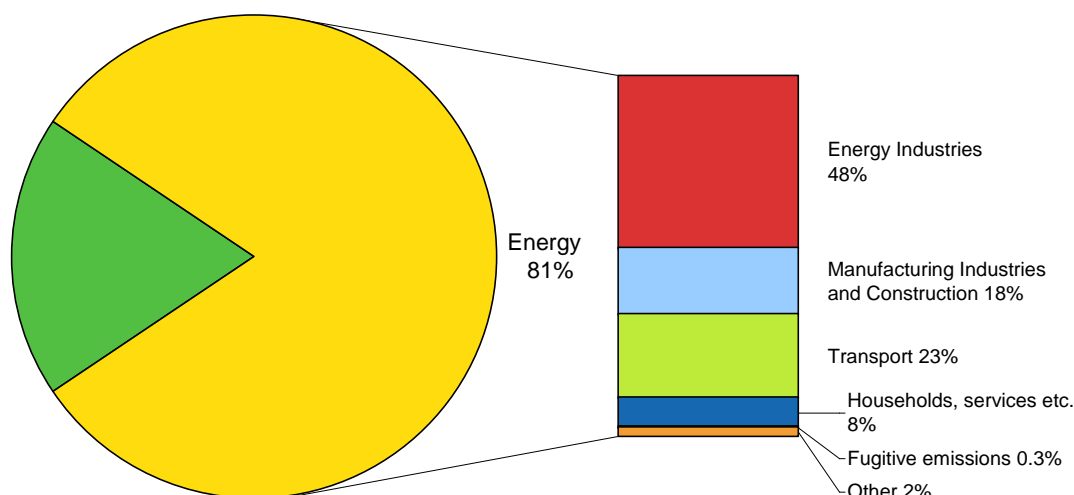


Figure 3.1_1. Emissions from the energy sector compared with the total emissions in 2007. Due to independent rounding the sums do not add up.

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 arising 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 oxidation of fugitive CH₄ and NMVOCs have been taken into account, 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 4.

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 2007 were 16% higher. The main contributors to the excess are the energy industry with approximately 60% growth and transport with around 15% growth in emissions relative to 1990. Emissions from manufacturing industries and construction (-14%) and the rest of the energy sector (-26%) 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 1990-2007 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
1. Energy	54.6	53.2	52.5	54.4	59.7	56.3	62.0	60.3	57.2	56.6	54.6	59.9	62.5	70.0	65.9	54.3	65.6	63.6
A. Fuel combustion	54.3	52.9	52.2	54.1	59.5	56.0	61.8	60.1	57.0	56.4	54.5	59.7	62.4	69.8	65.7	54.1	65.5	63.4
CO ₂	53.0	51.6	50.9	52.8	58.1	54.6	60.3	58.6	55.5	54.9	52.9	58.2	60.7	68.1	64.0	52.5	63.7	61.7
CH ₄	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.29	0.30	0.30	0.29	0.28	0.28	0.28
N ₂ O	1.00	0.99	1.00	1.05	1.10	1.08	1.15	1.19	1.20	1.23	1.22	1.30	1.36	1.44	1.45	1.37	1.49	1.49
B. Fugitive fuel emissions	0.23	0.25	0.28	0.34	0.25	0.25	0.24	0.27	0.22	0.19	0.18	0.19	0.18	0.18	0.17	0.19	0.17	0.19
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	0.14
CH ₄	0.011	0.042	0.056	0.073	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
N ₂ O	0.0012	0.0011	0.0012	0.0016	0.0007	0.0008	0.0007	0.0012	0.0007	0.0006	0.0006	0.0006	0.0007	0.0006	0.0006	0.0007	0.0006	0.0009

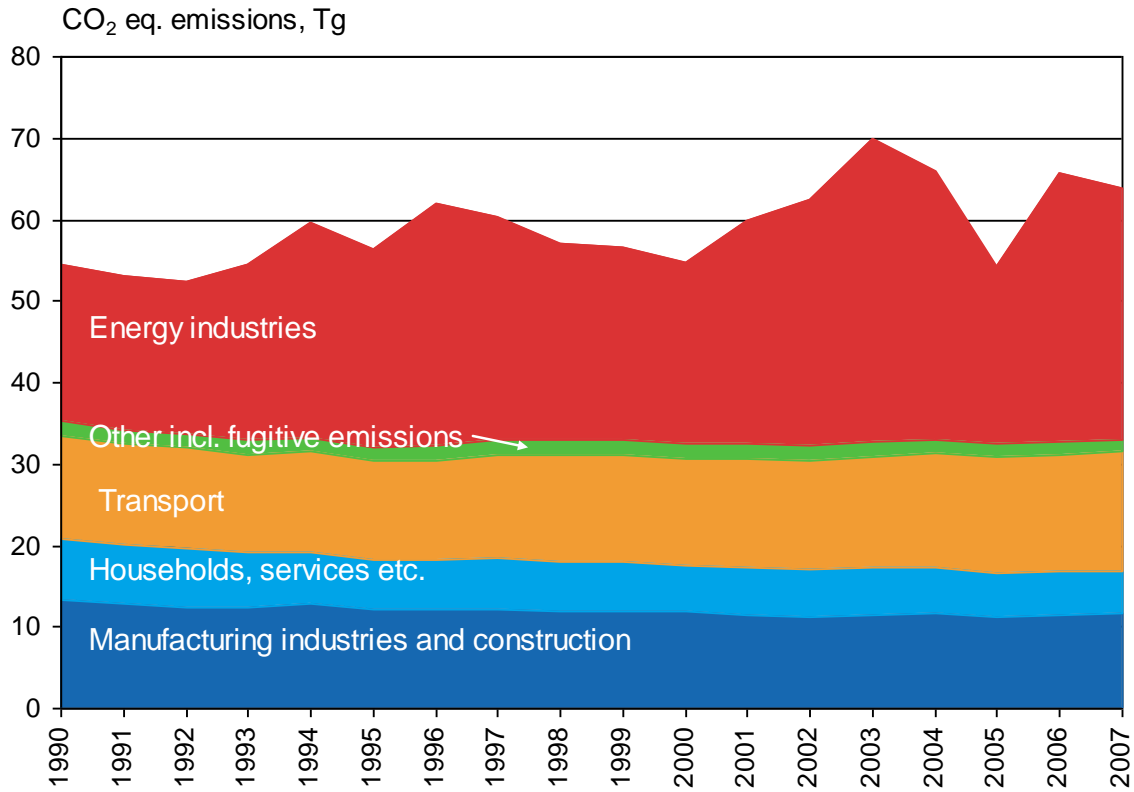


Figure 3.1_2. Emissions from the energy sector by subcategory in 1990-2007 (Tg CO₂ eq.).

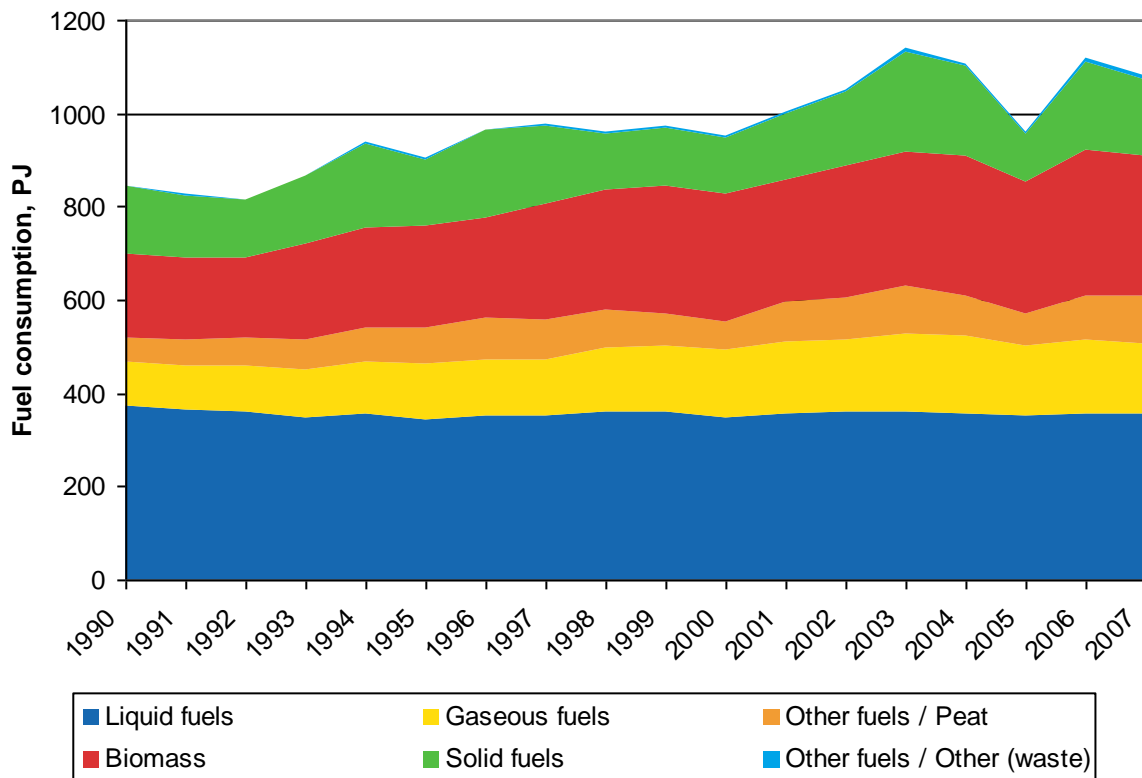


Figure 3.1_3. Consumption of fuels in 1990-2007 (PJ).

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 emissions of Fuels from non-energy use	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 (61.7 Tg) accounted for 97% of the energy sector's total emissions and 79% of total greenhouse gas emissions in 2007.

The portion of N₂O emissions from fuel combustion in 2007 was about 2%. N₂O emissions come mainly from fluidised bed combustion and transportation. CH₄ emissions from fuel combustion are relatively small and are mainly due to the incomplete combustion of wood fuels (small-scale combustion).

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. Electricity produced with Nordic hydro power was amply available for import in 2007, so the production of domestic condensing electricity decreased by 18 per cent from 2006 level (Figure 3.1_4).

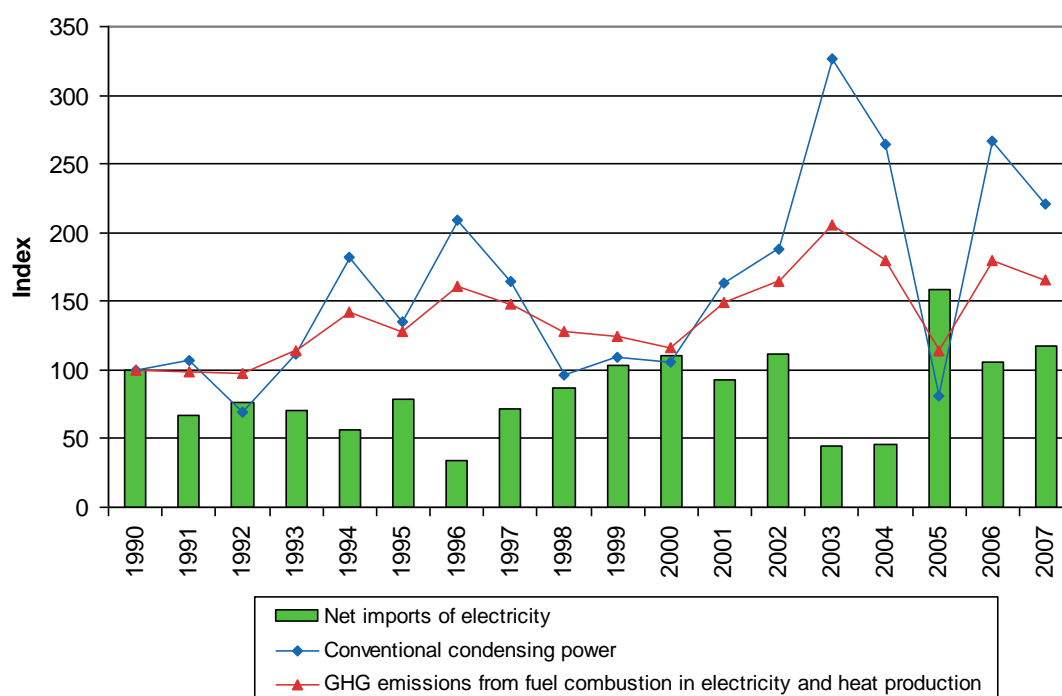


Figure 3.1_4. Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity and conventional condensing power indexed (index 1990=100) for 1990-2007 (Energy Statistics, Yearbook 2008).

Table 3.1_3. Emissions from fuel combustion in Finland in 1990-2007 (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1. Energy	54.6	53.2	52.5	54.4	59.7	56.3	62.0	60.3	57.2	56.6	54.6	59.9	62.5	70.0	65.9	54.3	65.6	63.6
A Fuel combustion total	54.3	52.9	52.2	54.1	59.5	56.0	61.8	60.1	57.0	56.4	54.5	59.7	62.4	69.8	65.7	54.1	65.5	63.4
CO ₂																		
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	21.6	32.5	30.4
2. Manufacturing Industries and Construction	13.2	12.7	12.2	12.3	12.6	12.0	11.9	12.1	11.7	11.7	11.7	11.3	11.0	11.3	11.4	11.1	11.4	11.2
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
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	5.4	5.3	5.1	5.0	4.9
5. Other	1.19	1.02	1.03	1.03	1.14	1.20	1.22	1.13	1.38	1.23	1.27	1.26	1.26	1.35	1.16	1.09	1.13	1.02
CH ₄	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.29	0.30	0.30	0.29	0.28	0.28	0.28
N ₂ O	1.00	0.99	1.00	1.05	1.10	1.08	1.15	1.19	1.20	1.23	1.22	1.30	1.36	1.44	1.45	1.37	1.49	1.49

Fuel combustion by fuel (PJ) and related CO₂, CH₄ and N₂O emissions for 1990-2007 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 in general 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 (emission data from environmental permits through the VAHTI data, see section 1.4 and Annex 2) makes it possible to take into account the 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 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 models, databases 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_4.

Firstly the data of point sources is 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 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.

Calculation systems of mobile sources (LIPASTO and its submodels 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. 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.

Also the breakdown of data published in the VTT LIPASTO website (LIPASTO) is different from CRF categories, which must be noticed, when comparing the figures (Table 3.3_12).

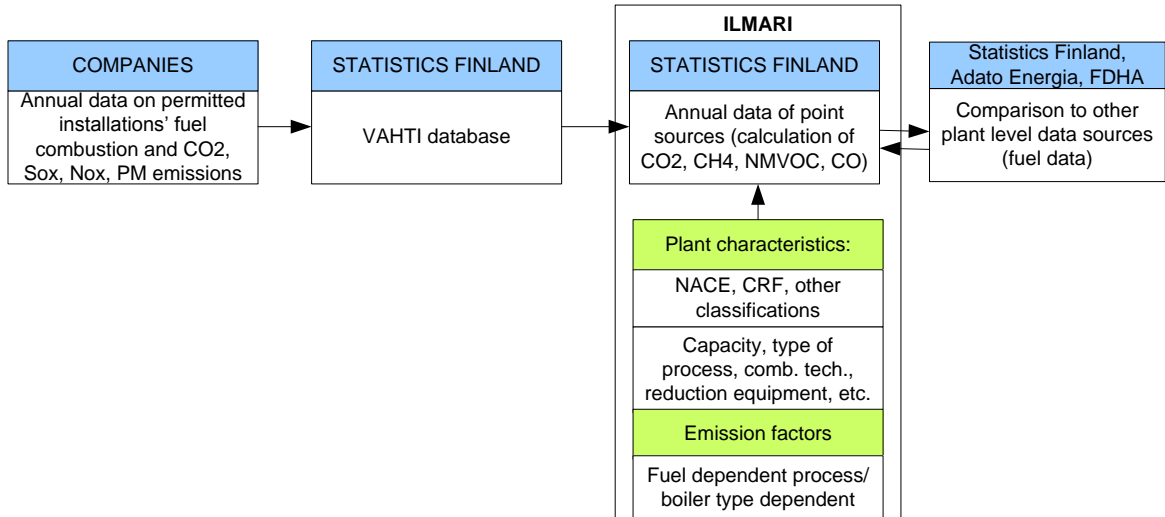
Table 3.1_4. The differences between LIPASTO reporting and greenhouse gas inventory.

LIPASTO submodel	GHG inventory
ILMI (aviation) - includes domestic and international aviation (definition of international is different)	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

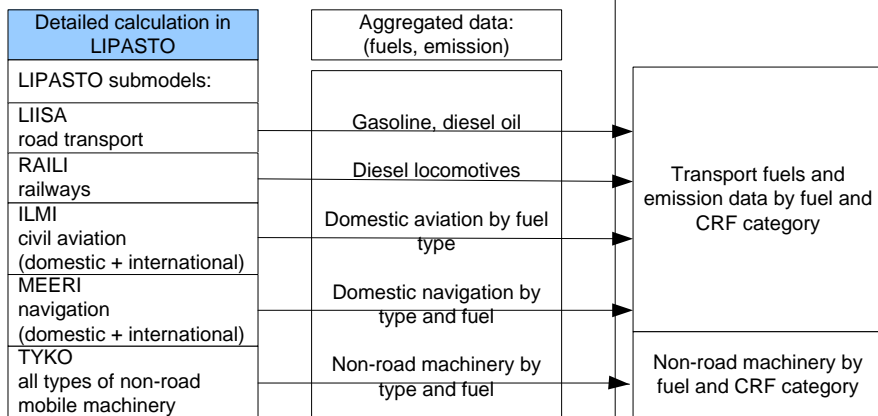
A newer version of the ILMARI calculation system has been developed, starting from 2002. Emissions from 2001 on have been calculated using this system. The calculation methods and formulas are the same as in the previous ILMARI, but the database system has been reconstructed. The activity data and time series consistency have been checked during 2005-2007. All results from the previous version of ILMARI have been converted to the present structure and stored in a specially developed 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. Some parts of the time series database are still under development (for example, a more automatic export of results to the CRF reporter).

Main data inputs of ILMARI

Point Sources



Transport and non-road machinery



Other emission sources

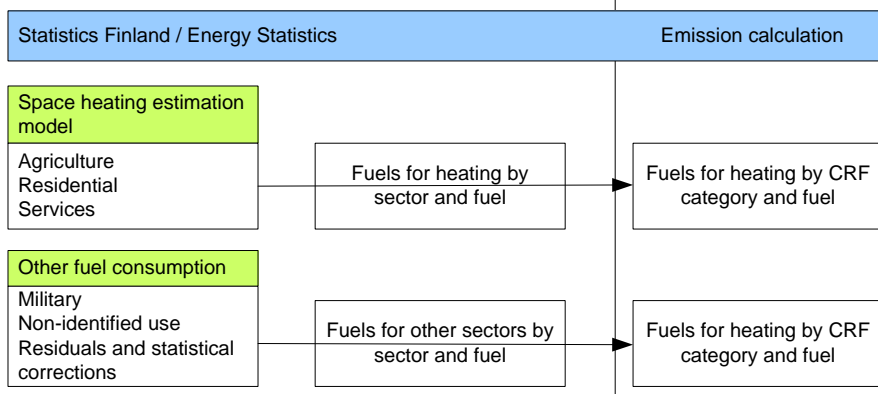


Figure 3.1_5 . Data sources in the ILMARI calculation system.

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

3.1.1.4 Key Categories

Several emission sources in the energy combustion sector are key categories. The key categories in 2007 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 2007 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
1.A. Fuel Combustion: Solid fuels	CO ₂	L, T
1.A. Fuel Combustion: Liquid fuels	CO ₂	L, T
1.A. Fuel Combustion: Gaseous fuels	CO ₂	T
1.A. Fuel Combustion: Other fuels	CO ₂	L, T
1.A 3b. Road Transportation Cars with Catalytic Converters	N ₂ O	L, T
1.A 3b. Road Transportation Cars without Catalytic Converters	N ₂ O	L
1.A 4. Other Sectors: Biomass	CH ₄	L
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. 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 2007 and 0.23 Tg in 1990. These emissions have decreased by 19% since the 1990 level (Table 3.1_8 and Figure 3.1_6) due to decreased emissions in oil refining. There have been some difficulties in oil refineries and petrochemical industry in 1993 and 1997 which caused higher emissions, incidentally these emissions have also had decreasing trend.

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.

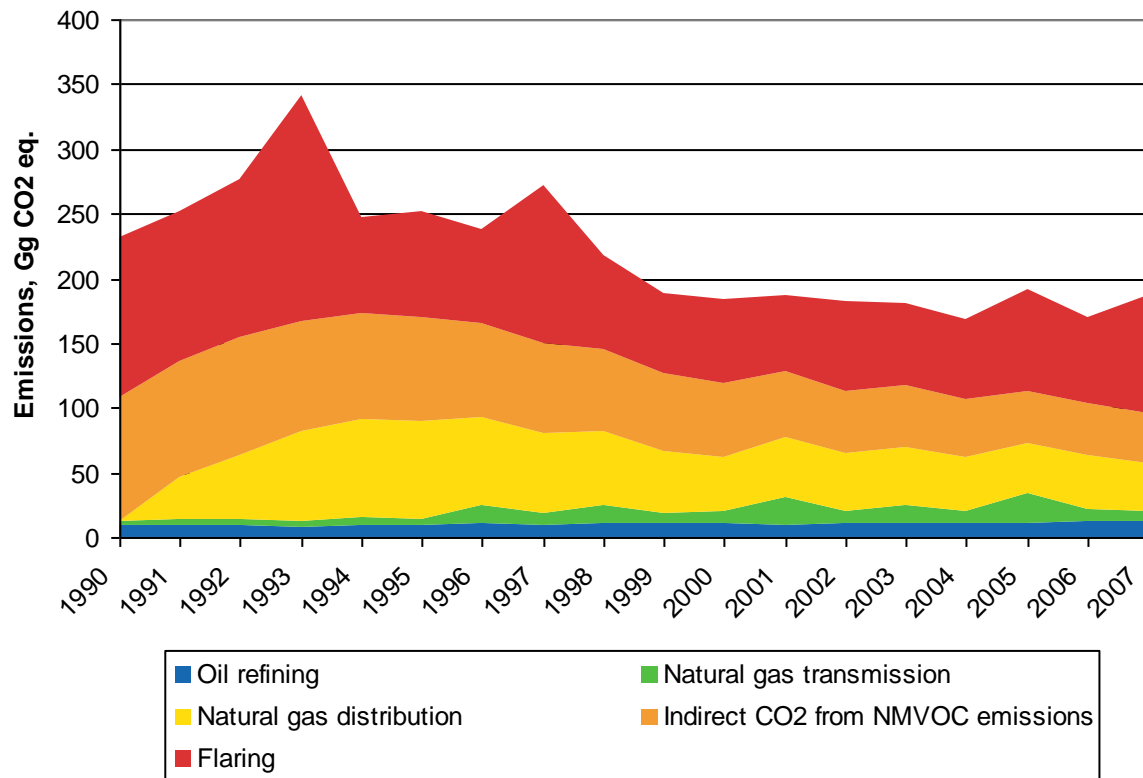


Figure 3.1_6. Fugitive emissions from fuels by subcategory in 1990-2007 (Gg CO₂ eq.)

3.1.2.3 Key Categories

There were no key sources in this sector in 2007.

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
CO₂																		
1.B 2c Flaring	123	115	121	172	72	81	72	122	71	61	65	58	68	63	62	77	66	91
- in oil refineries	51	43	51	82	35	41	24	32	26	26	22	22	22	18	11	28	15	25
- in petrochemical industry	72	72	70	90	37	40	48	90	45	35	44	36	47	45	51	49	51	66
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	0.48	0.49	0.51
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	1.90
1.B 2c Flaring	0.0019	0.0018	0.0019	0.0026	0.0011	0.0013	0.0011	0.0019	0.0011	0.0009	0.0010	0.0009	0.0010	0.0010	0.0009	0.0012	0.0010	0.0014
N₂O																		
1.B 2c Flaring	0.0038	0.0035	0.0037	0.0053	0.0022	0.0025	0.0022	0.0037	0.0022	0.0019	0.0020	0.0018	0.0021	0.0019	0.0019	0.0024	0.0020	0.0028
Indirect CO₂	95	89	91	86	83	79	72	68	63	60	56	52	49	48	45	41	41	37
Total CO₂ eq	232	252	276	341	247	252	238	272	217	188	184	187	182	181	169	191	170	187

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 1990–2007 are presented in Table 3.2_1.

The emissions from Manufacturing industries and construction by relevant subcategory and gas in 1990–2007 are presented in Table 3.2_2.

In 2007, the greenhouse gas emissions from energy industries amounted to 30.8 Tg and manufacturing industries and construction amounted to 11.4 Tg CO_2 equivalent. The share of energy industries was 49% of energy sector's total emissions. The share was 18% in manufacturing industries and construction. These subsectors accounted together for 54% 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).

Greenhouse gas emissions, Tg eq. CO_2

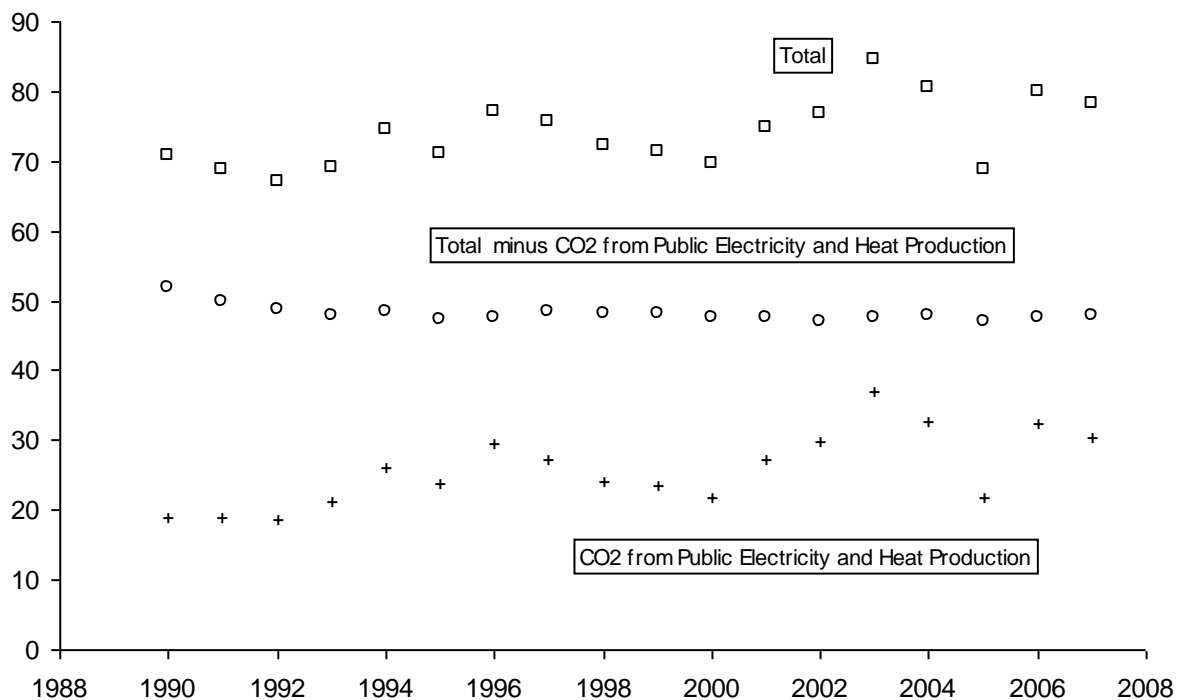


Figure 3.2_1. Effect of CO_2 emissions of 1.A 1a Public Electricity and Heat Production to total CO_2 equivalent emissions

Table 3.2_1. The emissions from Energy industries by relevant subcategory and gas in 1990-2007 (Tg CO₂).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL (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	32.9	21.9	32.8	30.8
CO₂	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	21.6	32.5	30.4
a. 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	33.6	29.4	18.7	29.4	27.3
b. 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
c. 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
CH₄																		
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
N₂O																		
Total	0.12	0.13	0.14	0.16	0.19	0.19	0.22	0.22	0.22	0.22	0.21	0.26	0.29	0.33	0.31	0.25	0.33	0.33

Table 3.2_2. The emissions from Manufacturing industries and construction by relevant subcategory and gas in 1990-2007 (CO₂ eq, Tg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL (Manufacturing industries and construction)	13.4	12.9	12.4	12.5	12.8	12.2	12.1	12.3	11.9	11.9	11.9	11.5	11.2	11.5	11.6	11.3	11.6	11.4
CO₂	13.2	12.7	12.2	12.3	12.6	12.0	11.9	12.1	11.7	11.7	11.7	11.3	11.0	11.3	11.4	11.1	11.4	11.2
a. Iron and Steel	2.56	2.62	2.68	2.90	2.96	2.74	2.88	3.20	3.35	3.42	3.69	3.31	3.36	3.59	3.56	3.67	3.80	3.41
b. Non-Ferrous Metals	0.336	0.231	0.135	0.173	0.136	0.108	0.109	0.129	0.134	0.142	0.143	0.146	0.126	0.121	0.112	0.097	0.098	0.102
c. 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	0.90	0.94
d. Pulp, Paper and Print	5.34	5.16	4.98	4.95	5.17	4.83	4.63	4.57	4.25	4.18	4.04	3.91	3.68	3.81	3.94	3.56	4.07	4.29
e. Food Processing, Beverages and Tobacco	0.82	0.79	0.76	0.72	0.71	0.70	0.66	0.61	0.56	0.49	0.32	0.32	0.32	0.26	0.24	0.21	0.20	0.17
f. Other	2.90	2.68	2.43	2.31	2.29	2.30	2.31	2.29	2.29	2.33	2.35	2.35	2.34	2.26	2.29	2.29	2.36	2.32
CH₄																		
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	0.015	0.014	0.015	0.014
N₂O																		
Total	0.173	0.160	0.148	0.165	0.170	0.167	0.171	0.187	0.183	0.189	0.189	0.183	0.173	0.174	0.182	0.170	0.163	0.156

Fuel combustion CO₂, CH₄ and N₂O emissions by fuels for 1990-2007 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. Fuel combustion data are available by installation and by fuel type. For each point source, SO₂, PM, NO_x and CO₂ emissions are reported plant 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, SO_x and NO_x).

Calculation of the CO₂ emissions is based on a country-specific (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_3.

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 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	51.9 (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 (heavy fuel oil), low sulphur	41.1	GJ/t	78.8	0.995	Neste/EE
Residual fuel oil (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 (95-102)	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	0.995	EE (=RFO)
Solid fuels					
Anthracite	33.5	GJ/t	94.6	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	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 20	GJ/t GJ/1000 m ³	109.6 59	0.99	IPCC1996, 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*	4.5	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	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.

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

Peat is in the Finnish greenhouse gas inventory reported as a subcategory 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 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 very different, thus in the case of Finland it is not reasonable to aggregate them to the same fuel category (see Table 3.2_4).

In Appendix_3b there are the shares of each fuel in fuel combustion sector. In the inventory and CRF Reporter Peat is reported separately as a subcategory of Other fuels. In the printed CRF tables it becomes summarised with relatively small amount of other fuels consisting mostly of wastes and waste derived fuels.

Table 3.2_4. Comparison of 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 MWth)	Usually large-scale (500 - 1 500 MWth)
NCV	10-13 GJ/t	25 GJ/t
Moisture content	40 - 50%	5%
Emission factor, CO₂	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 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 Tables 3.2_5 and 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
Soda recovery boiler	70 (> 80% black liquor)	All / < 50	3
Gas turbine	121 (gas turbine plant, oil) and 123 (gas turbine plant, other)	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 (census by Statistics Finland)
- electricity and heat production statistics (census by Adato Energia and Statistics Finland)
- district heating statistics (census by the Finnish District Heating Association)
- structural business statistics (survey by Statistics Finland)
- business register (by Statistics Finland)
- data from 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) for 1990-2007 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 be now also found in their own categories in CRF reporter.

Table 3.2_7. Fuel consumption in Energy industries (CRF 1.A 1) and Manufacturing industries and construction (CRF 1.A 2) in 1990-2007 (PJ).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1.A 1																		
Liquid Fuels	38.5	38.9	39.3	39.7	45.9	43.2	49.0	42.0	42.9	43.7	37.1	40.7	44.9	43.8	38.2	38.0	40.5	41.3
Solid Fuels	101.4	92.9	84.5	105.6	140.1	109.1	154.3	134.4	91.7	93.6	91.2	112.7	131.7	189.5	164.7	76.6	162.8	141.1
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	119.7	113.8	104.4	111.7	96.5
Other Fuels	37.7	41.3	44.9	49.9	58.4	64.4	70.2	70.7	67.4	60.0	50.8	75.0	81.8	89.0	78.5	60.0	80.5	89.9
- 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	86.5	75.0	55.6	77.4	85.0
- 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	1.87	2.51	3.50	4.40	3.18	4.94
1.A 2																		
Liquid Fuels	59.8	56.8	53.6	50.9	53.1	53.7	52.1	52.9	55.0	56.4	55.1	54.2	53.6	54.0	56.0	54.4	53.5	51.9
Solid Fuels	43.6	40.7	37.9	38.4	38.3	33.7	31.4	32.2	30.9	30.8	31.0	28.0	26.9	27.1	27.3	27.6	25.9	22.6
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	39.3	40.7	37.1	39.4	42.7
Other Fuels	15.8	15.1	14.5	15.3	16.7	16.5	18.6	18.8	16.1	14.8	13.9	14.1	13.2	16.3	15.2	14.7	18.3	19.0
- 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
- Waste	1.7	1.5	1.4	1.5	1.6	1.6	2.2	2.3	2.5	2.4	2.5	2.5	2.6	3.1	2.7	2.5	3.2	2.9

3.2.3 *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 5. 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 2007. 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 might be larger than for fossil fuels, because the moisture and carbon content of peat fuel varies. This variability was 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 in 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 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 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.

There are several QC procedures which 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. There are 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 any case. 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.

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 data sets. 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, if needed. The results of point source checks are presented in Table 3.2_8.

Table 3.2_8. The results of the point source QC procedures for 2007 data.

	Number	Quantity	PJ
Fuel records total (corrected values)	2 554	61 028	794
Fuel records original	2 304	60 440	759
Non-corrected original	1 957	50 011	653
Imputed fuel records	287	3 283	59
TJ corrected	208	0	-27
Quantity corrected	64	-1 961	0
Quantity and TJ corrected	38	-1 379	100
Fuel code corrected	39	547	11
Total corrected records (net Quantity and PJ corrections)	597	-472	34

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 were some more corrections, mainly more imputed fuel records. The statistics on the results of the second round corrections have not yet been finished.

After the point sources' data have been checked, 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 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. 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 2007 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 were made still during 2006 and 2007.

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.

There is a more comprehensive list about Tier 1 and 2 level QC activities in the Energy sector in the internal documentation (in Finnish).

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 plants included in the ETS are marked. Thus summaries of total ETS and non-ETS plants can be made fairly easily.

Total CO₂ emissions taken from the ETS data were 42.4 Tg in 2007. The corresponding amount taken from the GHG inventory data was 42.5 Tg. In the ETS data 0.35 Tg of CO₂ and in the GHG data 0.22 Tg of CO₂ was transferred out of the ETS plants. The reduced amount is different because from the GHG data only part of transferred emissions from forest industry could be reduced due to limitation of permanent CO₂ storage. 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 0.07 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.

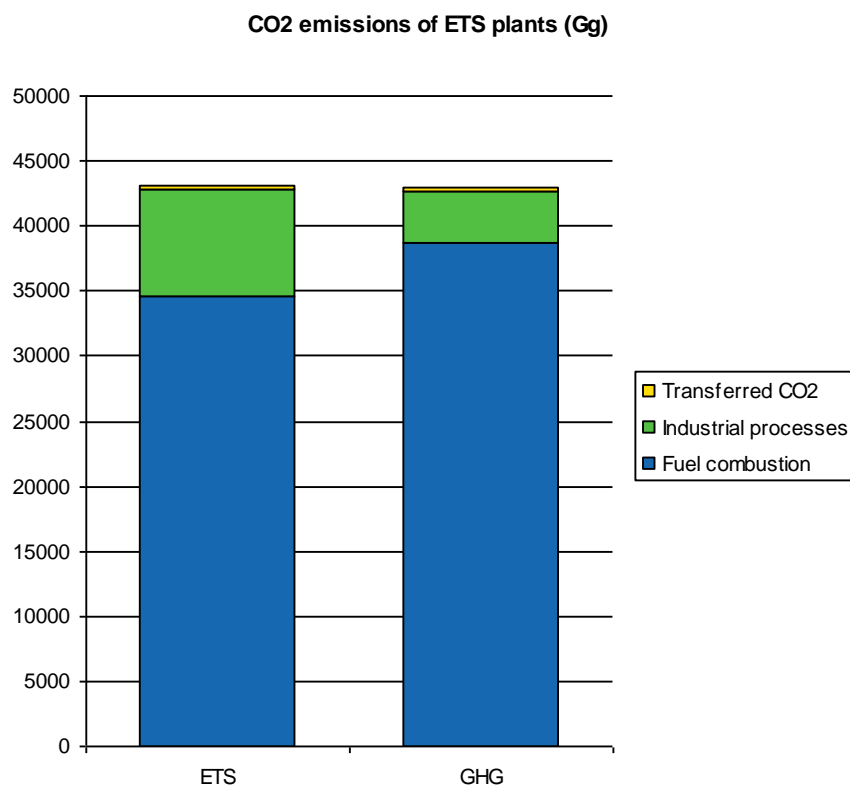


Figure 3.2_2. CO₂ emissions of ETS plants compared with the corresponding emissions reported in the greenhouse gas inventory.

3.2.5 Source-specific recalculations

Time series of CO₂ transfer to PCC was added to subcategory 1.A 2f. (see details in Section 3.2.7.)

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 2006 were substituted with final data in subcategories of 1.A.

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 - 2007. In the Energy sector ETS data were 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.

From 2008 on ETS plants will be using more measured plant level calorific values and emission factors. These have to be checked against the national values used in the GHG inventory calculations.

The process description and internal user manual of the Energy sector calculations have been under revision in 2008 and it will be continued in 2009.

3.2.7 CO₂ transfer

In Finland six pulp and paper plants are directing a part of their fossil fuel combustion based CO₂ emissions to PCC (Precipitated Calcium Carbonate) plants nearby. PCC is widely used in different kinds of paper and paper board as filling or coating material. The first PCC plant using CO₂ in Finland started in 1993.

A small amount of CO₂ emissions from a power plant is used in sugar refining and part of process emissions from hydrogen plant are recovered by other company. CO₂ emissions released from one hydrogen production plant are transferred to be bottled as CO₂ gas which is used in many different purposes.

Statistics Finland clarified in 2008 which parts of transferred CO₂ are emitted into the atmosphere after the storage, and which can be considered to be transferred to a long-term (indefinite) storage.

- CO₂ in PCC: According to the Finnish experts⁴ CO₂ will be released, when PCC containing paper or sludge is burned. If the recycled sludge is stored in landfills or used in landscaping, the CO₂ is stored for long-term (Appelo and Postma, 1996, Garrels and Christ, 1965).
- bottled CO₂: according to present knowledge the CO₂ is used in applications from which it is released to the atmosphere immediately or within a timeframe of some years after the transfer.
- CO₂ in sugar refining: Until 2006 all formed calcium carbonate containing filtration residue have been stored in landfill nearby, but nowadays it is used for liming of agricultural soils. According to GPG LULUCF (IPCC 2003) all the carbon in the lime is assumed to be released to the atmosphere during the same year it is applied to soil. Landfilled residue is fairly permanent storage.

Based on the information received from the experts, recycled sludge used in landfills or landscaping and exported paper are into account as long-term storage for CO₂ and this part of transferred CO₂ has been reduced from the emissions from the pulp and paper plants in the inventory. The reduction has been done in the CRF Reporter in the source 1.A 2f (Transferred CO₂), where CO₂ emission is marked as negative. Also it was decided that bottled CO₂ could not been taken into account as stored CO₂ based on the information available. CO₂ transferred for sugar production is assumed to be emitted when applied to agricultural soils (the emissions are reported under Agriculture).

Methodology

The methodology for estimating the part of CO₂ to be deducted from the emissions for the specific pulp and paper plants is given the below. The amount of CO₂ transferred to PCC is estimated based on the amount of PCC produced. All CO₂ in PCC containing paper is assumed to be long-term stored unless the paper or sludge from recycled paper is combusted. Emissions from combustion of PCC containing paper or sludge from recycling are taken into account for domestically used paper. Emissions from PCC in exported paper are not taken into account, as these emissions are not occurring with the national borders of Finland. The data on domestic paper consumption and export of paper are obtained from the Finnish Paper Industry.

$$CO_{2\text{stored}} = CO_{2\text{transferred}} * SF,$$

$$CO_{2\text{transferred}} = PCC_{\text{production}} * [CO_2]/[CaCO_3]$$

$$SF = (PB_{\text{export}} + PB_{\text{recycled}})/(PB_{\text{export}} + PB_{\text{domestic consumption}}),$$

where

SF = storage factor

PB_{export} = export of paper and board products

PB_{recycled} = recycled paper and board products

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

PBdomestic consumption = total domestic consumption of paper and board products

Calculated stored CO₂ is subtracted from subcategory 1.A 2f, or actually a negative emission figure is reported in this subcategory (Table 3.2_9).

Table 3.2_9. PCC production and transferred CO₂, 1993-2007

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
PCC production, 1 000 t	2	46	123	167	241	290	356	413	403	401	430	473	425	482	532
Used CO₂, Tg	1	20	54	74	106	128	156	182	177	176	189	208	187	212	234
Storage factor, %	96.4	96.5	96.3	96.5	96.5	96.9	97.0	97.3	97.8	97.6	97.8	96.7	94.5	95.3	94.6
CO₂ subtracted from 1.A 2f, Tg	1	19	52	71	102	124	152	177	173	172	185	201	177	202	221

3.3 Transport (CRF 1.A 3)

Source category description

In 2007, the greenhouse gas emissions from transportation amounted to 14.7 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 2007.

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 engine fleet) and piston engine aircraft, domestic flights only	Emissions from helicopters are not calculated separately. These emissions are included in calculation of category 1.A 5.
b. Road Transportation	Transportation 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.

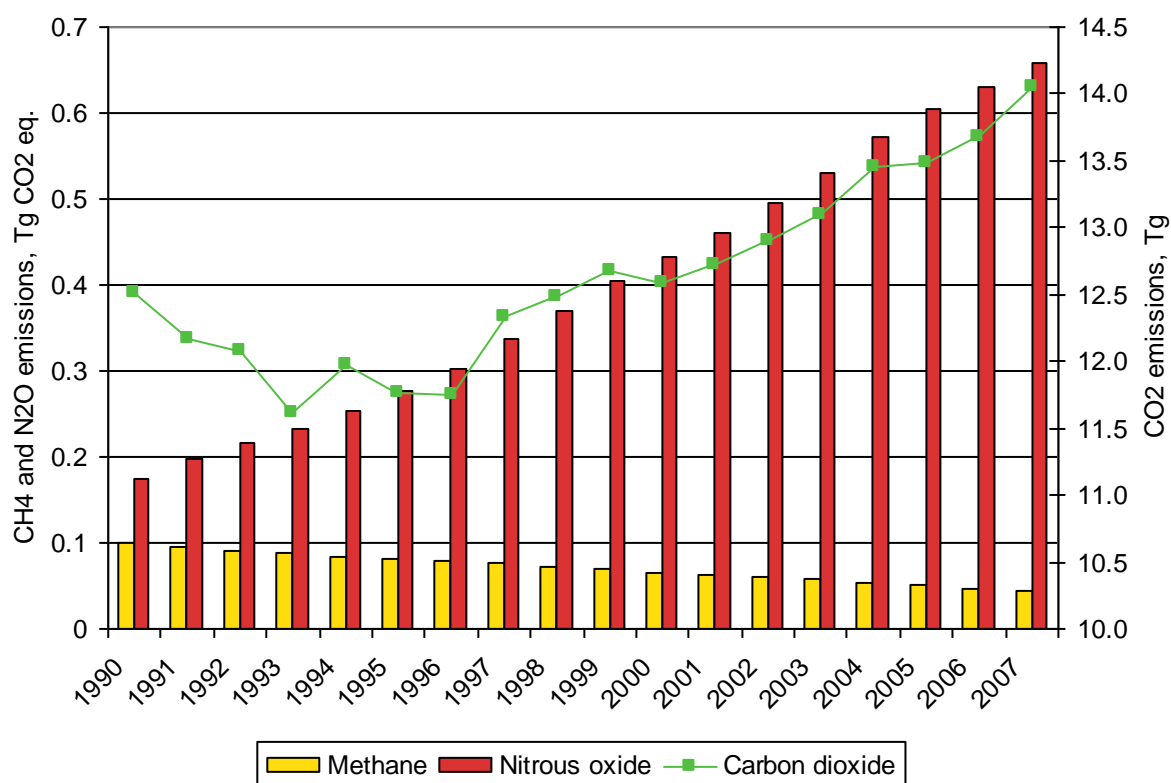


Figure 3.3_1. Emissions from transport sector by gas in 1990-2007 (Tg CO₂ eq.).

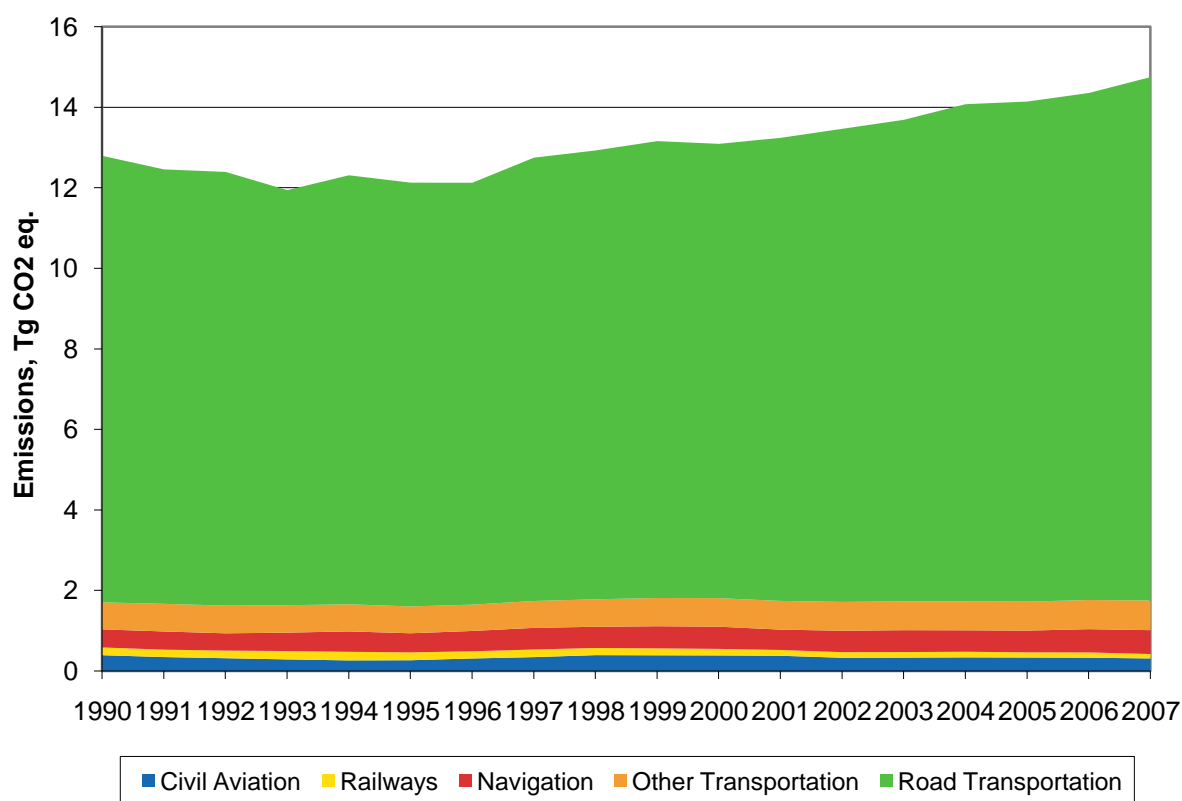


Figure 3.3_2. Emissions from transport by subcategory in 1990-2007 (Tg CO₂ eq.).

Road transportation is the most important emission source in transport, covering over 88% of sector's emissions in 2007. 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. N₂O has increased rapidly in proportion to the cars equipped with the catalytic converters because catalytic converters "produce" N₂O ten times more than cars without converters. However, increase in N₂O has only a minor effect on the increase of total transport GHG emissions measured as CO₂ equivalents.

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 1990-2007 can be seen in Table 3.3_3.

Table 3.3_2. Emissions from the Transport sector in 1990-2007 by subcategory (Tg CO₂-eq).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TOTAL CO₂	12.8	12.5	12.4	11.9	12.3	12.1	12.1	12.7	12.9	13.2	13.1	13.2	13.5	13.7	14.1	14.1	14.4	14.7
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
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
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
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
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
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	0.73
CH₄																		
3. Transport	0.100	0.095	0.092	0.088	0.085	0.082	0.079	0.076	0.073	0.070	0.066	0.063	0.061	0.059	0.054	0.051	0.047	0.045
N₂O																		
3. Transport	0.17	0.20	0.22	0.23	0.25	0.28	0.30	0.34	0.37	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.63	0.66
a. Civil Aviation	0.0049	0.0043	0.0039	0.0036	0.0033	0.0033	0.0039	0.0043	0.0049	0.0048	0.0048	0.0047	0.0041	0.0041	0.0042	0.0042	0.0041	0.0039
b. Road transport	0.16	0.18	0.20	0.22	0.24	0.26	0.29	0.32	0.35	0.39	0.42	0.45	0.48	0.52	0.56	0.59	0.62	0.64
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
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
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

Table 3.3_3. Fuel consumption by fuel type in transport in 1990-2007 (PJ)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1.A 3a 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
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
1.A 3b 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	73.3	73.8	75.1	74.7	73.9	73.8
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
Natural gas	NO	NO	NO	NO	NO	NO	0.00	0.01	0.01	0.04	0.05	0.06	0.11	0.13	0.12	0.11	0.15	0.16
1.A 3c 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.A 3d 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
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
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.A 3e 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
Motor gasoline	2.43	2.65	2.77	2.75	2.70	2.66	2.68	2.75	2.87	3.05	3.14	3.18	3.24	3.27	3.35	3.40	3.44	3.52
Gasoil	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

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 slightly over 2% and the amount of emissions was 0.31 Tg (CO₂ eq) in 2007. It was 0.39 Tg in 1990. See Figure 3.3_3 and Table 3.3_4.

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 9.4 % drop in number of flights.

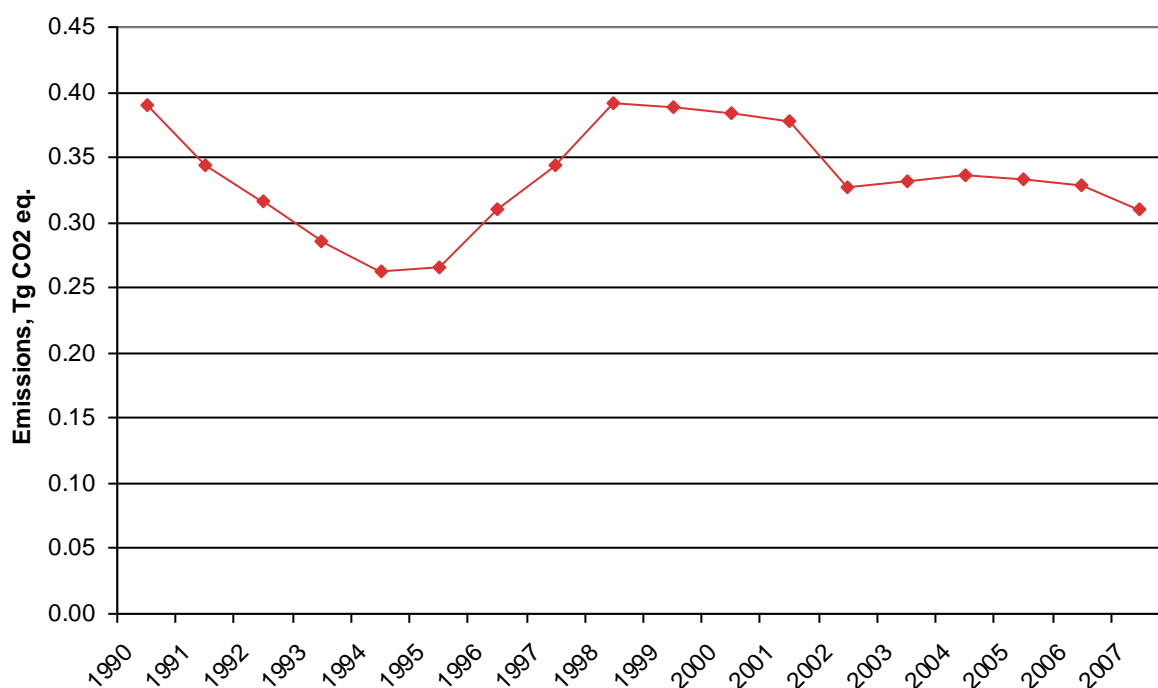


Figure 3.3_3. Emissions from domestic civil aviation in 1990-2007 (Tg CO₂ eq.)

Table 3.3_4. Emissions, fuel consumption and number of flights or flight hours by fuel type in the Civil Aviation (1.A 3a) sector in 1990-2007.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1.A 3a Civil Aviation																		
CO ₂ (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
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
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
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
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

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 Trade and Industry. 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)

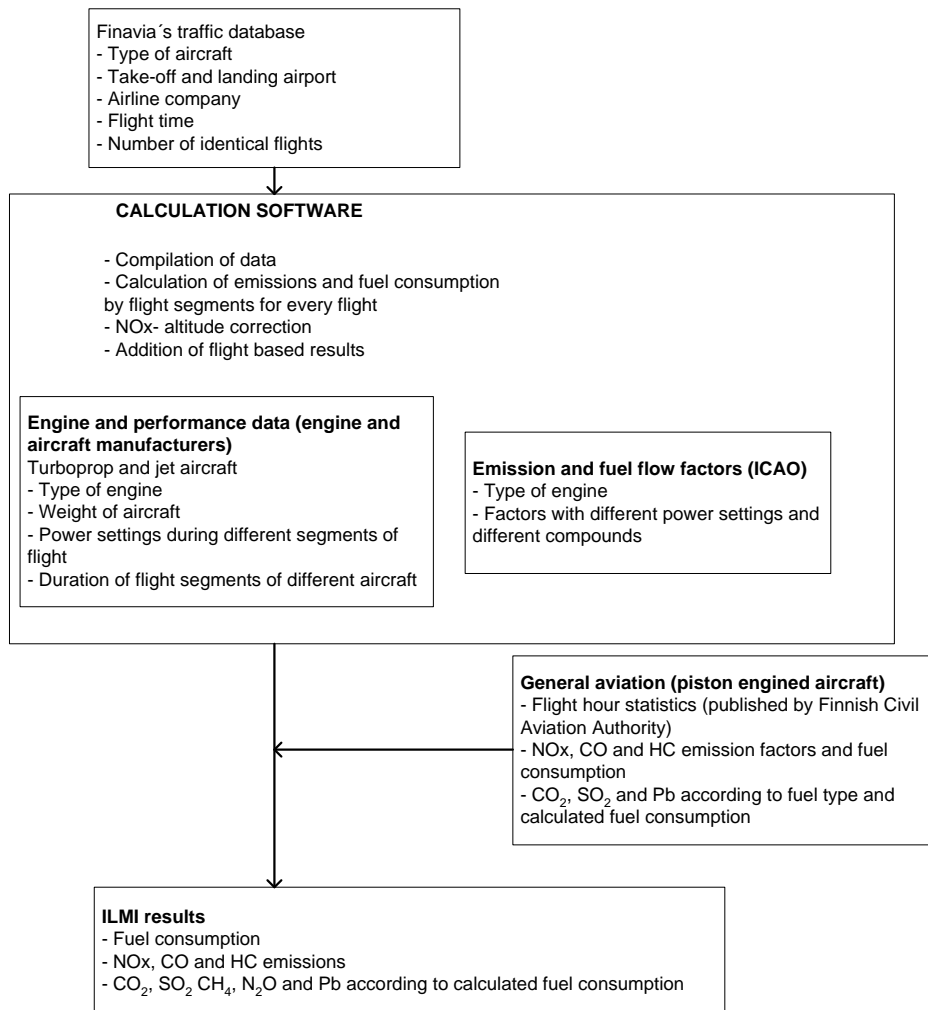


Figure 3.3_4. The ILMI calculation model.

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 5. 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

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

No source-specific improvements are planned.

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 13 Tg (CO₂ eq.) in 2007, it was almost 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 17% higher than the year 1990 (Figure 3.3_5).

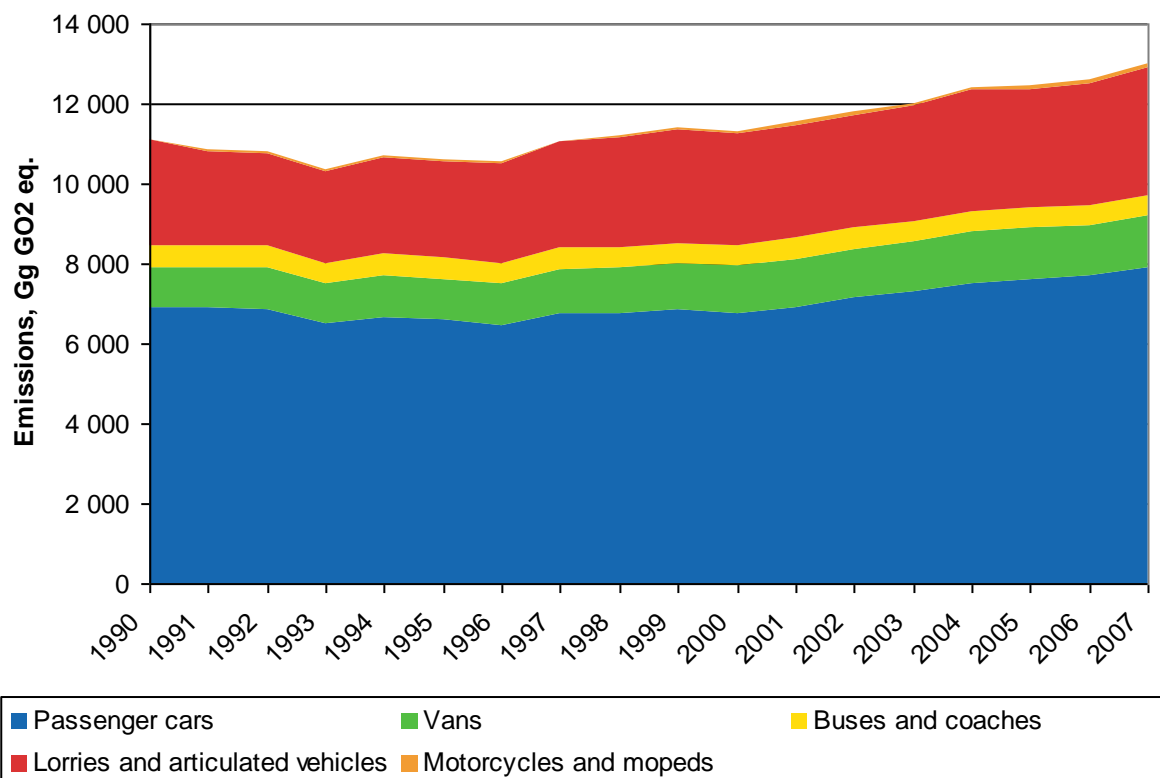


Figure 3.3_5. Emissions from road transportation by types of vehicle in 1990-2007 (Gg CO₂ eq.) (the detailed transport calculation models LIPASTO of VTT Technical Research Centre of Finland).

The main reason for emission growth is increased kilometrage. Fuel consumption per vehicle has stayed quite stable. Cars equipped with catalytic converters producing much more N₂O emissions than cars without have saturated the fleet. Thus in 2007 the share of N₂O eq. was 5% of the total road transportation emissions compared to 1.4% in 1990 (see also table 3.3_6).

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. 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 Road Administration (Finnra)) 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 Road Administration (Finnra) 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. Total gasoline sales in Finland were 2,481 million litres of which 194 million litres (7.8%) was used in leisure boats and working machines (see the next paragraph). Diesel fuel sales were 2,607 million litres which is estimated to be used solely in road transportation.

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 used in leisure boats is calculated with the MEERI model (See section 3.3.3). Diesel oil sold in Finland is used almost exclusively in road traffic.

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 Road Administration (Finnra) 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 Road Administration. 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 1990-2007 is presented in Table 3.3_5.

Table 3.3_5. 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

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 Finnish Vehicle Administration).

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 (78% of all gasoline cars, 88% 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_6. 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

	Gasoline, CAT (TJ)	Gasoline, non-CAT (TJ)	share of CAT, %
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

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 3.3_7). 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.

Table 3.3_7. CO₂ emission factors, net caloric value and density used in calculation of emissions from road transportation (Neste Oil, Finland).

Fuel type	Emission factor g/kg fuel	Net caloric value TJ/kilotonne fuel	Density kg/m ³ fuel
Gasoline E95 and E98	3 133	43.0	750
Diesel oil	3 148	43.0	845

Emissions factors for CH₄ and N₂O are a sum of hot driving, idle and cold start-ups. The emission factors are based on a literature review by VTT (Juhani Laurikko) and last updated in 2001.

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 5. 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.

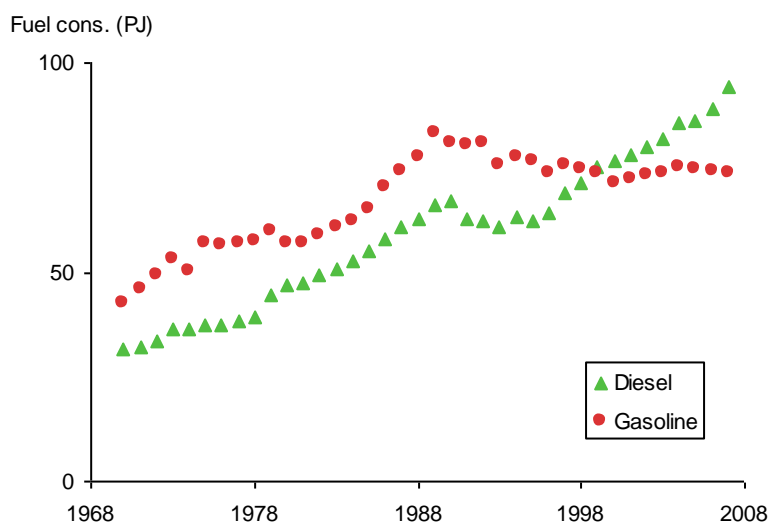


Figure 3.3_6 Consumption of diesel and gasoline in road transportation in 1970-2007 (Energy Statistics, Yearbook 2007)

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 1990-2007. 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.

In internal self-evaluations experts of transport sectors examined the actual activity and the results attained and compared them with the objectives set and the plans made. For the 2007 inventory, the findings of

internal self-evaluations have been discussed in quality meetings that were held between the inventory unit and the expert organisations in January 2009.

3.3.2.6 Source-specific recalculations

There were small differences (in most years less than 1%) in gasoline total consumption time series taken from LIPASTO transport model compared to Energy Statistics fuel sales data. These differences were corrected in Road transport gasoline consumption to ensure full consistency between Energy Statistics and GHG inventory. Corresponding CO₂ emissions were recalculated.

CO₂ emissions from blended biofuels have been separated for the first time as biomass emissions in Road transport subcategory.

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. According to official statistics, there is no consumption of pure biofuels in Finland.

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. The following emission factors were used: 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 ethanol and biodiesel as well as CO₂ emissions are presented in Table 3.3_8.

Although there is gasoline consumption in other subcategories, all biogenic emissions have been allocated to Road transport just for simplicity and transparency. In all other sectors the value of biogasoline would be very small, and the biogenic emissions would be very close to zero.

Table 3.3_8. Amount of blended biogasoline (ethanol), blended biodiesel and carbon dioxide emissions 2002-2007 (Statistics Finland).

	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

The consumption figures are 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 Trade and Industry, 2006), but in 2006 bioethanol re-entered the market.

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.

As a response to the latest inventory review, N₂O emission factors will be checked and updated if needed.

3.3.3 Railway transportation

Railway transportation in Finland comprises railway transport operated by diesel locomotives.

Railway transportation is a minor emission source in the transport sector. The emissions of railway transportation were 0.11 Tg (CO₂ eq) in 2007, 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.

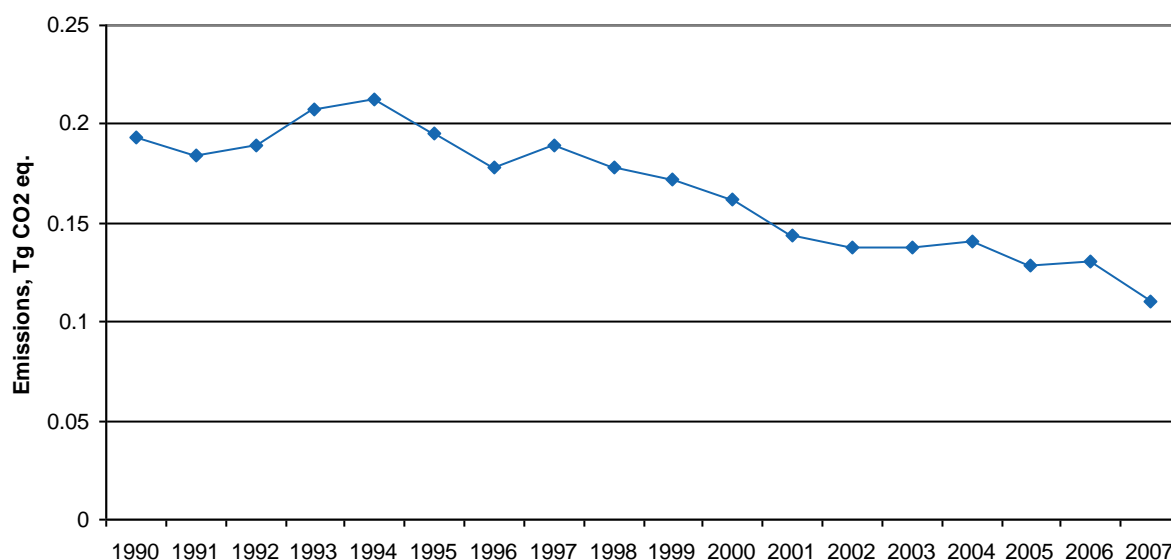


Figure 3.3_7. Emissions from railway transportation in 1990-2007 (Tg CO₂ eq.)

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, 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 by 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

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 based on national figures. The factor slightly differs from that expressed in the IPCC guidelines (3,140 g/kg fuel). The factor has been obtained from the product analysis by Neste Oil laboratories.

Table 3.3_10. Emission factors used in the calculation of emissions from Railway transportation (Neste Oil Ltd, IPCC guidelines).

Fuel type	CO ₂ emission factor g/kg fuel	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	3 164	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 5. 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.

In internal self-evaluations experts of transport sectors examined the actual activity and the results attained and compared them with the objectives set and the plans made. Regarding the 2007 inventory an error was revealed in the original passenger transport activity data. When corrected it was found out that it only had a minor effect on the total results and thus no recalculations were needed. Findings of internal self-evaluations were discussed in the quality meeting held between the inventory unit and the expert organisations in January 2009.

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 sector (CRF 1.A 4c).

Domestic navigation also is a minor emission source in this category. The emissions of domestic navigation were 0.59 Tg (CO₂ eq) in 2007, it was 4% 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.

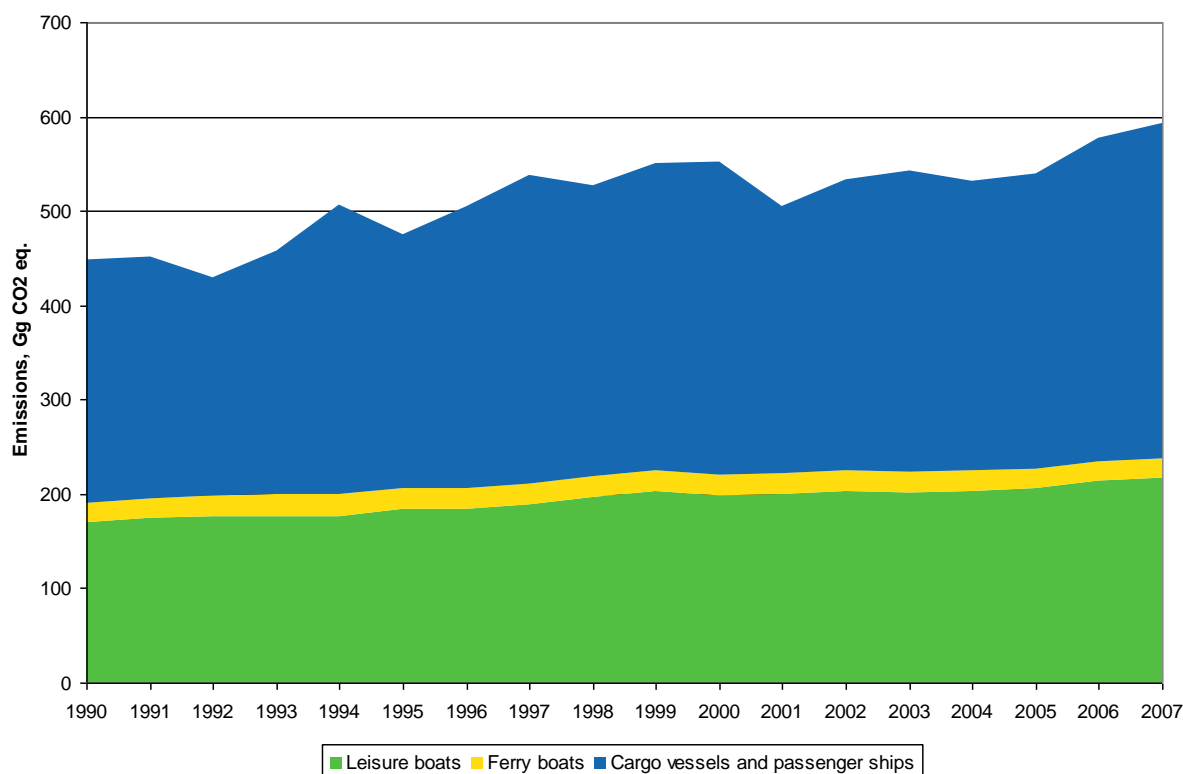


Figure 3.3_8. Emissions from domestic navigation by ship types in 1990-2007 (Gg CO₂ eq.)

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 although the trend has been increasing and it will continue as such.

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 from 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 Finstaship and ferryboat consumption from Destia) and corresponding emission factors.

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

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

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

3.3.4.2 Activity data

A detailed database on every ship visit in Finnish ports is obtained from the Finnish Maritime Administration. The database includes data on ship type, age, size (GRT), 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 island 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 Island of Åland.

Data on total fuel consumption of icebreakers are obtained from the Finnish Maritime Administration.

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).

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 Maritime Administration.

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.

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

The Finnish Maritime Administration'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

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. 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 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	CO ₂ emission factor g/kg fuel	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	3 133	0.039	3.76	43.0	750
Gasoil	3 195	0.0854	0.1708	42.7	845
Heavy fuel oil HFO	3 238	0.082	0.287	41.0	970

3.3.4.4 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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. Gasoline is used mainly by leisure boats. The share of gasoline 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.

In internal self-evaluations experts of transport sectors examined the actual activity and the results attained and compared them with the objectives set and the plans made. For the 2007 inventory, the findings of internal self-evaluations were discussed in quality meetings that will be held between the inventory unit and the expert organisations in January 2009. Especially the great changes in leisure boating that concerns next reporting period were discussed. These changes are presented in the section 3.3.4.7 Source-specific planned improvements.

3.3.4.6 Source-specific recalculations

No source-specific recalculations have been done.

3.3.4.7 Source-specific planned improvements

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. In addition, the summer was rainy. All this led up to clearly low use of the leisure boats. The present MEERI model does not include an easy way to handle such changes in the leisure boat usage. Recently an additional small funding was given to study the changes in boating and to modify the model to better handle boat usage and factor behind.

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_14.

Other transportation is the second largest source of emissions in the transport sector. The emissions were 0.74 Tg (CO₂ eq) in 2007, it was 5% of the sector's emissions and almost 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, snowmobiles) while emissions from business activities have decreased (diesel). Emissions by fuel in 1990-2007 are presented in Figure 3.3_9.

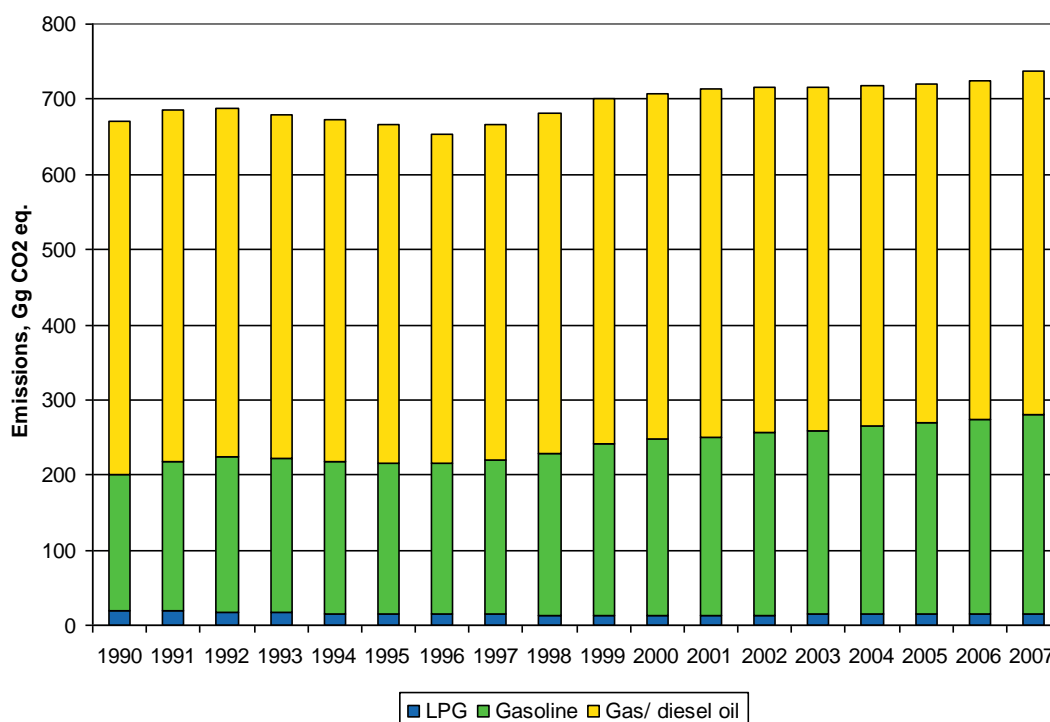


Figure 3.3_9. Emissions from other transportation by fuel in 1990-2007 (Gg CO₂ eq.)

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	990	724	602	262
2007	1 026	738	596	259

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 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

CRF subcategory	Type of machine
1.A 3e Off-road vehicles and other machinery, cont.	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 5. 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.

For the 2007 inventory, the findings of internal self-evaluations were discussed in quality meetings that were held between the inventory unit and the expert organisations in January 2009.

Results of the updated non-road TYKO model have been compared with the 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 6.5 Tg (CO₂ eq) in 2007; it was over 10% of the energy sector's emissions and over 8% of total greenhouse gas emissions of Finland. Emissions were 9.0 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).

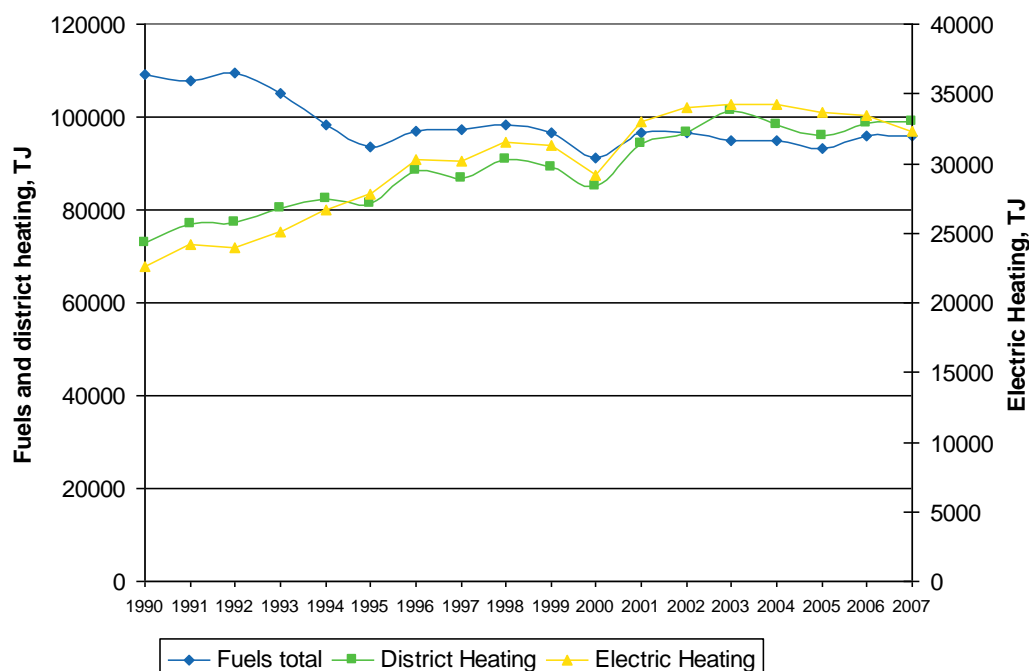


Figure 3.4_1. Energy consumption of heating in residential, commercial and public buildings, 1990-2007 (Energy Statistics, Yearbook 2008).

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 than 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. In addition, 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 1990-2007 by subcategory are presented in the Table 3.4_1.

Table 3.4_1. Emissions from sectors 1.A 4 Other sectors and 1.A 5 Other in 1990-2007 by subcategory (Tg CO₂).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2002	2001	2002	2003	2004	2005	2006	2007
CO₂																		
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	5.4	5.3	5.1	5.0	4.9
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	1.23	1.19	1.17	1.12	1.13	1.10
b. Residential	3.07	2.96	2.97	2.92	2.69	2.52	2.57	2.56	2.60	2.54	2.34	2.48	2.41	2.29	2.25	2.15	2.12	2.04
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	1.95	1.93	1.87	1.73	1.77
5. Other	1.19	1.02	1.03	1.03	1.14	1.20	1.22	1.13	1.38	1.23	1.27	1.26	1.26	1.35	1.16	1.09	1.13	1.02
Stationary, non-specified	0.92	0.75	0.75	0.73	0.79	0.89	0.95	0.87	1.14	0.97	0.98	0.99	0.97	1.08	0.94	0.83	0.86	0.73
Stationary, feedstock and non-energy use	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
Mobile	0.058	0.110	0.113	0.132	0.163	0.130	0.113	0.114	0.104	0.129	0.159	0.137	0.160	0.169	0.122	0.166	0.170	0.187
CH₄																		
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	0.194	0.197	0.196	0.195	0.193	0.196	0.193
5. Other	0.0028	0.0023	0.0021	0.0021	0.0022	0.0023	0.0024	0.0021	0.0028	0.0026	0.0024	0.0024	0.0024	0.0024	0.0021	0.0019	0.0019	0.0016
N₂O																		
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	0.077	0.077	0.075	0.075	0.073	0.072	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	0.29	0.28
Indirect N ₂ O emissions from NO _x	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

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 (see Section 3.1.1.3., figures 3.1_4 and 3.1_5).

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 known energy uses of feedstock and lubricants are subtracted from the corresponding total amounts. For the rest of the feedstock 100% (previously 90%) 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. Emissions from natural gas used as feedstock are calculated and reported in sector 2.B 5. These non-specified emissions from burning of feedstocks (which are not included in 1.A 2 or 2.B 5) are included in category 1.A 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 times 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 subcategory 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 fuel used for the heating of commercial, institutional and residential buildings, which are estimated by a space heating estimation model 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 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).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1.A 4 (stationary)																		
Liquid Fuels	75.8	74.5	75.8	69.6	64.4	58.9	60.5	60.3	61.3	60.1	55.4	58.0	56.8	54.5	53.7	51.0	49.2	48.7
Solid Fuels	0.51	0.38	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
Gaseous Fuels	1.90	2.19	2.62	2.98	3.23	3.23	3.53	3.64	3.56	3.75	3.60	3.96	4.14	4.13	3.88	3.93	3.99	3.77
Other Fuels	1.21	0.86	0.67	0.87	0.77	0.95	1.01	1.03	1.05	1.03	0.97	1.04	1.08	1.13	1.15	1.09	1.16	1.16
- peat	1.20	0.85	0.65	0.85	0.77	0.95	1.01	1.03	1.05	1.03	0.97	1.04	1.08	1.13	1.14	1.09	1.16	1.16
- waste and other	0.003	0.009	0.016	0.012	0.002	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	NO	NO
1.A 4 (mobile)																		
Liquid Fuels	14.9	14.6	14.3	14.0	13.9	13.9	13.6	13.9	14.2	14.1	14.0	13.8	13.9	13.9	13.8	13.6	13.2	13.0
1.A 5 (stationary)																		
Liquid Fuels	11.5	8.8	8.4	8.6	9.7	10.4	10.4	9.1	12.5	10.2	10.5	10.0	10.1	9.9	9.0	8.4	8.5	6.6
Solid Fuels	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Gaseous Fuels	1.01	1.62	2.46	1.70	1.41	2.53	3.67	3.99	4.39	3.89	4.03	4.84	4.43	6.71	5.39	4.31	4.72	4.83
Other Fuels	0.24	0.16	0.08	0.06	0.10	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
- peat	0.24	0.16	0.08	0.06	0.10	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A 5 (mobile)																		
Liquid Fuels	0.8	1.5	1.5	1.8	2.2	1.8	1.5	1.6	1.4	1.8	2.2	1.9	2.2	2.3	1.7	2.3	2.3	2.6
1.A 5 (non-specified burning of feedstocks)																		
Liquid fuels	2.83	2.27	2.30	2.28	2.51	2.43	2.16	1.94	1.89	1.82	1.76	1.82	1.77	1.41	1.28	1.17	1.29	1.48

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	CH₄ kg/TJ	N₂O kg/TJ	CO kg/TJ	NM VOC kg/TJ
Oil	10	2	20	5
Coal	300	4	200	200
Natural gas	3	1	50	5
Peat	50	4	200	200
Wood, households and agriculture	200, 50	2	2 100	600, 200
Wood, commercial buildings	50	2	2 100	200
References	IPCC Table 1–7 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–8 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–10 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–11 Peat: the same EF as for coal

3.4.3 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 partly commercially traded, and because use 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 has been improved considerably after recalculation (see Section 3.4.5). Both the activity data and emission factors have been checked. It must be noted that category 1.A 5 includes residuals and statistical corrections, which reflect the problems in the energy balance in some years.

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. There is a reference calculation based on energy balance, showing activity data (PJ) and CO₂ emissions.

3.4.5 Source-specific recalculations

There were minor corrections in the activity data for non-specified burning of feedstocks (1990-1992, 2006).

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 is no emission 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 2007 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 petrol 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, Statistical yearbook 2008) on oil refining activities.

Estimates of carbon dioxide emissions from flaring are derived directly from data received from the industry. They are based on the quantity of hydrocarbons flared. However, generally the composition of the hydrocarbons that are flared is not known precisely and the estimates are therefore quite uncertain.

Fugitive emissions from gas transmission are calculated by Gasum Oy (Riikonen A. 2008). Calculations are based on measurements for the years 1996-2007. 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 (1996-2007) made by Helsinki Kaasu Oy (Riikonen A. 2007) 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. 2008) and emissions from the petrol distribution chain and refuelling of vehicles on expert estimation of the Finnish Gas and Oil Federation for the years 1990-2007. (Pohjolainen, 2008). Indirect CO₂ emissions were calculated using the equation below. It was assumed for years 1990-2007 that

the average carbon content is 80% by mass under the sector fugitive emissions from oil and natural gas based on 2006 IPCC Guidelines. Used fossil carbon content fraction of NMVOC for years 1990-2007 is based on limited published national analyses of speciation profile (Netherlands NIR 2005, EPA 2002).

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

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).

3.6.2.3 Activity data

Activity data for oil refining are taken from Energy Statistics (Energy Statistics, Statistical Yearbook 2008), indicating the quantity of oil refined.

For emissions from flaring no activity data are reported. The total quantity of oil refined is reported as background information but it is not directly related to emissions and estimates are not based on it. Emission estimates are roughly based on the quantities of hydrocarbons flared. As the exact composition and amounts of the flared substances are not known, reporting an estimate of the quantity of flared hydrocarbons is not thought to supply any relevant information.

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 5. 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 2007 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: - the unknown composition of flared hydrocarbons which introduces a very large uncertainty
- the not exactly known quantities of flared hydrocarbons which introduces a significant uncertainty

Uncertainty in emissions from flaring was estimated to be $\pm 50\%$.

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.

Flaring emissions are also less accurate for the early inventory 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

General (Tier 1) Quality Control (QC) procedures

- Assumptions and criteria for the selection of activity data and emission factors are documented.
- For a sample of emission estimates, the correctness of the calculation formulas has been checked.
- For a sample of emission estimates, the use of appropriate units throughout the calculations has been checked.
- The adequacy of documentation for internal use and to facilitate reviews has been checked.
- The consistency of input data and methods over the time series has been checked. Existing inconsistencies have been documented.
- Methane emissions from the transmission of gas were compared with previous estimates (reported under category 1.B 2b iii Other leakage).

Tier 2 QC:

Gas transmission:

- Emission estimates have been compared with estimates based on the IPCC's emission factor.

3.6.5 Source-specific recalculations

NM VOC emissions from the petrol distribution chain and refuelling of vehicles have been recalculated from year 2005 onwards. As a result of this recalculation the whole time series are now based on expert estimation of the Finnish Gas and Oil Federation. Indirect CO₂ emissions were recalculated, an average carbon content in NM VOC was estimated to be 80% due to IPCC 2006 GL earlier it was 85%. Emissions decreased due to these recalculations 6.0 Gg in 1990 and 2.6 Gg in 2006.

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 were 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 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 wrong category during 1990 – 1994
- some corrections to import/export figures of secondary products
- NCVs were corrected
- stock change data still partly estimated
- data for petrochemical industry was 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).

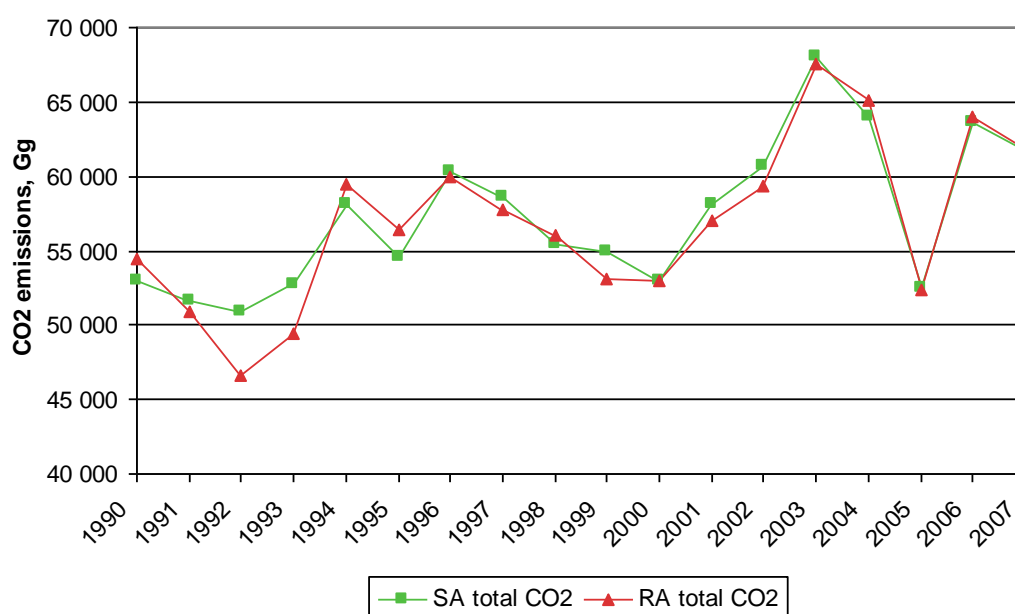


Figure 3.7_1. Carbon dioxide emissions of Reference and Sectoral Approach in 1990-2007 in Finland.

In the Reference Approach fuel mapping is different than in the Sectoral Approach in our case. 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 somewhat difficult to compare consumption figures and emissions by CRF fuel category.

The difference between the RA and SA was 0.4% for 2007 and 2.8% for 1990. There are some quite high differences especially in 1992 and 1993. No obvious reasons for these differences were 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.

There are some plans to continue this work, 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 time series data, which means recalculation of these years energy balances. 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.

The erroneous carbon factors of solid fuels, other kerosene and coking coal discovered in the latest inventory review have been checked and corrected for this submission. Also erroneous unit label of crude oil has been corrected.

3.8 International bunkers

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

Emissions from international bunkers were 1.7 Tg in aviation and 1.5 Tg CO₂ equivalents in navigation in 2007. Amount of emissions in international aviation has increased step by step for the whole time series except the beginning of the decade. 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.

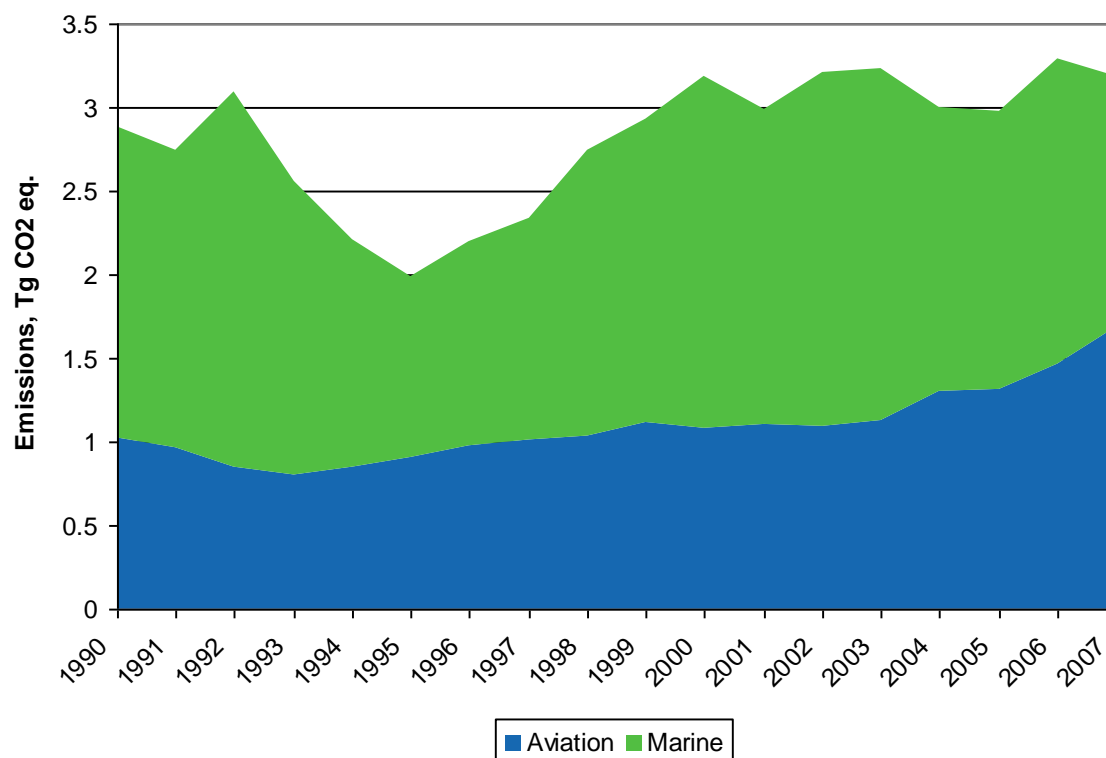


Figure 3.8_1 Emissions from international bunkers in 1990-2007, Tg CO₂ eq.

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-GHG) 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 review bunker fuel activity data and net calorific values were checked. All tonnage is taken directly from the Energy statistics background data. TJ is 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 IEA in Oil Questionnaire. There were small differences (< 0.5%) in physical quantities, caused probably by differing roundings during the time series. The NCVs used by IEA may differ from those used in the inventory.

The bunker fuel figures reported in tables 1C and 1A(b) 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.

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

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
Solid fuels	145.5	134.2	122.9	144.4	179.2	143.2	186.0	166.7	122.8	124.6	122.4	140.8	158.8	216.9	192.2	104.3	188.9	163.8
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
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
Blast furnace gases	7.3	7.7	8.0	8.8	8.8	8.1	9.1	9.5	10.0	10.5	11.2	9.8	10.1	11.0	10.8	11.0	11.5	10.6
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
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
Liquid fuels	374.9	365.5	360.1	345.4	355.1	344.7	349.4	349.9	359.3	361.0	347.7	353.7	359.1	358.5	357.0	352.6	354.9	356.9
Heavy fuel oil	71.0	68.3	65.6	61.0	64.9	57.9	60.0	54.1	53.0	54.8	48.9	51.5	52.2	50.9	46.8	42.9	44.7	42.1
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	87.1	85.3
Motor gasoline	85.6	85.5	85.8	80.8	82.6	81.7	79.0	81.0	80.1	79.5	76.7	77.8	79.2	79.6	81.0	80.7	80.1	80.0
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	89.0	94.3
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
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	24.0	24.7	26.2
Town gas	0.16	0.12	0.12	0.04	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
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
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
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
Other oil	4.5	3.9	3.7	3.8	3.8	3.9	3.6	3.1	2.8	2.8	3.0	2.9	2.5	2.0	2.0	2.2	2.7	2.9
Gaseous fuels	90.8	95.0	99.3	104.6	113.3	117.6	123.1	121.1	138.8	138.9	143.0	155.9	153.6	169.9	163.9	149.8	160.0	147.9
Natural gas	90.8	95.0	99.3	104.6	113.3	117.6	123.1	121.1	138.8	138.9	141.9	153.9	152.9	169.2	163.0	149.1	159.4	147.5
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

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Other	55.0	57.6	60.2	66.1	76.0	81.8	89.8	90.5	84.6	75.8	65.6	90.2	96.1	106.4	94.9	75.8	100.0	110.1
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	100.8	88.7	68.9	93.6	102.3
Mixed fuels (MSW/REF/RDF/PD F, etc.)	0.8	0.8	0.8	0.8	1.4	1.4	0.9	1.2	1.3	1.3	1.5	1.7	2.6	3.7	4.6	5.6	5.3	6.7
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	1.2	1.2	1.1
Biomass	178.5	176.0	173.4	205.8	213.7	217.1	217.0	247.0	255.7	273.7	272.1	260.7	281.0	286.8	299.0	279.4	314.7	299.6
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
Other wood fuels	90.3	88.0	85.7	100.0	101.4	104.6	107.7	116.4	129.9	129.9	130.4	133.6	138.2	146.1	151.5	147.0	155.4	142.1
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
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
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	0.6	0.7	0.7

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
Solid fuels	14.6	13.6	12.6	14.6	17.8	14.3	18.4	16.8	12.8	13.0	12.9	14.4	16.1	21.7	19.4	11.2	19.1	16.8
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
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
Blast furnace gases	1.8	1.9	2.0	2.2	2.2	1.9	2.2	2.4	2.5	2.6	2.8	2.4	2.5	2.7	2.7	2.7	2.8	2.6
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
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
Liquid fuels	27.8	27.0	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
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
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
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
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
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
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
Town gas	0.010	0.007	0.007	0.002	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
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
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
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
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	0.2	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
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
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
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
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
Mixed fuels (MSW/REF/RDF/P DF, etc.)	0.04	0.03	0.03	0.03	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.09	0.13	0.15	0.18	0.16	0.19
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

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Biomass	19.3	19.0	18.7	22.2	23.1	23.4	23.4	26.7	27.6	29.6	29.4	28.1	30.3	31.0	32.3	30.1	33.9	32.3
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
Other wood fuels	9.8	9.6	9.3	10.9	11.0	11.4	11.7	12.6	14.1	14.1	14.1	14.5	15.0	15.9	16.4	15.9	16.8	15.4
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
Hydrogen	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	0.022	0.024	0.04	0.06	0.06	0.06	0.07	0.07

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
Solid fuels	286.3	275.9	265.4	231.6	398.9	181.7	224.2	199.2	150.2	148.9	145.7	163.2	178.5	238.0	213.1	122.6	207.1	181.2
Hard coal	268.8	258.5	248.1	210.7	376.9	161.1	203.7	177.0	127.6	125.5	121.8	141.2	156.2	214.6	189.5	98.7	183.0	158.3
Coke	6.0	5.5	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	5.7	5.2	6.8
Blast furnace gases	7.3	7.7	8.0	8.8	8.8	8.1	9.1	9.5	10.0	10.5	11.2	9.8	10.1	11.0	10.8	11.0	11.5	10.6
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
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
Liquid fuels	5 891	5 585	5 427	5 202	5 014	4 849	4 709	4 538	4 451	4 296	4 019	3 900	3 777	3 605	3 390	3 175	2 965	2 823
Heavy fuel oil	255.9	241.5	227.2	185.8	171.0	136.5	146.7	137.4	140.8	143.9	127.6	136.2	138.4	138.7	129.0	119.5	125.6	123.1
Light fuel oil	801.3	790.9	780.5	773.4	754.5	743.4	753.7	741.2	777.9	765.8	711.8	723.3	715.9	691.1	678.0	649.6	627.1	609.2
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	2 558	2 412	2 229	2 051	1 861	1 741
Diesel oil	559.5	502.1	480.4	474.8	452.1	427.0	399.9	377.2	346.9	326.0	300.4	286.4	277.8	274.8	268.4	265.0	261.1	258.4
LPG	29.0	27.9	26.8	24.5	26.5	26.5	27.0	26.6	28.9	23.1	28.1	28.3	29.1	31.1	32.0	33.3	35.4	34.0
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	24.4	24.7	26.2
Town gas	0.49	0.37	0.37	0.12	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
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
Jet fuel	13.9	14.2	13.4	13.4	14.2	13.1	15.4	16.9	18.3	19.2	19.1	17.9	18.4	19.5	17.1	18.9	16.1	15.3
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
Other oil	14.1	12.2	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	6.5	7.3	8.1
Gaseous fuels	110.6	133.2	155.8	152.6	169.0	193.1	209.1	241.9	292.4	289.7	288.7	337.3	473.9	543.7	476.9	408.6	450.3	384.7
Natural gas	110.6	133.2	155.8	152.6	169.0	193.1	209.1	241.9	292.4	289.7	287.5	335.3	473.2	543.0	475.9	403.4	449.7	379.1
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
Other	239.5	231.1	222.6	250.9	280.0	308.7	340.6	350.4	334.6	297.9	284.2	353.9	376.3	413.9	367.1	307.6	412.4	440.0
Peat	230.5	225.2	220.0	247.0	273.8	303.3	334.0	343.5	325.3	289.6	274.3	345.4	365.6	400.5	352.2	290.6	398.5	421.2
Mixed fuels (MSW/REF/RDF/PDF, etc.)	4.0	2.7	1.4	1.5	3.5	3.6	2.1	2.5	3.0	3.0	5.5	4.2	6.0	9.1	11.5	15.0	12.6	17.3
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	4.2	4.7	4.3	3.5	2.0	1.3	1.5

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Biomass	8 086	8 131	8 177	8 310	8 359	8 625	8 990	9 076	9 170	9 041	8 843	9 221	9 421	9 462	9 392	9 301	9 536	9 313
Black/sulphite liquor	87.4	87.0	86.6	104.8	111.2	111.1	108.0	129.2	124.6	142.5	140.0	125.3	140.6	138.2	145.0	129.4	156.0	154.1
Other wood fuels	7 997	8 043	8 089	8 192	8 240	8 470	8 834	8 893	9 002	8 842	8 645	9 040	9 226	9 263	9 195	9 120	9 327	9 100
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
Hydrogen	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other non-fossil fuels	0.7	0.9	1.1	0.9	1.1	1.1	0.9	1.2	1.2	1.2	1.6	1.6	2.6	4.5	2.6	2.3	2.7	3.0

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
Solid fuels	293.1	279.5	266.0	300.1	321.7	274.4	313.3	300.2	247.3	247.6	240.4	273.7	294.3	361.3	336.5	241.1	324.2	300.4
Hard coal	274.3	261.3	248.4	278.1	294.6	248.1	291.8	276.6	223.4	222.7	214.8	250.4	270.6	336.4	311.1	215.0	298.2	273.2
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	6.4	6.6	6.0	10.1
Blast furnace gases	7.5	7.9	8.2	8.8	8.8	8.1	9.1	9.5	10.0	10.5	11.2	9.8	10.1	11.1	10.9	11.2	11.5	10.6
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
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
Liquid fuels	971	1 036	1 089	1 130	1 200	1 259	1 349	1 446	1 569	1 683	1 742	1 842	1 957	2 060	2 188	2 285	2 366	2 445
Heavy fuel oil	154.2	148.1	142.0	130.5	135.0	118.4	121.7	110.3	113.5	117.2	101.0	105.9	105.1	101.2	94.3	87.9	90.9	86.4
Light fuel oil	209.8	207.1	204.4	202.7	198.4	197.2	200.9	200.8	209.8	207.8	195.8	197.4	195.8	189.6	186.7	179.8	174.0	170.5
Motor gasoline	298.4	383.4	450.2	506.8	571.0	647.1	721.5	821.2	917.2	1 022	1 106	1 193	1 297	1 399	1 532	1 627	1 700	1 770
Diesel oil	219.7	211.1	207.6	209.4	207.9	210.2	214.1	222.8	229.6	238.5	243.9	251.0	259.8	269.6	276.8	286.7	296.4	311.1
LPG	10.7	9.7	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	18.2	19.6	18.5
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	48.4	48.9	51.3
Town gas	0.162	0.122	0.122	0.041	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.54	0.45	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
Petroleum coke	9.8	10.0	10.2	10.0	9.6	9.7	10.9	10.5	10.9	10.5	9.4	8.7	11.2	10.5	11.7	11.0	10.8	12.3
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
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
Other oil	7.8	6.5	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	4.6	4.6	4.8
Gaseous fuels	102.6	107.8	113.0	118.4	127.4	130.2	138.5	136.4	153.9	155.5	164.1	175.2	170.9	187.5	183.5	167.8	177.9	166.8
Natural gas	102.6	107.8	113.0	118.4	127.4	130.2	138.5	136.4	153.9	155.5	163.0	173.2	170.2	186.7	182.4	167.2	177.3	166.4
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
Other	171.8	185.7	199.5	225.1	258.2	296.0	347.6	352.0	332.0	284.5	264.7	374.9	418.9	460.8	409.2	332.0	420.2	460.8
Peat	168.7	182.7	196.7	221.9	252.5	290.3	341.3	345.5	323.1	276.7	257.2	365.4	405.9	440.6	386.4	305.0	396.9	430.0
Mixed fuels (MSW/REF/RDF/P DF, etc.)	1.16	1.30	1.44	1.51	3.52	3.59	3.22	3.35	3.37	3.03	3.47	5.07	7.72	15.22	18.18	24.53	20.93	28.48
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	2.53	2.34	2.27

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Biomass	282.2	274.4	266.6	328.9	344.5	356.6	381.2	446.7	476.8	531.1	523.8	510.9	535.1	541.8	580.3	549.5	600.5	556.9
Black/sulphite liquor	88.3	87.5	86.7	104.8	111.2	111.1	108.0	129.2	124.6	142.5	140.0	125.3	140.6	138.2	145.0	129.4	156.0	154.1
Other wood fuels	193.0	185.8	178.6	223.0	231.9	243.9	271.7	315.6	350.2	386.5	381.0	382.6	391.0	399.7	431.1	415.7	438.8	397.0
Biogas	0.10	0.09	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
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	1.55
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	1.84	1.58	2.57	2.57

4. INDUSTRIAL PROCESSES (CRF 2)

4.1 Overview of the sector

4.1.1 Description and quantitative overview

Industrial greenhouse gas emissions contributed 9% to the total anthropogenic greenhouse gas emissions in Finland in 2007 (Figure 4.1_1), totalling 6.7 Tg CO₂ equivalent.

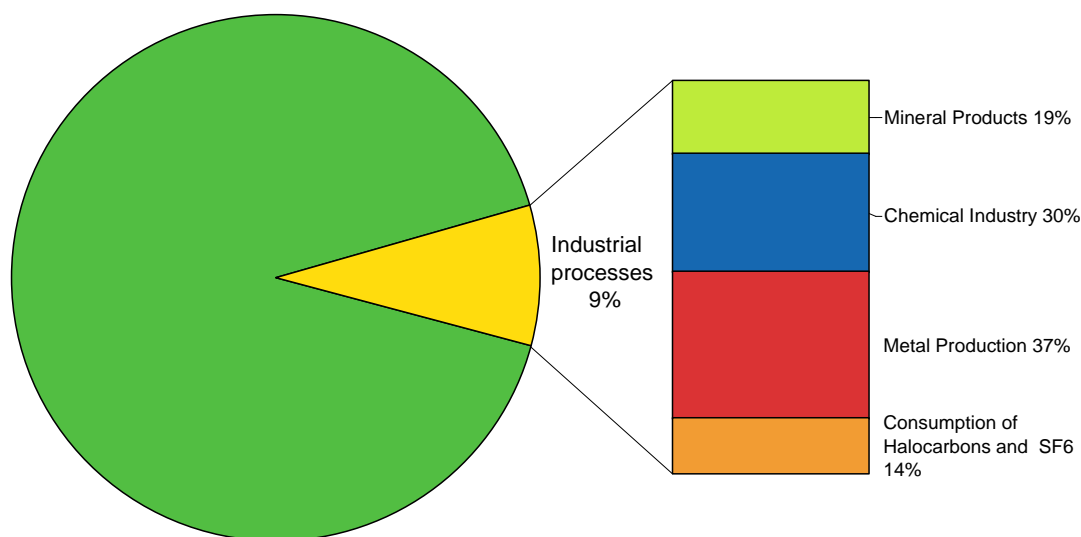


Figure 4.1_1. Emissions from industrial processes compared with total emissions in 2007.

Finnish emissions from industrial processes are divided into following emission categories: Mineral products (CRF 2.A), Chemical industry (CRF 2.B), Metal production (CRF 2.C), Consumption of halocarbons and SF₆ (CRF 2.F), and Other production (CRF 2.D). Under Mineral products Finland reports emissions from cement and lime production, limestone, dolomite and soda ash use. Emissions from nitric acid and hydrogen production are reported under Chemical industry. Emissions from Metal production include CH₄ emissions from coke production and CO₂ emissions from coke and heavy bottom oil used in blast furnaces. CRF category 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 4.

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 emissions from industrial processes in the Finnish inventory in 2007 were CO₂ emissions from iron and steel production, N₂O emissions from nitric acid production and CO₂ emissions from cement production with 3%, 2% and 1% shares of the total greenhouse gas emissions, respectively. F-gases emissions comprised together over 1% 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_1). The most significant change is the increase in emissions of F-gases which are now nine-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 2007; first fast decrease due to closing of a plant and after that started a slow increase of emissions. CH₄ emissions have increased by 78% 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 2007 approximately 31% higher than in 1990. In 2007 there was launching of a new hydrogen producing plant which increased CO₂ emission of over 400 Gg.

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).

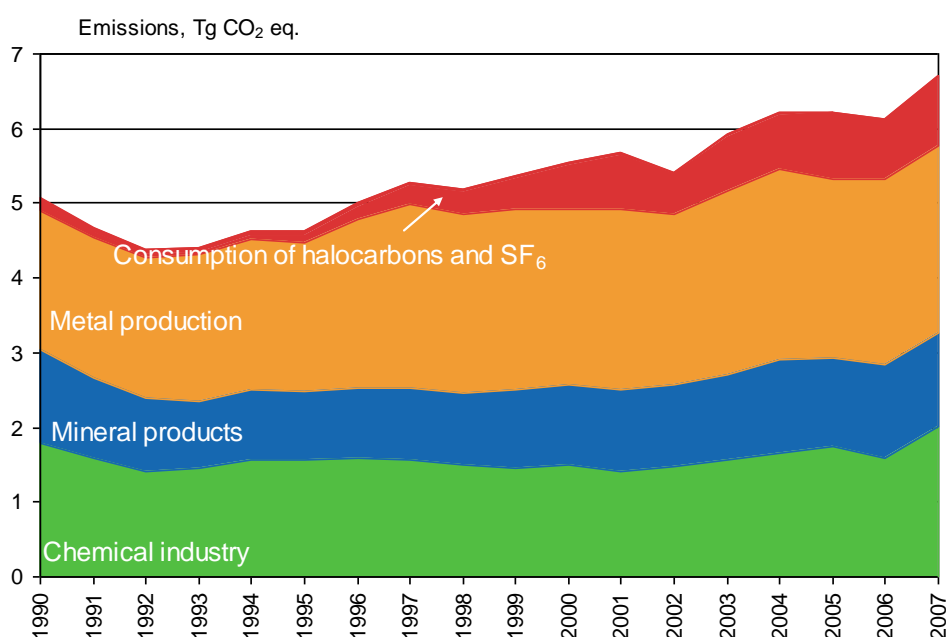


Figure 4.1_2. Total greenhouse gas emission from industrial processes in Finland in 1990-2007 (Tg CO₂ eq.).

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).

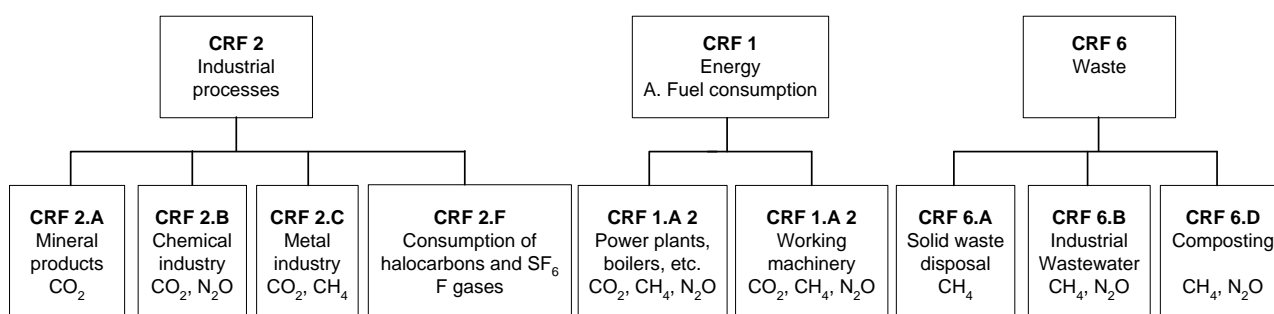


Figure 4.1_3. Emissions from industrial sources and their reporting categories in the national greenhouse gas inventory.

Table 4.1_1. Trend in greenhouse gas emissions from industrial processes (Gg CO₂ eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CO₂																		
A. Mineral Products	1 254	1 080	974	884	939	911	940	954	958	1 036	1 089	1 102	1 104	1 156	1 237	1 180	1 264	1 266
B. Chemical Industry	125	139	103	94	129	111	127	126	115	113	124	120	133	151	164	119	139	524
C. Metal Production	1 862	1 874	1 887	1 959	2 008	1 975	2 256	2 460	2 392	2 411	2 332	2 386	2 272	2 448	2 541	2 372	2 438	2 460
CH₄																		
C. Metal Production	5.11	4.95	5.23	9.17	9.68	9.66	9.56	9.23	9.58	9.45	9.56	9.55	9.58	9.40	9.49	9.38	9.13	9.08
N₂O																		
B. Chemical Industry	1 656	1 438	1 303	1 360	1 435	1 463	1 463	1 443	1 376	1 347	1 364	1 291	1 334	1 407	1 496	1 625	1 438	1 482
HFCs	0.02	0.05	0.10	0.10	6.52	29.3	77.3	167.8	245.2	318.6	501.7	656.9	463.4	652.1	695.1	863.8	747.7	903.9
PFCs	0.07	0.08	0.09	0.1	0.12	0.14	0.16	0.18	0.21	28.0	22.5	20.1	13.4	14.9	12.2	9.9	15.4	8.4
SF₆	94.4	67.3	36.6	33.6	34.9	68.5	72.2	76.0	53.2	52.0	51.5	55.0	51.3	41.7	23.2	19.6	40.4	22.6
Total	4 997	4 603	4 308	4 340	4 562	4 567	4 945	5 236	5 149	5 315	5 494	5 640	5 381	5 880	6 178	6 199	6 091	6 676

4.1.2 Key categories

The key categories in industrial processes in 2007 are summarised in Table 4.1_2.

Table 4.1_2. Key categories in Industrial processes (CRF 2) in 2007 (quantitative method used: Tier 2).

Source Category	Gas	Criteria
2.B 2 Nitric Acid Production	N ₂ O	L, T
2.C 1 Iron and Steel production	CO ₂	L
2.F 1 Refrigeration and Air Conditioning Equipment	HFCs, PFCs	L

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 one fifth in 2007 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 2007.

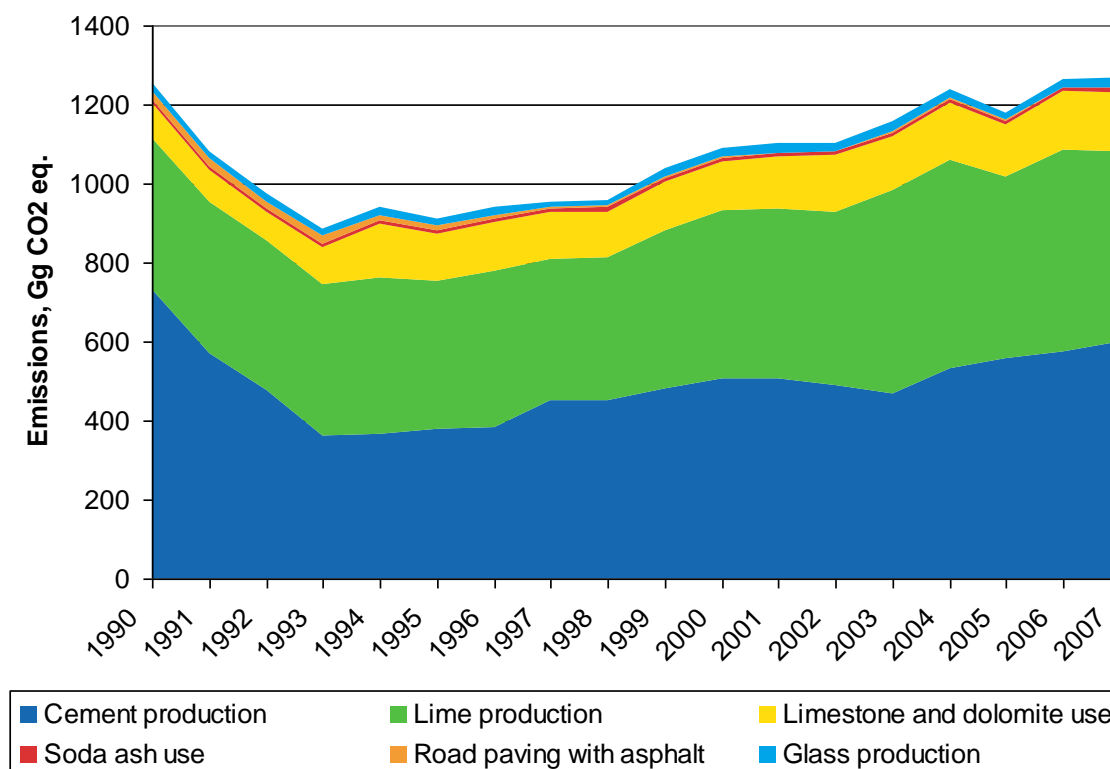


Figure 4.2_1. Greenhouse gas emission from Mineral products in 1990-2007 (Gg CO₂ eq.).

Cement production is the biggest source of greenhouse gas emissions in the Mineral products category, being 0.6 Tg in 2007. Emissions were almost 15% in 1990 and less than 10% in 2007 of the emissions in the Industrial processes sector and less than 1% of Finland's total emissions in 2007. There was a rapid decrease in the production volume at the beginning of the decade due to the closing down of one 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. The time series of cement production have been recalculated to improve the consistency of calculation and the revised methodology has been described in Section 4.2.2.

Lime production is the second largest source in the category Mineral products, emissions were 0.5 Tg in 2007. 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 3% during this period. The usage has been increasing and it was 68% greater in 2007 than in 1990. One plant producing phosphates has equipment to capture CO₂ and it supplies it to another plant.

Glass production is also a minor source in the category Mineral products. Emissions have been less 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
2.A 1 Cement Production	734	572	476	363	365	380	384	451	450	481	507	506	488	469	532	556	574	600
2.A 2 Lime Production	383	380	378	382	395	375	393	358	364	400	425	429	439	513	528	461	510	480
2.A 3 Limestone and Dolomite Use	88	83	74	95	137	116	125	118	116	123	125	134	144	138	146	132	151	152
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
2.A 6 Road Paving (indirect CO ₂)	21.0	19.9	18.8	17.7	14.4	11.0	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.A 7 Glass Production	20.8	18.1	20.3	18.0	18.9	19.4	21.5	15.4	15.6	20.5	21.2	23.7	22.2	23.3	20.5	19.9	20.8	21.9
2.A Totals	1 254	1 080	974	884	939	911	940	954	958	1 036	1 089	1 102	1 104	1 156	1 237	1 180	1 264	1 266

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:

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

where $w(.)$ are the weight fractions in clinker and $r(.)$ are the molecular mass ratios of 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.

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 1990-2007 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 5. 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 three years have been compared with ETS data.

4.2.2.6 Source-specific recalculations

Following the recommendation from the 2008 centralized review, Statistics Finland arranged a meeting where the above improved methodology was presented to the producer. At that 10 October meeting, the above methodology was adopted in agreement with the producer. The two graphs below show the current IEF with year-to-year changes not greater than 0.37 percent. Since the emissions factors are kept constant throughout the time series, the variation displayed is due to changes in clinker and cement kiln dust production data. The variation is smaller in 1990 - 1995, which is due to the approach taken to impute missing data, as discussed above.

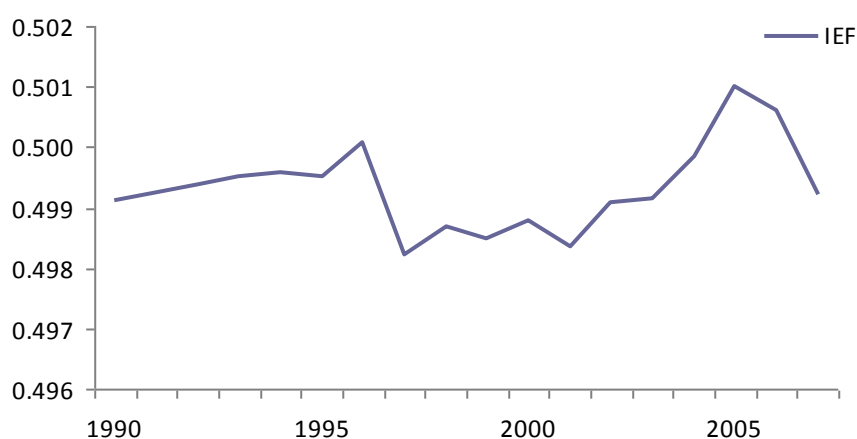


Figure 4.2_2. Time-series of implied emission factor

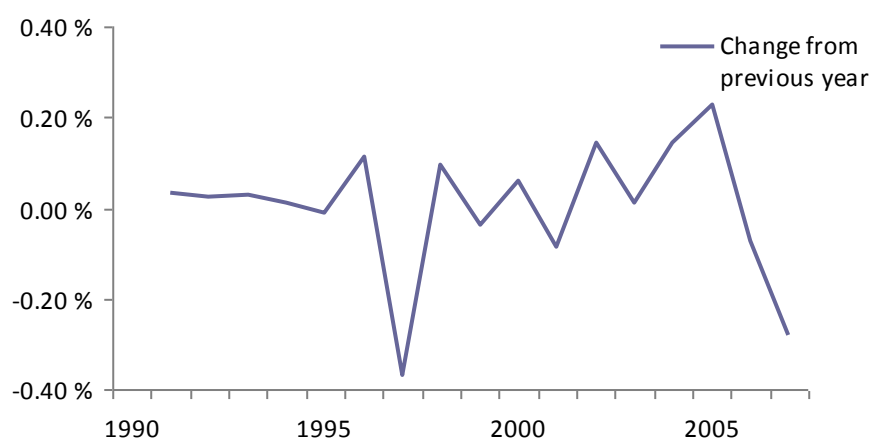


Figure 4.2_3. The change of emission factor from the previous year, %

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 5. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

For 2007 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 $\pm 4\%$.

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 2007 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: 1998-2007: 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 rawmaterials. And for activity data the most important QC procedure is that 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 for environmental or statistical reasons.

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 arisen 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

The amount of produced lime has been corrected for years 2005 and 2006, CO₂ emission increased by 6 Gg (2005) and 7 Gg (2006), because all CO₂ sources in the production process were taken into account.

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 2007 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 5. 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 $\pm 10\%$. 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.

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. And for activity data the most important QC procedure is that 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 for environmental or statistical reasons.

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. In the verification it was also noticed that one company using dolomite for sulphur dioxide control reports their emissions miscalculated to Energy Market Authority, their emission factor is too small.

2.4.6 Source-specific recalculations

Emission calculation of one dolomite using company was corrected for year 2006 and emissions decreased by 0.08 Gg and emission of a tile producing company was corrected for year 2006, the emission increased by 0.02 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 when calculating emissions from soda ash use. Activity data are collected directly from individual companies. Other data on soda ash users have been checked using industrial statistics and web sites of companies and discovered that their use does not cause CO₂ emissions. The amount of used soda ash is given in Table 4.2_3.

4.2.5.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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%. 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 2007.) 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.

4.2.5.5 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 for environmental or statistical reasons.

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 emission of another company has 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) for the first time for 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 use of asphalt have been calculated from NMVOC emissions for the time series 1990-2007. Indirect CO₂ emissions were calculated using the equation below. It was assumed that the average carbon content is 80% by mass for years 1990-2007 for all categories under the sector Industrial Processes based on 2006 IPCC Guidelines. Used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile. (Netherlands NIR 2005, EPA 2002).

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

4.2.6.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 emissions and reported to the UNECE CLRTAP Secretariat. For the 2007 NMVOC emissions an uncertainty analysis will be made by 15 May 2009 and the documentation will be 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 2006 NMVOC emissions was estimated at -32% - +34%. 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

Indirect CO₂ emissions were recalculated, an average carbon content in NMVOC was estimated to be 80% due to IPCC 2006 GL instead of earlier 85%, emissions decreased in 1990 1.3 Gg and in 2006 0.1 Gg.

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 t CO₂ / t Na₂CO₃.

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 2007 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

Quantitive estimates of uncertainty are provided in Annex 5. 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 ±10%. 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%...+7%. 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 2007.) 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. And for activity data the most important QC procedure is that 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 for environmental or statistical reasons.

The calculated emission data of 4 plants (out of 5) have been verified with ETS data and emissions have been found to be almost equal (+/-2%). Reason for difference is that in the inventory calculation not all carbonate is assumed to be calcinated in the production process. 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 use of soda ash of a company has been adjusted for years 2005 and 2006 and emissions increased by 0.02 Gg in both 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
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
<i>EF (t/t)</i>	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
<i>CKD Correction Factor</i>	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
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
<i>EF (t/t)</i>	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
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
<i>EF (t/t)</i>	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
Dolomite Consumption, 1 000 t	23	20	17	16	17	16	17	18	23	31	35	36	34	35	39	39	40	46
<i>EF (t/t)</i>	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
2.A 4																		
Sodium Carbonate Consumption, 1 000 t	20	17	17	20	20	22	20	20	22	22	20	18	21	21	21	20	15	24
2.A 6																		
Amount of NMVOCs, 1 000 t	7.16	6.79	6.42	6.05	4.90	3.74	2.74	1.32	1.27	1.00	0.98	0.98	0.98	1.06	0.758	0.775	0.682	0.911
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
<i>EF (t/t)</i>	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	0.455	0.455	0.454
Sodium Carbonate Consumption, 1 000 t	24	20	22	20	22	22	25	18	19	25	25	28	27	28	25	26	27	28

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 production is the only key source of this source category in the Finnish inventory. Emissions 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 2007 were 2.0 Tg CO₂ eq. and it was about 30% of this sector's emissions and over 2% of Finland's total emissions. Emissions from hydrogen production increased fourfold in a year because a new hydrogen plant was launched in autumn 2006.

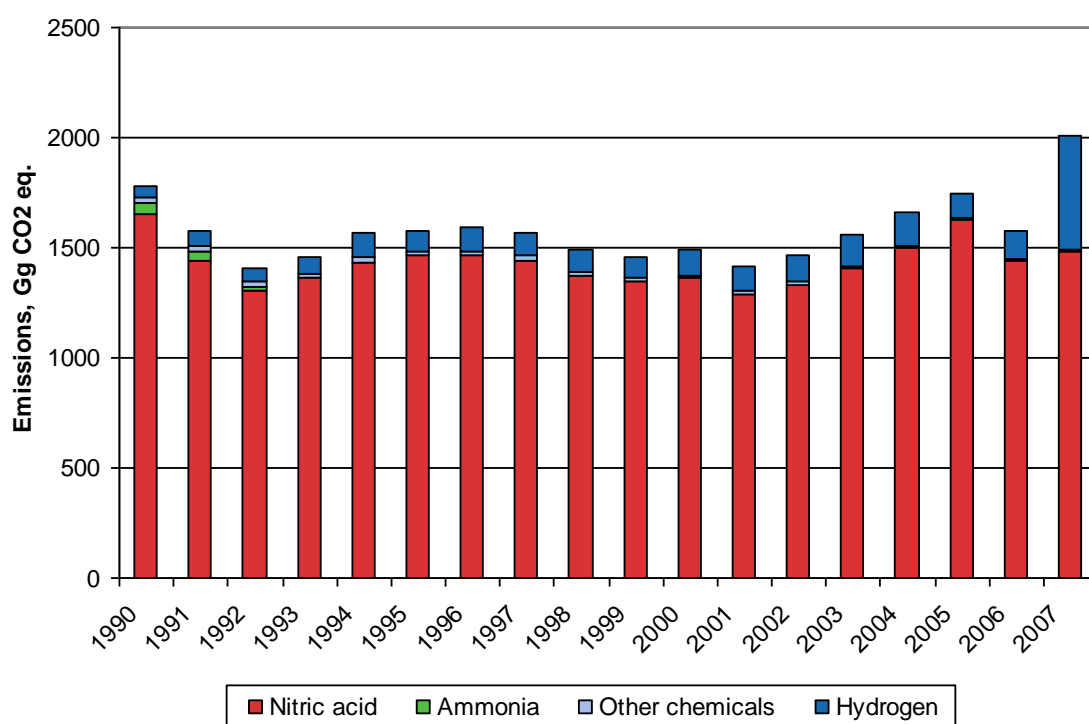


Figure 4.3_1. Greenhouse gas emission from Chemical industry in 1990-2007 (Gg CO₂ eq.).

Nitric acid is nowadays produced in Finland in three single-stage medium pressure plants. Emissions of N₂O from nitric acid production were approximately 4.8 Gg in 2007, which was almost 2% of Finland's total greenhouse gas emissions and 24% 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 at the beginning of 2005. The production of nitric acid has varied from about 430 to 620 Gg nitric acid per year.

Emissions of CO₂ from hydrogen production were approximately 517 Gg in 2007, which was over 0.6% 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. One new plant was launched up in 2006 and that increased 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 total time series of emissions from ethylene production were removed due to new information received from the producer. Methane emissions have never been released to atmosphere because all generated gases are redirected to natural gas use as energy. Calculated emissions decreased yearly less than 10 Gg CO₂, for year 1990 emissions decreased 3.9 Gg.

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
CO₂																		
2.B 1 Ammonia Production	44	45	19	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	130	517
2.B 5 Indirect	24	21	21	19	20	20	21	20	15	14	13	13	11	10	12	8	9	7
N₂O																		
2.B 2 Nitric Acid Production	5.34	4.64	4.20	4.39	4.63	4.72	4.72	4.66	4.44	4.34	4.40	4.17	4.30	4.54	4.83	5.24	4.64	4.78
2.B Totals in Gg CO₂ 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	2 006

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 N_2O 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 N_2O emitted per mass of nitric acid produced):

- plant A, 7.6 kg/t for 1990–2005;
- plant B, 9.5 kg/t for the years 1990–2004;
- plant C, 9.3 kg/t for 1990–2007;
- 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))

The operation of plant E has been improving since the start-up and emission factor has not been established. Plant B has been using new kind of catalyst from May 2005 and has succeeded to decrease the emissions, there have also been done some process changes and adjustment which have multiplied the production amount.

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 5. 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 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.

And for activity data the most important QC procedure is that production amount have been checked using as many independent sources as possible and only small differences (+/-1%) between figures have been noticed. All activity data are site-specific and reported for environmental or statistical reasons.

4.3.2.6 Source-specific recalculations

No source-specific recalculations have been done.

4.3.2.7 Source-specific planned improvements

As a source-specific QC procedure the quality system of measurements in the plants will be studied and the results of that study will be included into the next submission report.

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: $C_nH_m + nH_2O \rightarrow (n + m/2)H_2 + nCO$

CO inverting: $CO + H_2O \rightarrow CO_2 + H_2$

Natural gas as activity data: $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$

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 amount of used hydrocarbons is shown in Table 4.3_3.

4.3.3.4 Uncertainty and time series' consistency

Quantitive estimates of uncertainty are provided in Annex 5. 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%. 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. And for activity data the most important QC procedure is that 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 for environmental or statistical reasons.

The calculated emission data of one plant (out of 5) have been verified with ETS data and emissions have been found to be equal.

4.3.3.6 Source-specific recalculations

The calculation method of a hydrogen production plant was defined and corrected. Hydrogen is produced in a different process than earlier thought and an emission factor was too high. Emissions were decreased for the whole time series. In 1990 emissions decreased 3.1 Gg and in 2006 8.7 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 1990-2007 for all categories under the sector Industrial Processes based on 2006 IPCC Guidelines. Used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile (Netherlands NIR 2005, EPA 2002).

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

The amount of NMVOCs emitted in the chemical industry in 1990-2007 are presented in Table 4.3_3.

4.3.5.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 emissions and reported to the UNECE CLRTAP Secretariat. For the 2007 NMVOC emissions an uncertainty analysis will be made by 15 May 2009 and the documentation will be 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 2006 NMVOC emissions was estimated at -32% - +34%. 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 NMVOC 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

Indirect CO₂ emissions were recalculated, an average carbon content in NMVOC was estimated to be 80% due to IPCC 2006 GL instead of earlier 85%, emissions decreased in 1990 1.5 Gg and in 2006 0.6 Gg.

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
Ammonia	28	29	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric acid	549	480	428	445	461	476	477	480	452	453	451	430	448	477	503	582	599	615
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	39.8	190
NMVOC emissions	8.32	7.05	7.08	6.41	6.67	6.75	7.07	6.90	4.98	4.85	4.35	4.40	3.78	3.38	4.00	2.64	3.05	2.36

4.4 Metal Production (CRF 2.C)

4.4.1 Source category description

This source category in the Finnish inventory includes CH₄ emissions from coke production (reported in CRF tables under Iron and steel production) and CO₂ emissions, mostly from coke and heavy bottom oil used in blast furnaces. 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 is one of the key sources 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 2007 and this was over 37% of sector's and over 3% 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 55% since 1990 while total emissions of iron and steel industry have increased only 34% 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 the production of steel was lower due to market situation. 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 1990-2007.

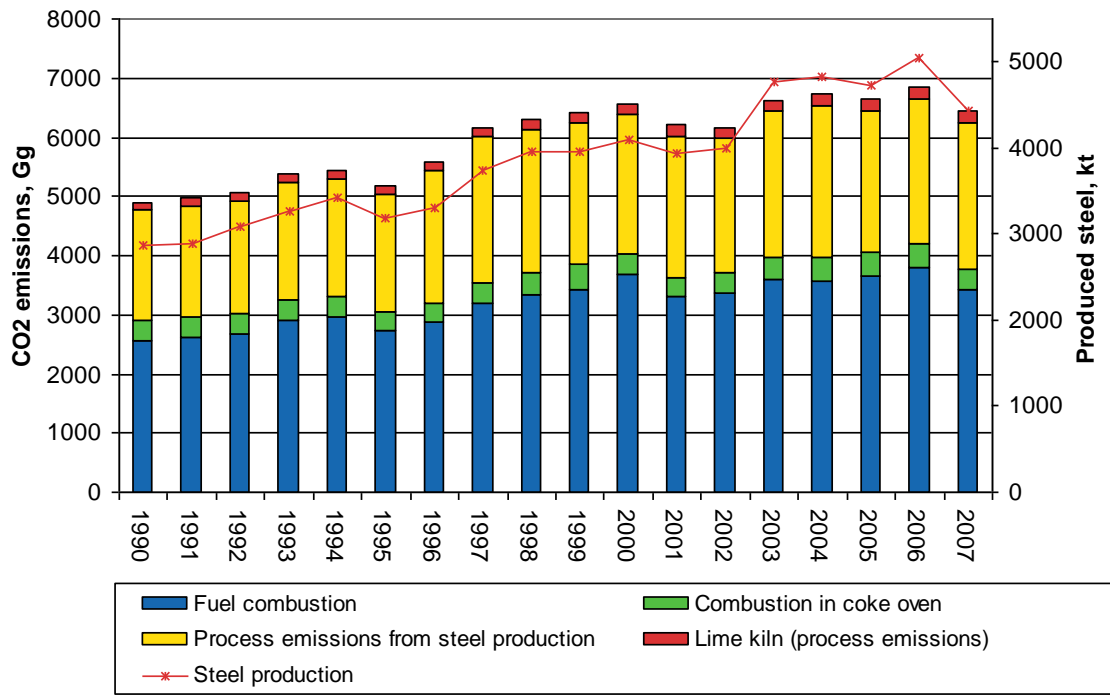


Figure 4.4_1 Total emissions of steel production and amount of produced steel.

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
CO₂																		
2.C 1 Iron and steel production - Production of steel	1 858	1 870	1 883	1 954	2 002	1 971	2 252	2 455	2 386	2 406	2 327	2 380	2 267	2 443	2 536	2 367	2 433	2 455
2.C Indirect from all processes of this category	3.0	3.1	3.2	3.5	3.6	3.1	2.9	3.5	3.8	3.5	4.0	3.6	3.3	3.4	3.2	3.4	3.3	2.9
CH₄																		
2.C 1 Iron and steel production - Coke 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
Totals in Gg CO₂ eq.	1 867	1 879	1 892	1 968	2 017	1 985	2 266	2 469	2 401	2 420	2 342	2 395	2 281	2 458	2 550	2 382	2 447	2 469

4.4.2 Steel production

4.4.2.1 Methods

The calculation method of CO₂ emissions from the iron and steel industry is country-specific. 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 (bottom-up) data. The methodology is slightly plant-specific, because all plants differ from each other.

The main common feature for all plants is that fuel-based emissions for each installation are calculated in the ILMARI system from the use of fuels, excluding coke and heavy bottom oil used in blast furnaces, and subtracted from total CO₂ emissions (described below). Fuel-based emissions are allocated to CRF 1.A 2a and CRF1.A 1c (coke ovens). The rest of emissions are allocated to process emissions in CRF 2.C 1 (and CRF 2.A 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. 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 emissions is 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, except 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 ETS. Starting from 2007 submission, 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_6. 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.

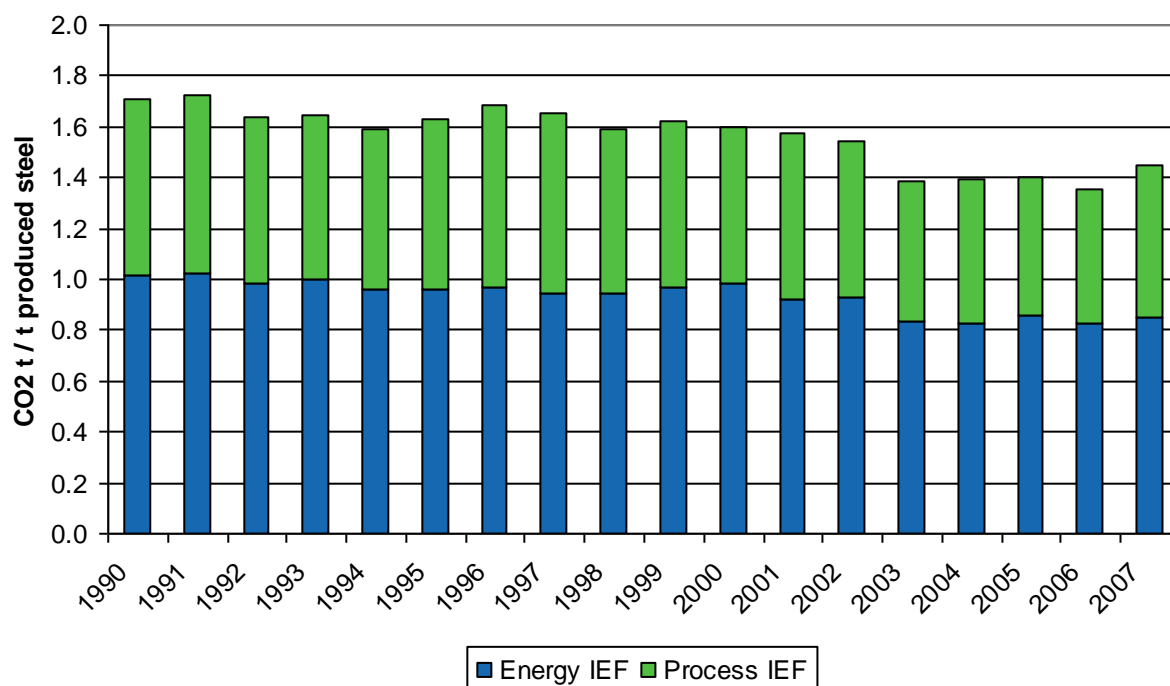


Figure 4.4_2. Implied emission factors for CO₂ in energy production and industrial processes in steel industry for years 1990-2007.

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, 2007) and special surveys by Statistics Finland. The production amount of steel can be found in Table 4.4_4.

4.4.2.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 $\pm 10\%$ in 1990 and 2007. 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.

4.4.2.6 *Source-specific recalculations*

There were minor corrections in the plant level data for 2005-2006. Emissions decreased 24 Gg in 2005 and 26 Gg in 2006.

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 5. 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 2007.

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 for environmental or statistical reasons. Activity data have been checked using as many independent sources as possible.

4.4.3.6 *Source-specific recalculations*

There has been done no recalculation.

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

Year	Production of coke	Production of crude steel	NMVOC emissions	Methane emissions
1990	487	2 861	1.14	0.24
1991	471	2 890	1.09	0.24
1992	498	3 077	1.11	0.25
1993	874	3 256	1.18	0.44
1994	922	3 420	1.28	0.46
1995	920	3 176	1.09	0.46
1996	910	3 301	1.00	0.46
1997	879	3 734	1.24	0.44
1998	912	3 952	1.30	0.46
1999	900	3 956	1.21	0.45
2000	910	4 096	1.36	0.46
2001	909	3 938	1.27	0.45
2002	912	4 003	1.13	0.46
2003	895	4 766	1.19	0.45
2004	904	4 832	1.07	0.41
2005	894	4 738	1.20	0.45
2006	870	5 054	1.15	0.43
2007	865	4 431	1.13	0.43

4.4.4.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 emissions and reported to the UNECE CLRTAP Secretariat. For the 2007 NMVOC emissions an uncertainty analysis will be made by 15 May 2009 and the documentation will be 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 2006 NMVOC emissions was estimated at -32% - +34%.

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 are 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 NMVOC 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 for environmental of statistical reasons and part of activity data is statistics. All activity data have been checked using as many independent sources as possible.

4.4.4.4 Source-specific recalculations

Indirect CO₂ emissions were recalculated, an average carbon content in NMVOC was estimated to be 80% due to IPCC 2006 GL instead of earlier 85% emissions decreased in Steel production 0.2 Gg for the whole time series.

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 2007 they amounted to 6.3 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.

4.5.2 Methodological issues

NMVOC emissions from the forest industry, including pulp and paper as well as mechanical wood industry, are calculated at the Finnish Environment Institute. Activity data for the calculation are obtained from the Finnish Forest Industries Federation and from the VAHTI system and the emission factors from the Finnish Forest Industries Federation, Report August 1996 and the Finnish Forest Industries Federation, Annual report 2006, Sawmills and board production.

NMVOC emissions from the food industry are also calculated at the Finnish Environment Institute. Activity data for the calculation of NMVOC emissions from the food industries are obtained from Suomen Hiiva Oy, the National Research and Development Centre for Welfare and Health (Stakes), the Finnish Food and Drink Industries' Federation, the Finnish Food Safety Authority (EVIRA) and from the Finnish Fisheries Research Institute. Used emission factors are taken from the NPI (1999), Joint EMEP/Corinair Atmospheric Inventory Guidebook (2001) and YTV (1995).

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	4.4	1.4

4.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 emissions and reported to the UNECE CLRTAP Secretariat. For the 2007 NMVOC emissions an uncertainty analysis will be made by 15 May 2009 and the documentation will be 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 2006 NMVOC emissions was estimated at -32% - +34%. Due the diversity of the calculation the uncertainty in these subcategory is quite high. For example the uncertainty of data from VAHTI 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 $\pm 80\%$.

4.5.4 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.

In the calculation of NMVOC emissions from other 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 for environmental or statistical reasons and part of activity data is statistics. All activity data have been checked using as many independent sources as possible.

4.5.5 Source-specific recalculations

No recalculations have been done.

4.5.6 Source-specific planned improvements

No source-specific improvements are under consideration at the moment.

4.6 Consumption of Halocarbons and SF₆ (CRF 2.F)

4.6.1 Source category description

In 2007, greenhouse gas emissions under the source category CRF 2.F Emissions of consumption of halocarbons and SF₆ amounted to 0.9 Tg CO₂ eq, which is about 1% 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 2007, emissions were about nine-fold compared with emissions in 1995, which was chosen as the base year for F-gas emissions under the Kyoto Protocol in Finland (Table 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 to use of HFCs as a refrigerant agent and simultaneously to increase of emissions towards the end of the decade. There are two deflections in the upward trend. Those are temporary drop in year 2002 and a fall from year 2005 to inventory year 2006.

There are not known changes on the market that would cause such fluctuation. In the quantities of imported chemicals, 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 interannual variation in the beginning of the 2000's is expected to be 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 trend level and in the light of uncertainties shows, however, that it is hard to assess to which extend estimate 2002 is too low and how big part of the fluctuation is due to high estimates in adjacent years and to which extend 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 received also from these companies and a closer study proved that the exported HFC quantity could have been overestimated and the imported HFC quantity underestimated in some extent in the 2006 inventory. However, the study also showed that new evaluation of activity data based on 2007 responses would lead to a bit higher emission estimation but the emissions would, anyhow, be on a lower level than in 2005 or 2007. This indicates real fluctuations in the emission trend. 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 emissions of F-gases.

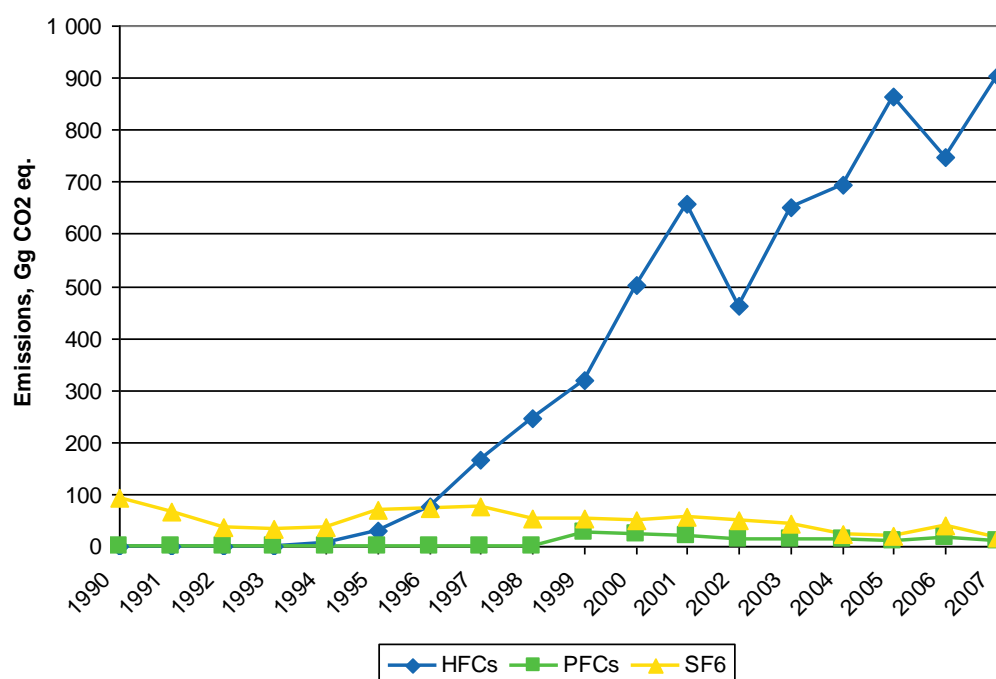
As opposed to the global growing trend, PFC emissions in Finland have declined since the peak level in the late 1990's. In Finland two most important sources of PFC emissions are usage of PFC in refrigerants and in semiconductor manufacturing processes. Both, the usage of PFC-218 (C_3F_8) for servicing 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 presumable caused by low response rate in the 2007 survey. According to the 2008 survey responses the quantity of PFC imported to Finland is only slightly below the level of 2005 whereas in 2006 the imputed amount was considerably larger causing larger emissions.

SF_6 emissions from electrical equipment are an exception amongst the F-gases emitting 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 not very large. Therefore, changes in market activity do have a large impact in emission level and can cause inter-annual fluctuation. The peak for 1990 coincides with the high level of economic activity in the country in general, and the fall of 2–4 years after coincide with the darkest years of the early 1990's recession. After the recession rather large amount of equipment was installed again in 1995 and also larger amount of gas was used for maintenance. 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. The peak in 2006 is due to varying activity data of one large importer. During recent years, the imported quantity of SF_6 is sold either to be used in semiconductor manufacturing or in electrical equipment.

Based on the level and trend analyses, refrigeration and air conditioning are key categories. SF_6 from electrical equipment is a key category due to its trend.

Table 4.6_2. Actual emissions of HFCs, PFCs and SF₆, 1990-2007 (CO₂ equivalent Gg).

Year	HFCs	PFCs	SF ₆	Total F-gases
1990	0.02	0.07	94.4	94.5
1991	0.05	0.08	67.3	67.4
1992	0.1	0.09	36.6	36.8
1993	0.1	0.1	33.6	33.8
1994	6.52	0.12	34.9	41.5
1995	29.33	0.14	68.5	98.0
1996	77.3	0.16	72.2	149.7
1997	167.8	0.18	76.0	243.9
1998	245.2	0.21	53.2	298.6
1999	318.6	28.0	52.0	398.5
2000	501.7	22.5	51.5	575.7
2001	656.9	20.1	55.0	732.0
2002	463.4	13.4	51.3	528.1
2003	652.1	14.9	41.7	708.6
2004	695.1	12.2	23.2	730.5
2005	863.8	9.9	19.6	893.2
2006	747.7	15.4	40.4	803.5
2007	903.9	8.4	22.6	934.9

**Figure 4.6_1.** Actual emissions of HFCs, PFCs and SF₆, 1990-2007 (CO₂ equivalent Gg).

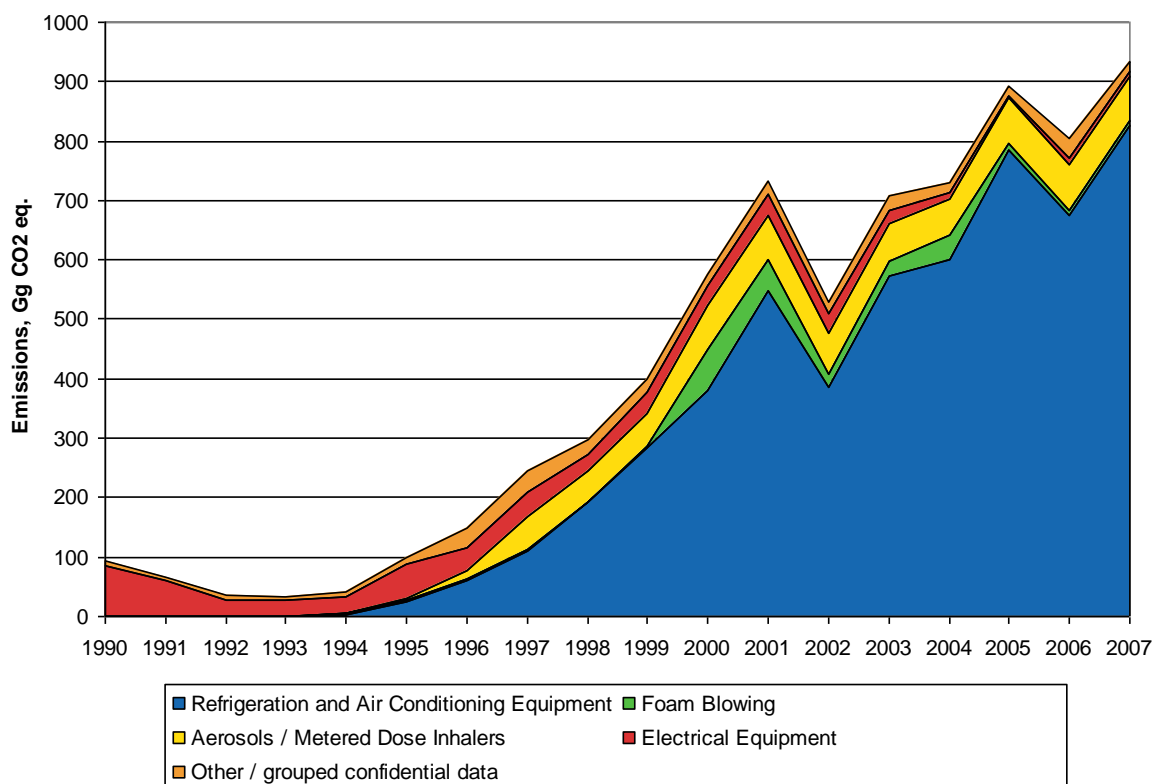


Figure 4.6_2. Actual emissions of F gases by subcategory, 1990-2007 (CO₂ equivalent Gg).

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 (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	The Revised 1996 IPCC Guidelines and the Good Practice Guidance give little advice on how to model the effect of leakage from products and the annually installed new foam products on HFCs banked in foams. See Section 2.3.7 of Oinonen (2003) on how these effects were modelled. Imports of HFC-245fa and HFC-365mfc into Finland have been detected. The quantities have been small so far. At the present level of activity, these HFCs are likely to give a negligible contribution to emissions.
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.
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 are not reported separately due to confidentiality.

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

emissions = imports – exports – destruction – 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 high 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 the 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 year 2000.

As the majority of the producers have changed to use hydrocarbons as blowing agent, the emissions from this sub-category are mainly emissions from products. It is estimated that in the beginning of the 2000's about 80% of the emissions were originated from manufacturing processes, whereas, in 2007 only about 6% were due to manufacturing and the rest 94% from foam products. The foam products are expected to emit most of the HFC that they contain in first year or two after their production and then stay rather steady until the end of product life which can be up to two decades.

Only HFC-134a emissions are calculated in the Finnish inventory. The imported amounts of HFC-245fa and HFC-365mfc and their use in manufacturing have been small and considered as negligible. In the 2007 inventory the amount of HFC-134a used in manufacturing of appliances was considerably smaller than before. In the upcoming inventory years also the emissions of HFC-245fa and HFC-365mfc should be closely followed since their importance may grow in the future.

Open-celled foams (soft foams) have not been produced in Finland with HFCs.

Actual emissions are calculated by IPCC Tier 2 described in more detail in the Appendix_4 of Chapter 4. Potential emissions were 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 was from the Good Practice Guidance (p. 3.85).

$$x = (1 - f)a + fb,$$

where $f = 0.5$,

a = Tier 1b emission in 2006, and

b = Tier 1b emission in 2007.

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 the 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 were used in the calculation.

The 2007 inventory is based on a country-level material balance. In 2003 the basic model (Equation 3.15 in the Good Practice Guidance 1996 p. 3.56) was developed further as it had previously given unrealistically large year-to-year variation on the level of emissions. Reasonable results were obtained using the newly developed model which presents the emission data as a three-year running mean. The results of the 2003 and 2004 inventory were reported with the Tier 3c method over three successive years of data.

In 2005, 2006 and 2007, the model suggested a negative value for the emission estimate when data from three latest years were used. This is due to the fact that most of the quantity of SF₆ gas imported over those years has been banked into equipment. The large storage term in equation draws the emission estimate down to negative values, which, obviously, is not realistic. Because of these reasons, the emissions for 2005, 2006 and 2007 were calculated with the same model but the estimates were based on one year of activity data.

A detailed account of the approach is given in the Appendix_4.

Data grouped due to confidentiality (CRF 2.F 9)

This category describes the following sources and emissions that have been grouped due to confidentiality:

- HFC-23 from refrigeration and air conditioning 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.

Semiconductors are reported with the IPCC Tier 1 method (Equations 3.31 and 3.32 in the Good Practice Guidance).

For reporting SF₆ from shoes "adiabatic property applications" are used, (Equation 3.23 in the Good Practice Guidance p. 3.65) HFC-125 and HFC-134a emissions from fixed fire fighting systems are reported with the "direct" method, i.e. the company that sells, installs and services the systems keeps statistics on the quantities released in fires and the quantities released due to system malfunction. These quantities are directly reported as emissions. HFC-23 from refrigeration and air conditioning are reported with the IPCC Tier 2 methodology and SF₆ from magnesium die casting is reported by using "direct reporting" (Equation 3.12 Good Practice Guidance p. 3.48).

4.6.2.2 Emission factors

Emission factors are described below for those 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 were not available, IPCC default factors were used (Good Practice Guidance, p. 3.96). The factors (probability density functions) used are shown in the table 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	
		$f_{M,i}$	$f_{B,i}$
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)
3	PU injected	N(0.125,0.020)	N(0.005,0.01)
4	PU appliance	N(0.075,0.020)	N(0.005,0.01)
5	PU discontinuous panel	N(0.125,0.020)	N(0.005,0.01)
N = normal distribution, with mean (<i>m</i>) and standard deviation (<i>s</i>) given in parenthesis N(<i>m</i> , <i>s</i>).			

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 the CO₂ 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 semiconductors 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)

Data on refrigerant imports for 2007 were obtained through a survey conducted in February to August 2008. Seven companies reported imports. Few major importers of refrigerants in Finland did not respond to the survey despite further requests. There is no legislative obligation for companies to report data. Therefore, the bulk import data for these companies had to be evaluated based on the data from previous years (2004-2006). The total estimated quantity of bulk refrigerants imported in 2007 was 697,356 kg. This quantity is 14% larger than the quantity imported in 2006 and but only 5% larger than quantity imported in 2005. In a closer study of activity data for 2006 it can be estimated that imputed data due to non-response could be slightly underestimated.

The total quantity of bulk refrigerants exported in 2007 was 593 kg. The exported quantity was 91% smaller than in 2006. The response rate in the 2007 survey was poor and most of the data was imputed, which resulted in a highly uncertain estimate of exported amount. In the 2008 survey most of the companies, which previously have been exporting bulk refrigerants, responded. Several of them were not exporting any bulk refrigerants anymore. The trend in bulk refrigerant exports has been decreasing since 2001 and the decrease is explained by some of the bigger companies giving up the refrigerant sales business. 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 was obtained from the Finnish Vehicle Administration (AKE). 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). In 2007 the imported used vehicles were taken into account in the emission estimates for the first time. The number of imported used cars was obtained from the Finnish Vehicle Administration (AKE) and the proportion of vehicles equipped with MACs was assumed to be the same as in newly registered vehicles.

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 that export was treated as negligible. The assumption and its effect to the total emissions was re-evaluated parallel with the 2007 inventory. Passenger car manufacture takes place at one plant in Finland. According to the company, currently 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 was added to the inventory, even though the export is much smaller than the import.

Also, the effect of manufactured MACs, their export and import of used vehicles to previous years calculations were studied. It was noticed that the total f-gas emissions as CO₂ equivalents would be only slightly (~2%) smaller than the reported figures. The correction would not affect to the base year. These amounts are well included to 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 correction of time series would not for certain lead to improved emissions estimate.

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 were obtained directly from manufacturers and importers. Exported equipment was similar to those imported.

Moreover, there is manufacturing of equipment in Finland. Data on charged refrigerant quantities were based on a survey. Imported refrigerants are also used in charging new equipment during installation and to convert existing equipment to a new refrigerant.

The survey to collect activity data for the inventory has been carried out annually since 2002. The response activity to the survey in 2008 was higher than in 2007 but 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 in use for the first time but it was still also possible to answer by postal mail since year 2008 was considered as transition period in order to receive more responses. The survey gave a response activity of about 53% in the refrigeration and air conditioning sector. 50% of the answers were received from the new electronic data collection system and other half by postal mail, phone, e-mail or fax. There are difficulties to reach some of the servicing companies via modern communication systems, as most of their work is done out of office. As the companies have no legal responsibility to report data on use of F-gases, at least one or two reminders are needed in order to reach a good response activity level. In the 2008 survey two reminders were sent, from which the second was not as effective as the first reminder.

In order to impute missing data, it has been assumed that the non-respondents behave similarly to 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.

The final piece of information needed to quantify the emissions model is the destructed refrigerant quantities. The quantity destructed was imputed, inferred from original reported quantities, based on assumption that non-respondents were a random sample of all respondents.

Table 4.6_6 summaries the refrigerant activity data. Note that all 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 still consists of HCFC-containing refrigerants.

Table 4.6_6. Summary of refrigerant activity data for inventory year 2007.

	Number of reporting companies	Quantity (kg)
Bulk refrigerants imported	7	697 356
Bulk refrigerants exported	31	593
Refrigerants in equipment imported	25	186 638
Refrigerants in equipment exported	20	43 204
Refrigerants used in manufacturing equipment	35	53 810
Refrigerants used in installation and conversion of equipment	169	122 235
Destructed refrigerant	88	42 275

¹In addition, the companies which previously have been exporting bulk refrigerants responded other activities but no exporting of bulk refrigerants.

HFCs from foam blowing (CRF 2.F.2)

Activity data for calculating emissions from foam blowing are presented in Table 4.6_6. The data are obtained from an annual survey of Finnish companies manufacturing, importing and exporting relevant foam products and raw materials used in foam blowing.

In 2004 the quantity of blowing agents used in manufacturing of products was nearly double in comparison with previous years. This was due to 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 since one large manufacturer has not been using HFC-containing products in their insulations since 2006. Emissions from product use have stayed approximately at the same level since 2004.

Note that the calculation model (see Appendix_4) requires data from previous inventories. These are described in Oinonen (2000, 2003 and 2004).

Table 4.6_7. Foam blowing activity data for 2007.

Activity	Blowing agents	Number of reporting companies	Quantity (kg)
Bulk import	HFC-134a	1	C
Imported in polyol	HFC-134a, HFC-245fa, HFC-365mfc	4	8 320
Imported in products	HFC-134a	0	0
Used in manufacturing	HFC-134a, HFC-245fa, HFC-365mfc	7	12 454
Exported in products	HFC-134a, HFC-245fa, HFC-365mfc	3	72

CRF 2.F 4 HFCs from aerosols and metered dose inhalers

Data are obtained from an annual survey of Finnish companies manufacturing, importing and exporting aerosol products (MDI, sprays for dust removal, tear gas, one-component foam). The response activity in the 2008 survey was 86%. All the largest companies responded.

CRF 2.F 8 SF₆ from electrical equipment

Activity data are obtained from an annual survey of Finnish companies manufacturing, importing and exporting electrical equipment. In the 2007 survey the response activity in this field of industry was very good, all of the largest respondents answered. Therefore, the reliability of the data is considered good and data imputation was not needed.

CRF 2.F 9 Data grouped due to confidentiality

Activity data for 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.

SF₆ is no longer used in running shoes. Although there are no longer imports or sale of SF₆-containing shoes, there will be some emissions from SF₆ "banked" in shoes sold in previous years. As the use of SF₆ stopped in 2004, the emission source has declined and the potential emissions based on the one-year data have become smaller than the actual emissions. The emissions from shoes are considered to become negligible three years after the sale of SF₆-containing shoes has stopped (after the inventory year 2007).

In 2007 a diminutive quantity of SF₆ was imported for use of magnesium die casting but this use is expected to terminate.

4.6.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2007 inventory. As a summary, the simulation suggests a 95% confidence interval for the level of emissions from refrigeration and air conditioning in 2007 ranging from 309 to 483 tonnes. A Monte Carlo estimate for the mean of emissions was 374 tonnes and the median of output distribution equals to 369 tonnes.

Simulation results suggest that most of the uncertainty was due to uncertainty of the quantities imported in bulk. Also, uncertainty of the factor alpha (see Appendix_4) has 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 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.

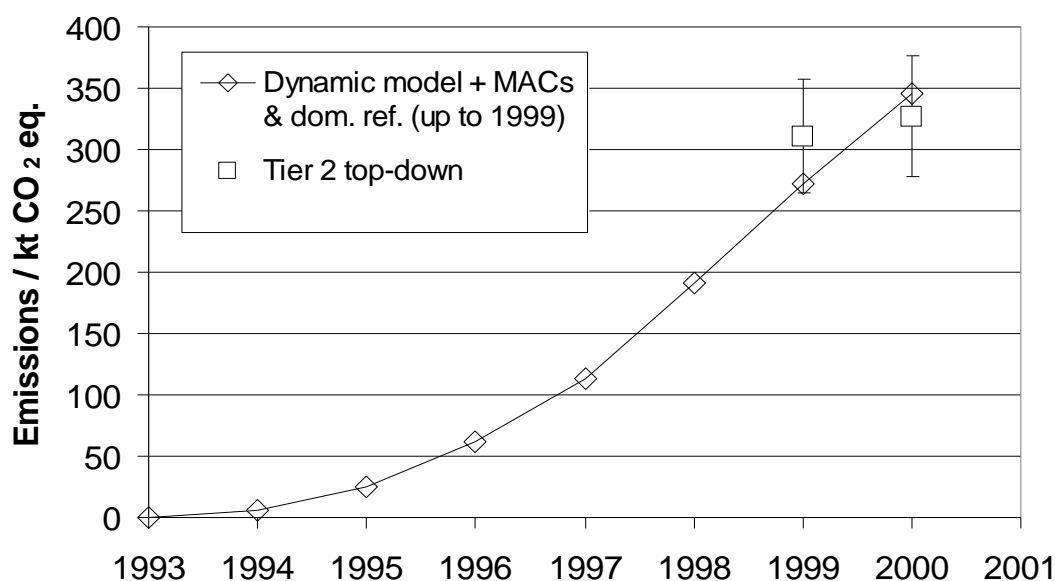


Figure 4.6_3. Emissions calculated with the dynamic model and the Tier 2 top-down method for two overlapping years (1999 and 2000).

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 occur in 2001 2002 and perhaps in 2005, 2006. However, when these deviations are presented in relation to the emission level (Figure 4.2_3), it can be seen that the deviation of these inventory years is comparable with other fluctuations.

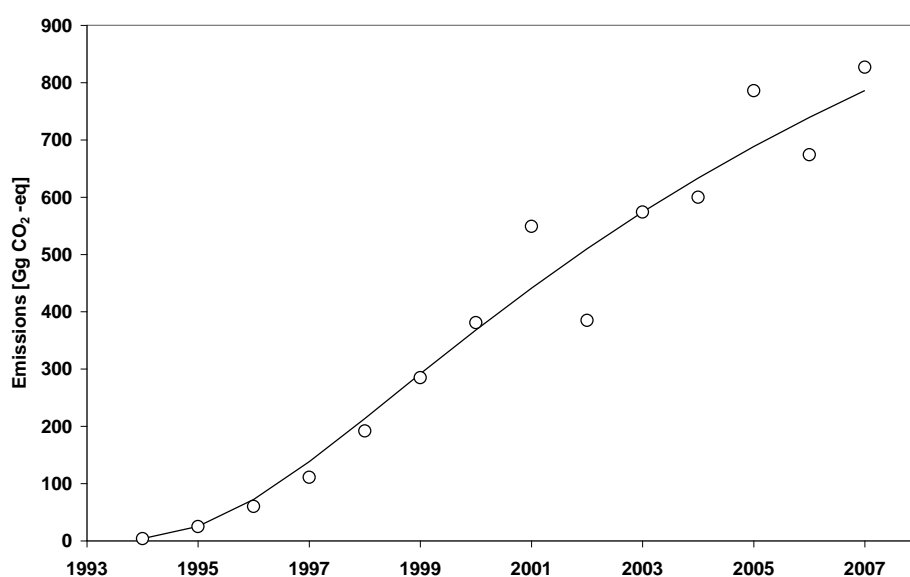


Figure 4.6_4. Emission estimates for category 2.F.1 reported in inventory reports (open circles) and the emission trend curve.

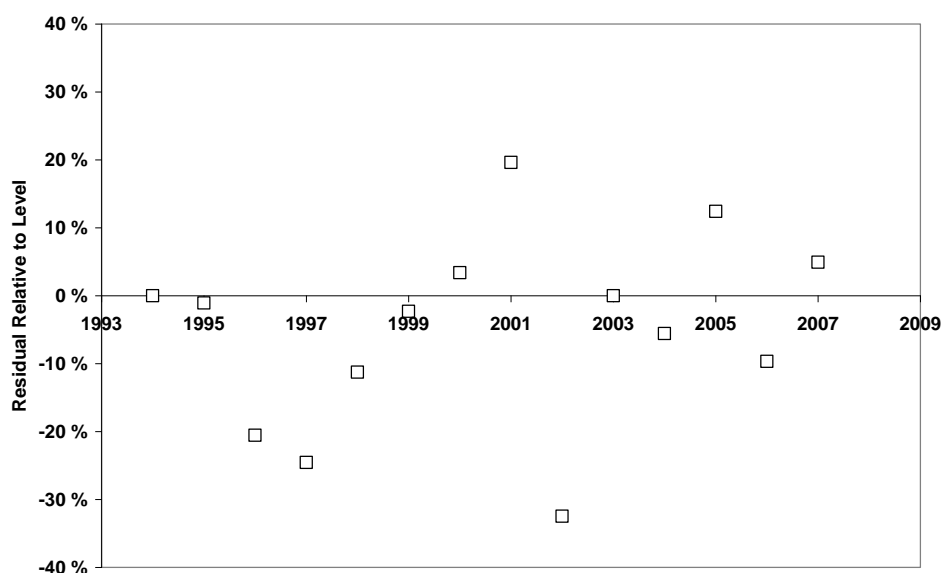


Figure 4.6_5. Deviations of reported emissions relative to the emission level.

Part of the inter-annual fluctuation is due to variation in activity data. In general, the survey response activity has been good (74%...83%) 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 is approximately five-fold to term *M*. The referred calculation method and the Tier 2 equation are described in detail in the 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 emissions. The result of simulation suggests an emission level of 6.29 tonnes with a give-or-take of about 3.3 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 factor for use and manufacture of XPS.

CRF 2.F 4 HFCs from aerosols and metered dose inhalers

For the year 2007 Tier 2 actual emissions from aerosols totalled 92 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 2006 in Mg and b = Tier 1b potential emission in 2007 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:

$$\begin{aligned}\text{Var}[x] &\approx (1 - 0.5)^2 \times 5^2 \text{ Mg}^2 + (0.5)^2 \times 5^2 \text{ Mg}^2 + (83.731 \text{ Mg} - 89.613 \text{ Mg})^2 \times 0.02^2 \\ \text{Var}[x] &\approx 12.61 \text{ Mg}^2\end{aligned}$$

The Good Practice Guidance recommends that uncertainties be expressed as two times the standard deviation. The uncertainty is thus $2 \times (12.61 \text{ Mg}^2)^{1/2} \approx 7 \text{ Mg}$ and the emission estimate (92 ± 7) tonnes.

CRF 2.F 7 SF₆ from electrical equipment

A new method Tier 3c was adopted in 2003 to calculate 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. The industry's own annual estimate of SF₆ emissions has previously been approximately 0.2 Mg. The differences in previous inventories (prior to 2003) have been analysed and discussed with the industry.

In 2003 and 2004 the SF₆ emissions from electrical equipment were estimated with the Tier 3c model over three successive years of data. This was done to avoid large annual variation of emission estimates. However, in 2005-2007 the emissions expressed as a three years' running mean gave a negative value for the emission estimate. This is a result from the fact that most of the imported gas is stored in equipment which leads to growing storage term in the model's mass balance. Over time, the "gas banks" grow and finally exceed the imports, which will lead to a negative value as an output. Therefore, 2005-2007 emissions are reported with the same method (T3c) but the calculations are based on one-year of activity data.

To assess the impact of change of the observed time period, the emission estimates for the inventory years 2003 and 2004 were obtained from archived calculation spreadsheets. Using one-year data, the emission estimates for 2003 and 2004 would have been close to zero. The reported emission estimates (three years of data) for those years were 0.4 tonnes and 0.015 tonnes, respectively, and for both years the scenario tree estimation suggested the model outcome to be a slight underestimate. The reproduced scenario tree analysis suggests that if the estimates for both 2003 and 2004 were based on one-year data they would still be within the previously reported uncertainty limits. As presented in previous reports this would be no more than 0.9 tonnes for 2003 and 1.5 tonnes for 2004. For the given reasons, no need for recalculation was seen necessary to correct the time series at this point. However, the homogeneity of time series and further examination of the T3c model itself should be assessed more closely in this sector. This would require a survey from which more detailed activity data would be received. For 2007 inventory same survey forms were still sent and no changes to old T3c model was made since the SF₆ emissions from electrical equipment are very small.

For the year 2007 the Tier 3c model emission estimate was 0.31 tonnes. The uncertainty of the emission estimate was studied with a scenario tree analysis. The start values of 0.308 tonnes, 0.231 tonnes and 0.385 tonnes for the Tier 3c emission estimate were used to produce low, normal and high emission scenarios. Giving a median of 0.34 tonnes, the scenario tree analysis suggests that the value calculated with the Tier 3c model is a representative estimate. The accounted emission estimate was a bit higher than the Finnish electrical equipment industry's emission estimate (0.08 tonnes). Both emission estimates have decreased from 2006. Industry's own survey and emission estimate, however, only accounts emissions from the equipment use and disposal but does not cover emissions from manufacturing of equipment.

It is not known with certainty whether the equipment is being disposed of and how much emission is 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 seven tonnes in 2007.

The time series has been recalculated once (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 leads to an approximate doubling of the level of emissions.

CRF 2.F 9 data grouped due to confidentiality

Uncertainty for this category was quantified using Monte Carlo simulation. The result is a give-or-take of about 0.3 Mg for the actual emissions mean value 1.54 Mg.

There is a discontinuity in the time series for grouped data. This is mainly due to phasing-out of halons in fixed fire fighting systems and their substitution with an extinguishant that is a mixture of HFC-125, HFC-134a and CO₂. First this led to growth of HFC emissions and gas banks in this category. Now the halons are mostly replaced in the existing systems and therefore, the imported quantities of HFCs for this purpose are decreasing, which also leads to lower emission estimates.

In addition to the substitution of ODS in fire fighting systems, there have been changes in 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. Some use in magnesium die casting was still reported in 2007 but this activity is expected to cease.

Generally, there is a growing trend in use of PFCs in semiconductor manufacturing processes but in Finland the amount of used gases remained fairly steady in previous years. It was assessed earlier that the PFC emissions from semiconductor manufacture might start to increase in Finland, too. However, during years 2003-2006 the PFC emissions have been approximately at the same level and the year 2007 shows a decline due to one manufacturers phasing out of the market.

There are several trends that simultaneously affect emissions from this category and it is hard to estimate how the category level emission trend will develop in future.

4.6.4 Source-specific QA/QC and verification

General (Tier 1) Quality Control (QC) procedures

- Documentation of assumptions, criteria for the selection of activity data and emission factors
 - Assumptions, criteria for the selection of activity data and emission factors are documented and argued in the notes and in the NIR under the sectoral descriptions.
 - Numeric values of assumptions of different parameters are also presented in the spreadsheets of calculation applications and included in the uncertainty simulations of emissions.
- Correctness of the calculations has been checked.
 - Each year a representative sample of emission calculations is done manually with pencil and paper before using software applications to produce emission estimates. This is done to check the correctness of the used formulas and accuracy of the calculations.
 - It is checked that the outcomes of spreadsheet calculation applications are similar to those produced manually.
 - For all of the emission estimates, the use of appropriate units throughout the calculations is checked.
- Adequacy of documentation
 - Documentation for internal use is detailed enough to reproduce emission and uncertainty estimates.
 - Inventory data and supporting data are stored to facilitate reviews.
- Consistency of input data and methods over the time series
 - Existing inconsistencies or data caps are documented in the NIR.
 - In categories where different methods have been used over time the need for recalculation is assessed and presented in the NIR

- Comparison of emissions from different categories with previous estimates
 - If there are any significant changes in trends the estimates are rechecked and the differences are explained in the NIR in each emission category.

Specific (Tier 2) Quality Control procedures:

- Emission comparison
 - Results for each category were compared with those obtained using a simpler model; i.e. actual emissions (T2 and T3) were compared with potential emissions (T1) (CRF table 2(II)).
 - Emission estimates for each category were compared with corresponding estimates by industry if those were available.
 - Trends were graphed and explained for all sources.
- Quality of activity data
 - Activity data for 2007 were compared with corresponding data for 2004, 2005 and 2006 to see any significant changes in the reported data. If changes were noted the correctness of the data was checked with the survey respondent.
 - Nearly all data are obtained directly via surveys and prepared for calculation by the inventory agency. Where secondary data sources are used it is checked that the data source is reliable.
 - Data from the sector of electrical equipment are compared to the data collected via the industry's own survey.
 - Data of destructured 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 accounting.
- Uncertainty estimates
 - Uncertainties were quantified for all source categories.
 - The assumptions on which uncertainty estimations were based are documented in each source category.
 - Importance analysis was used to elucidate the factors that have significant bearing on the uncertainty of each category.

4.6.5 Source-specific recalculations

No recalculations have been made since the previous inventory submission.

4.6.6 Source-specific planned improvements

A web-based system to collect activity data from the sector of refrigeration and air-conditioning was in use for the first time in the 2007 inventory. The respondents were able to fill in the questionnaire in the internet after which the data were automatically transferred to the calculation data base. For the 2008 inventory the questionnaire and instructions will be improved based on feedback from the industry in order to reach better response activity.

For calculating SF₆ emissions from electrical equipment the data gathered by the industry are utilised in addition to the data collected by the inventory institute via an annual survey. The emission estimates produced according to UNFCCC methodology are compared with the industry's own estimates for verification. There is some year to year variation in the emission trend from this sector and, therefore, the suitability of the calculation model will be evaluated in the future. The need of further examination of the T3c model itself was somewhat reconsidered parallel with the 2007 inventory and it was noticed that re-evaluating of the model would require a survey from which more detailed activity data would be received. For 2007 inventory same survey forms were still send and no changes to the model was made since the SF₆ emissions from electrical equipment are very small.

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

Potential emissions 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. 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.

Carrying out the calculations yields (all values in tonnes)

$$X_{1a} = \begin{bmatrix} 18.929 \\ 121.956 \\ 270.731 \\ 112.504 \\ 4.005 \\ 1.274 \end{bmatrix} - \begin{bmatrix} 0.000 \\ 0.003 \\ 0.010 \\ 0.004 \\ 0.576 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 0.324 \\ 1.682 \\ 1.986 \\ 1.233 \\ 0.150 \\ 0.019 \end{bmatrix} = \begin{bmatrix} 18.605 \\ 120.271 \\ 268.735 \\ 111.267 \\ 3.279 \\ 1.255 \end{bmatrix}.$$

The sum of the elements of X_{1a} is equal to 523.412 tonnes.

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.

Carrying out the calculations yields (all quantities in tonnes)

$$X_{1b} = \begin{bmatrix} 18.929 \\ 121.956 \\ 270.731 \\ 112.504 \\ 4.005 \\ 1.274 \end{bmatrix} + \begin{bmatrix} 13.568 \\ 14.974 \\ 155.961 \\ 1.407 \\ 0.000 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 0.000 \\ 0.003 \\ 0.010 \\ 0.004 \\ 0.576 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 3.134 \\ 6.894 \\ 28.744 \\ 4.428 \\ 0.000 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 0.324 \\ 1.682 \\ 1.986 \\ 1.233 \\ 0.150 \\ 0.019 \end{bmatrix} = \begin{bmatrix} 29.039 \\ 128.351 \\ 395.952 \\ 108.246 \\ 3.279 \\ 1.255 \end{bmatrix}.$$

The sum of the elements of X_{1b} is equal to 666.122 tonnes.

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), divided by 1,000:

$$X_{1a,eq} = X_{1a} G / 1000 = \begin{bmatrix} 18.605 \\ 120.271 \\ 268.735 \\ 111.267 \\ 3.279 \\ 1.255 \end{bmatrix} * [650 \quad 2800 \quad 1300 \quad 3800 \quad 140 \quad 7000] / 1000 = 1130.$$

$$X_{1b,eq} = X_{1b} G / 1000 = \begin{bmatrix} 29.039 \\ 128.351 \\ 395.952 \\ 108.246 \\ 3.279 \\ 1.255 \end{bmatrix} * [650 \quad 2800 \quad 1300 \quad 3800 \quad 140 \quad 7000] / 1000 = 1314.$$

The quantities correspond to an 19% and 15% increase from the previous year but only 9% and 8% increase compared to inventory year 2005, respectively.

Actual emissions

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 inventory (Oinonen 2004). A value for g was calculated based on observed changes in Tier 1a potential emissions. A geometric mean of annual growth in Tier 1a emissions between 1994 and 2007 yields a value of 19.5%. Substituting these values in the above equation yields

$$\alpha = 1 - \frac{1}{(1 + 0.195)^{10}} \approx 0.832.$$

Actual emissions are then

$$X_2 = \begin{bmatrix} 29.039 \\ 128.351 \\ 395.952 \\ 108.246 \\ 3.279 \\ 1.255 \end{bmatrix} - \left(\begin{bmatrix} 5.909 \\ 41.315 \\ 26.424 \\ 40.529 \\ 0.370 \\ 0.159 \end{bmatrix} + \begin{bmatrix} 2.219 \\ 7.426 \\ 37.120 \\ 5.930 \\ 0.000 \\ 0.000 \end{bmatrix} + \begin{bmatrix} 13.568 \\ 14.974 \\ 155.961 \\ 1.407 \\ 0.000 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 3.134 \\ 6.894 \\ 28.744 \\ 4.428 \\ 0.000 \\ 0.000 \end{bmatrix} \right) \times 0.832 = \begin{bmatrix} 13.595 \\ 81.076 \\ 237.239 \\ 72.106 \\ 2.971 \\ 1.123 \end{bmatrix}.$$

The sum of the elements of T_2 is equal to 408.110 tonnes. Emissions were thus 38% higher than in 2006 but only 8% higher than in 2005.

Estimates expressed in Gg CO₂-equivalent are

$$X_{2,eq} = X_2 G / 1000 = \begin{bmatrix} 13.595 \\ 81.076 \\ 237.239 \\ 72.106 \\ 2.971 \\ 1.123 \end{bmatrix} * [650 \quad 2800 \quad 1300 \quad 3800 \quad 140 \quad 7000] / 1000 = 827.$$

Expressed in CO₂-equivalents, emissions were 23% higher than in 2006 but only 5% higher than in 2005.

SF₆ from electrical equipment (CRF 2.F 8)

The principle of conservation of mass says that any input of gas minus output of gas must equal accumulation of gas within the system (Finland, let us call it briefly S)

$$m_{in} - m_{out} = m_{acc}, \quad (\text{Assuming generation within } S \text{ is zero.}) \quad (1)$$

where

m_{in} = input of gas into S over a given period of time

m_{out} = output of gas from S over a given period of time

m_{acc} = accumulation of gas within S over a given period of time.

Some proportion of quantity m_{out} is formed of releases into the atmosphere above S . This proportion of gas flowing out of S is the object of analysis. Let us denote this quantity by x . To be able to calculate x , we need to account for all the components of m_{in} , m_{out} and m_{acc} . First of all, input of mass into system S may take place via imports of gas-containing equipment and containers. Thus

$$m_{in} = i = i_e + i_c, \quad (2)$$

where

i = imported mass over a given period of time (Δt)

i_e = mass imported in equipment over Δt

i_c = mass imported in containers over Δt .

Second, output of gas from system S may take place in the form of exports and emissions

$$m_{out} = e + x = e_e + e_c + x, \quad (3)$$

where

e = exported mass over Δt

e_e = mass exported in equipment over Δt

e_c = mass exported in containers over Δt

x = mass emitted into atmosphere over Δt .

Thirdly, gas accumulated within the system may be estimated as the sum of the masses of gas accumulated (banked) in equipment and in containers

$$m_{\text{acc}} = b = b_e + b_c, \quad (4)$$

where

b = mass banked over Δt

b_e = mass banked in equipment over Δt

b_c = mass banked in containers over Δt .

Moreover, there are two separate stocks b_e : (1) gas in equipment sold to users and banked at users as new capacity, and (2) gas imported in equipment, or charged into new equipment at the factory within S , but not sold, and thus banked in importers' and manufacturers' stocks. The banked quantity is affected by the retiring capacity (old equipment taken out of use); it reduces the total quantity of gas banked in equipment over a given period of time. We thus have

$$b_e = b_{e,u} + b_{e,st} - r_{e,u}, \quad (5)$$

where

$b_{e,u}$ = mass banked in users' equipment over Δt

$b_{e,st}$ = mass banked in manufacturers' and importers' stocks over Δt

$r_{e,u}$ = the nameplate capacity of retiring equipment over Δt .

In practice, $b_{e,st}$ can be estimated from

$$b_{e,st} = i_e + c_e - e_e - s_e, \quad (6)$$

where

c_e = quantity charged into equipment within S over Δt

s_e = quantity sold in equipment for use within S over Δt .

$b_{e,u}$ appearing in (5) is estimated as the sum of s_e and the nameplate capacity of new equipment that is charged with gas during installation.

A similar equation holds for quantities banked in containers, $b_c = b_{c,u} + b_{c,st}$. It is assumed that there are no "retiring" quantities of unused gas. Equation (4) can then be rewritten as

$$m_{\text{acc}} = b_{e,u} + b_{e,st} - r_{e,u} + b_{c,u} + b_{c,st}. \quad (7)$$

Substituting (2), (3) and (7) into (1), and rearranging, gives

$$x = i_e + i_c + r_{e,u} - e_e - e_c - b_{e,u} - b_{e,st} - b_{c,u} - b_{c,st}. \quad (8)$$

x is thus the residual amount of gas, imported into S over Δt , which was not further exported from the system during that period of time, and which was not banked in equipment or in containers. It should be noted that in Equation (8) all terms, excluding $r_{e,u}$, are estimated from activity for a given calendar year (or over a period of years). $r_{e,u}$, on the other hand, must be estimated from historical data, or from current data using extrapolation. In both cases some average lifetime of equipment need to be assumed.

The UNFCCC guidelines require emissions to be quantified using two additional models besides that given by Equation (8). These models give an estimate of what are called potential emissions and they are defined as follows (remembering that generation and destruction does not take place within S):

$$x_{1a} = i_c - e_c \quad (9)$$

$$x_{1b} = i - e. \quad (10)$$

Models (9) and (10) are called Tier 1a and Tier 1b, respectively.

HFCs from foam blowing (CRF 2.F 2)

Emissions of HFC-134a used as a foam blowing agent were calculated using the Tier 2 model described in the Good Practice Guidance (pp. 3.93-3.95)

$$AE_{t,i} = f_{M,i}M_{t,i} + f_{B,i}B_{t,i} + R_{t,i} - D_{t,i},$$

where

$AE_{t,i}$ are HFC blowing agent (actual) emissions from foam type i in year t ,

$f_{M,i}$ is the emission factor describing manufacturing and first-year losses for the given foam type (note that the emission factor is assumed time-independent),

$B_{t,i}$ is the amount of HFC blowing agents banked in foams of type i in year t ,

$f_{B,i}$ is the emission factor describing HFC blowing agent losses from foam of type i in use,

$R_{t,i}$ are the HFC blowing agent losses occurring during decommissioning of retiring foam products of type i in year t , and

$D_{t,i}$ is the amount of HFC blowing agents destroyed in year t (recovered from foams of type i).

For the purposes of this document, the notation was modified from that used in the Good Practice Guidance.

Given the recent introduction of HFC blowing agents and the long average lifetime of foam products, both $R_{t,i}$ and $D_{t,i}$ were taken to equal zero:

$$R_{t,i} = D_{t,i} = 0,0 \quad t \leq 2007$$

The Good Practice Guidance (2000) and the Guidelines give little advice on how to estimate $B_{t,i}$, the amount of blowing agent banked in a given type of foam in a given year (a new blowing agent introduced to the bank annually, as well as the effect of leakage from products in use, should be modelled into the equation). In the Finnish inventory, the amount of blowing agent banked in foams was modelled as

$$B_{t,i} = (1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} - \sum_{n=0}^j IP_{t-n,i} - f_{B,i} \left((1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} - \sum_{n=0}^j IP_{t-n,i} \right)$$

That is, the amount of HFC banked in a given type of foam in year t in Finland equals the total amount of HFC blown into that type of foam since the introduction of that blowing agent, and not emitted during manufacturing, $(1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i}$ less the amount that was exported in products manufactured in Finland,

$\sum_{n=0}^j E_{t-n,i}$, plus the amount that was imported to Finland contained in products manufactured elsewhere,

$\sum_{n=0}^j IP_{t-n,i}$, less the amount that has escaped from foam during use,

$$f_{B,i} \left((1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} + \sum_{n=0}^j IP_{t-n,i} \right).$$

Actual emissions from foam type i in year t are thus given by

$$AE_{t,i} = f_{M,i}M_{t,i} + f_{B,i} \left((1 - f_{M,i}) \sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} + \sum_{n=0}^j IP_{t-n,i} - f_{B,i} \left(\sum_{n=0}^j M_{t-n,i} - \sum_{n=0}^j E_{t-n,i} + \sum_{n=0}^j IP_{t-n,i} \right) \right)$$

Total HFC blowing agent emissions from all foam types in year t are then given by

$$AE_{tot,t} = \sum_{i=1}^k AE_{t,i}$$

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 2006, and

b = Tier 1b potential emission in 2007.

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 2006 and 2007, 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 2007. 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 4.

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 2007. 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 are 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 48%. 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.

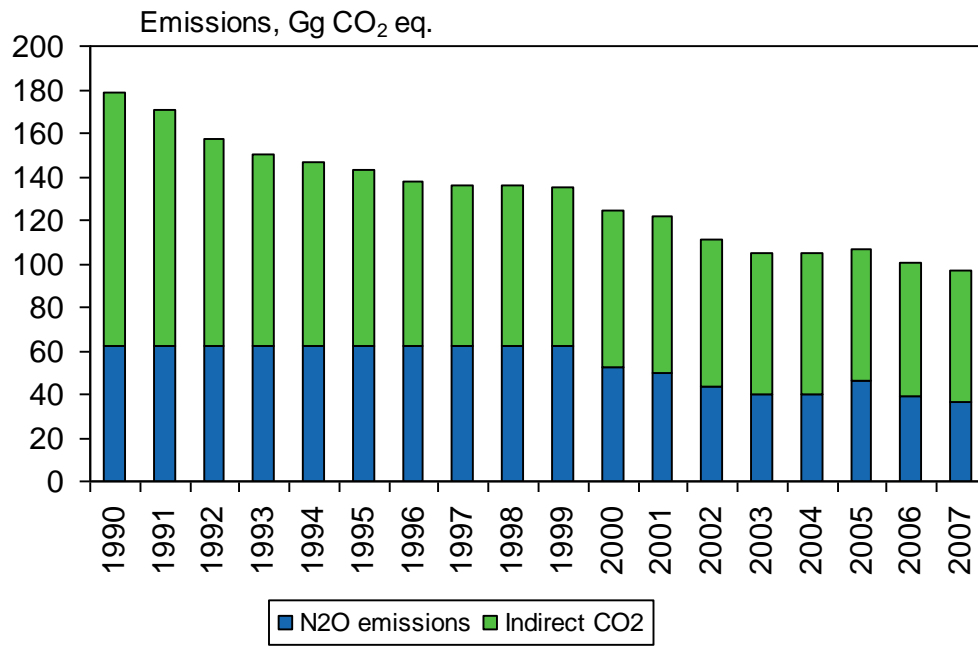


Figure 5.1_1. Trend in GHG emissions from solvents and other product use in 1990-2007 (Gg CO₂ eq.)

Table 5.1_1. N₂O, NMVOC and indirect CO₂ emissions in 1990-2007 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
N₂O																		
Use of N ₂ O in industrial, medical and other applications	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.17	0.16	0.14	0.13	0.13	0.15	0.13	0.12
CO₂ (indirect)																		
From NMVOC emissions	116.4	108.5	95.6	88.4	84.6	80.8	76.0	73.7	74.3	73.0	72.0	72.4	67.7	64.2	64.8	59.9	60.8	60.7
NMVOC																		
Paint application	27.5	26.0	22.0	20.5	20.0	19.0	18.0	18.0	18.0	17.9	17.9	17.0	15.8	14.7	14.6	14.0	14.5	14.4
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
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
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
Total emissions¹ (Gg CO₂ equivalents)	178	171	158	150	147	143	138	136	136	135	125	122	111	104	105	106	100	97

¹ Total emission is the sum of the N₂O emissions and the indirect CO₂.

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 1990-2006, Informative Inventory Report (Finnish Environment Institute, 2008)

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 1990-2007. 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. Used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile. (Netherlands NIR 2005, EPA 2002).

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

5.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 emissions and reported to the UNECE CLRTAP Secretariat. For the 2007 NMVOC emissions an uncertainty analysis will be made by 15 May 2009 and the documentation will be 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 2006 NMVOC emissions was estimated at -32% to +34%.

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 NMVOC emissions from other 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 for environmental of statistical reasons and part of activity data is 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 2007 these emissions totalled 36.4 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 2007 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

Quantitive estimates of uncertainty are provided in Annex 5. 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 2007 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 1990-2006, Informative Inventory Report (Finnish Environment Institute, 2008).

Indirect CO₂ emissions from this category have been calculated from NMVOC emissions for the time series 1990-2007. 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. Used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile. (Netherlands NIR 2005, EPA 2002).

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

5.3.3.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 emissions and reported to the UNECE CLRTAP Secretariat. For the 2007 NMVOC emissions an uncertainty analysis will be made by 15 May 2009 and the documentation will be 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 2006 NMVOC emissions was estimated at -32% to +34%.

Due the diversity of the calculation the uncertainty in this subcategory is quit high. For example the uncertainty of data from VAHTI 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%.

5.3.3.3 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 NMVOC emissions from other 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 for environmental of statistical reasons and part of activity data are 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 2007 were 5.5 Tg CO₂ equivalents in total. Agriculture is the third largest greenhouse gas emission source sector after the energy sector and industrial processes with a 7% share of the total greenhouse gas emissions in 2007 (Figure 6.1_1).

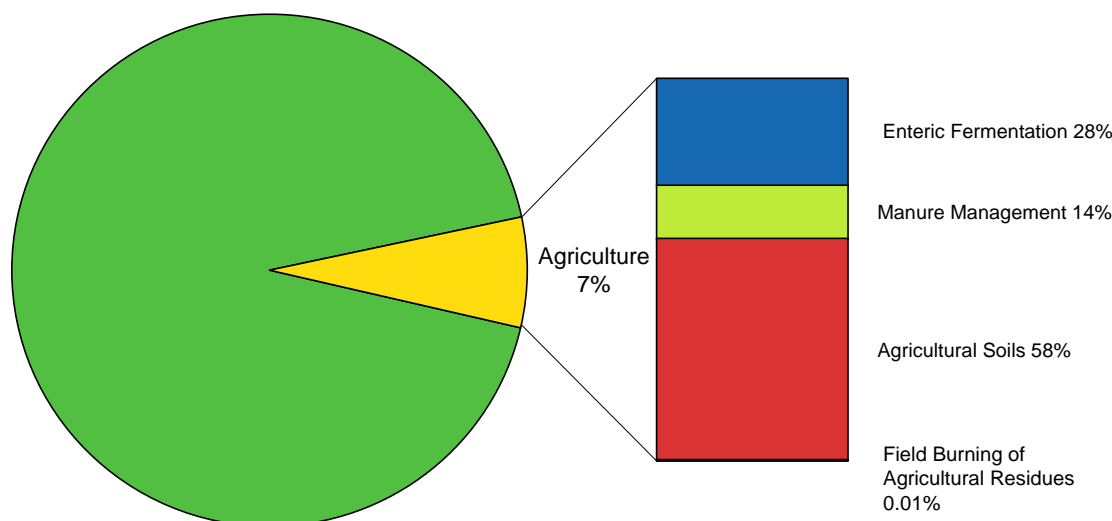


Figure 6.1_1. Agricultural emissions from the total greenhouse gas emissions in 2007.

Agricultural greenhouse gas emissions in Finland consist of CH₄ emissions from enteric fermentation of domestic livestock and CH₄ and N₂O emissions from manure management as well as direct and indirect N₂O emissions from agricultural soils and burning of agricultural residues. Direct N₂O 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 N₂O emission sources include emissions from atmospheric deposition and from nitrogen leaching and run-off to watercourses. Nitrogen flow in agriculture is presented in Figure 6.1_4. The CH₄ emissions from enteric fermentation were 28%, CH₄ emissions from manure management 5%, N₂O emissions from manure management 9% and N₂O emissions from agricultural soils 58% 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 4.

Emissions in the Agriculture sector have decreased by about 22% over the period 1990-2007 (Figure 6.1_2). One reason for this is Finland's membership in the EU that resulted in changes in the economic structure followed by an increase in the average farm size and a decrease in the number of small farms (Pipatti 2001). Those changes also caused a 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 35% during the inventory period.

Some inter-annual variation between the years can be noticed from the time series (Table 6.1_2). This is mainly caused by fluctuation in activity data between the years because of changes in animal numbers, for example, which is largely affected by agricultural policy and subsidies. Especially CH₄ and N₂O 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. N_2O 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.

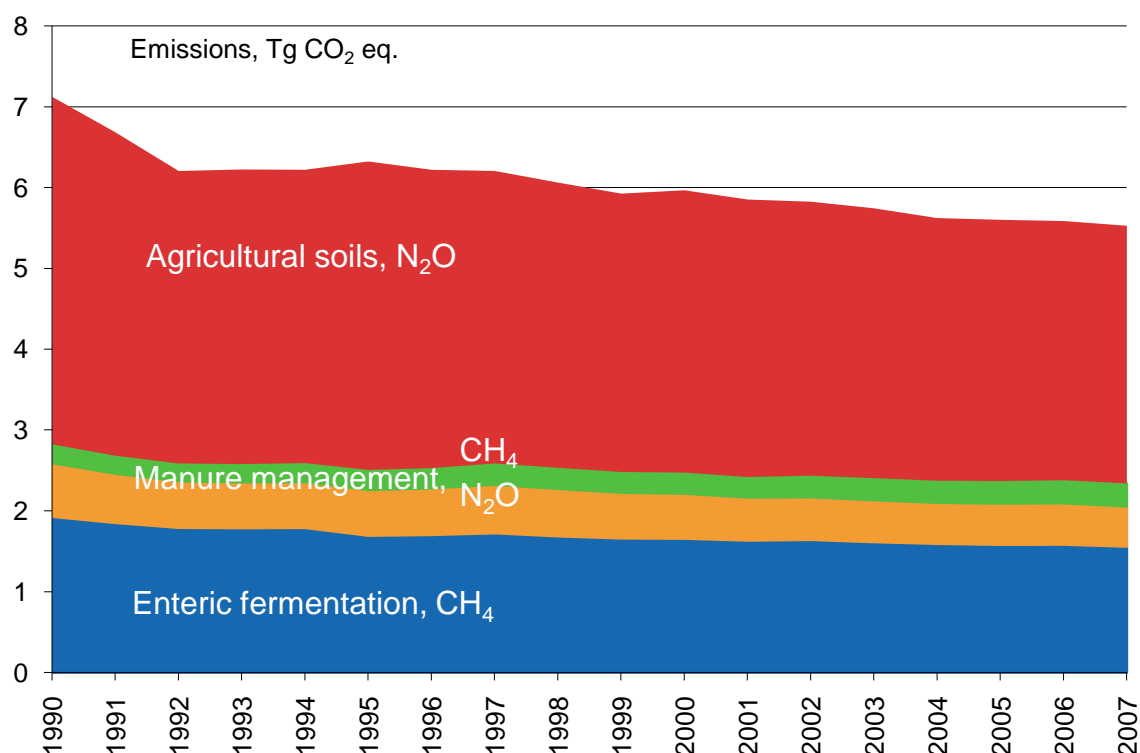


Figure 6.1_2. Trend in agricultural emissions by source category in 1990-2007 (Tg CO₂ eq.).

Carbon dioxide emissions from agricultural soils are reported in the Land use, Land-use change and Forestry (LULUCF) sector (Chapter 7) under Cropland and Grassland categories including CO₂ emissions from liming. 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 2007 and agricultural emissions reported in the Land Use, Land Use Change and Forestry sector 7.4 Tg CO₂ eq. in 2007 (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 2007 was 18% (14.2 Tg CO₂).

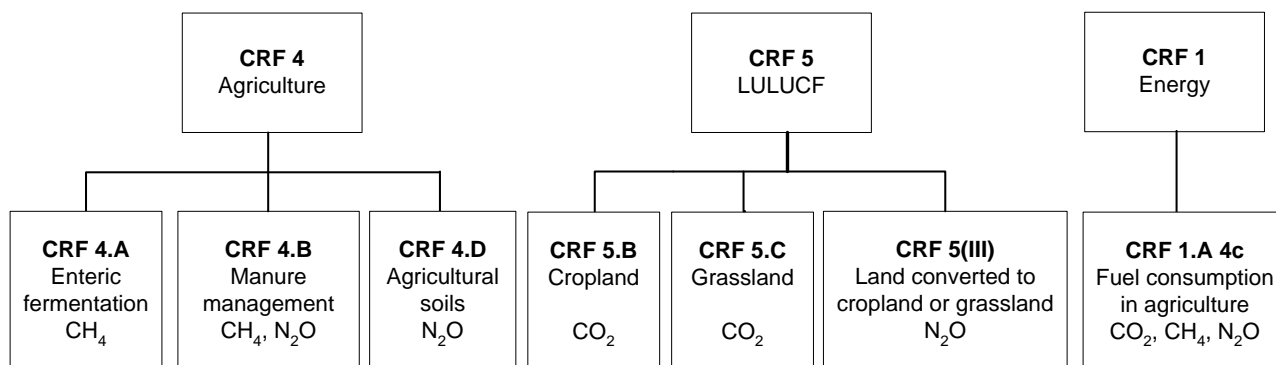


Figure 6.1_3. Emissions from agricultural sources and their reporting categories in the national greenhouse gas inventory. LULUCF=land use, land-use change and forestry.

Table 6.1_1. Finland's agricultural greenhouse gas emissions from sector Agriculture by source and gas in 1990-2007.

Year	Enteric fermentation (Gg)	Manure management (Gg)		Agricultural soils (Gg)	Total CH ₄ Emissions* (Gg)	Total N ₂ O Emissions* (Gg)	Burning of agricultural residues (Gg CO ₂ eq.)	Total emissions (Gg CO ₂ eq.)
	CH ₄	CH ₄	N ₂ O	N ₂ O	CH ₄	N ₂ O	CH ₄ , N ₂ O	CH ₄ , N ₂ O
1990	91.9	10.9	2.1	13.9	102.9	16.0	2.4	7 125.7
1991	88.2	10.5	2.0	12.9	98.7	14.9	0.22	6 684.6
1992	85.4	10.4	1.9	11.7	95.8	13.5	0.16	6 206.6
1993	85.2	10.7	1.8	11.8	95.9	13.6	0.48	6 225.9
1994	85.3	11.0	1.8	11.7	96.3	13.5	0.17	6 222.0
1995	80.7	11.7	1.8	12.3	92.4	14.1	0.44	6 324.8
1996	81.1	11.8	1.9	11.9	93.0	13.8	0.73	6 222.1
1997	82.2	12.5	1.9	11.7	94.6	13.6	0.41	6 207.4
1998	80.4	12.3	1.9	11.4	92.7	13.3	0.31	6 063.6
1999	79.1	12.2	1.8	11.1	91.3	12.9	0.15	5 926.8
2000	79.0	12.3	1.8	11.3	91.3	13.1	1.01	5 968.9
2001	77.9	12.0	1.7	11.1	89.9	12.8	0.54	5 854.1
2002	78.2	12.6	1.7	10.9	90.9	12.6	0.66	5 827.3
2003	76.9	12.9	1.7	10.8	89.9	12.4	0.63	5 745.3
2004	75.9	12.9	1.6	10.5	88.9	12.1	0.51	5 624.5
2005	75.4	13.2	1.6	10.4	88.6	12.1	0.30	5 602.8
2006	75.4	13.5	1.7	10.3	88.9	12.0	0.44	5 587.9
2007	74.3	13.5	1.6	10.3	87.8	11.9	0.82	5 529.7

* includes burning of residues

Key categories

The key categories in agriculture in 2007 are summarised in Table 6.1_2.

Table 6.1_2. Key categories in Agriculture (CRF 4) in 2007 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
4.A. Enteric fermentation	CH ₄	L
4.B. Manure management	N ₂ O	L
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

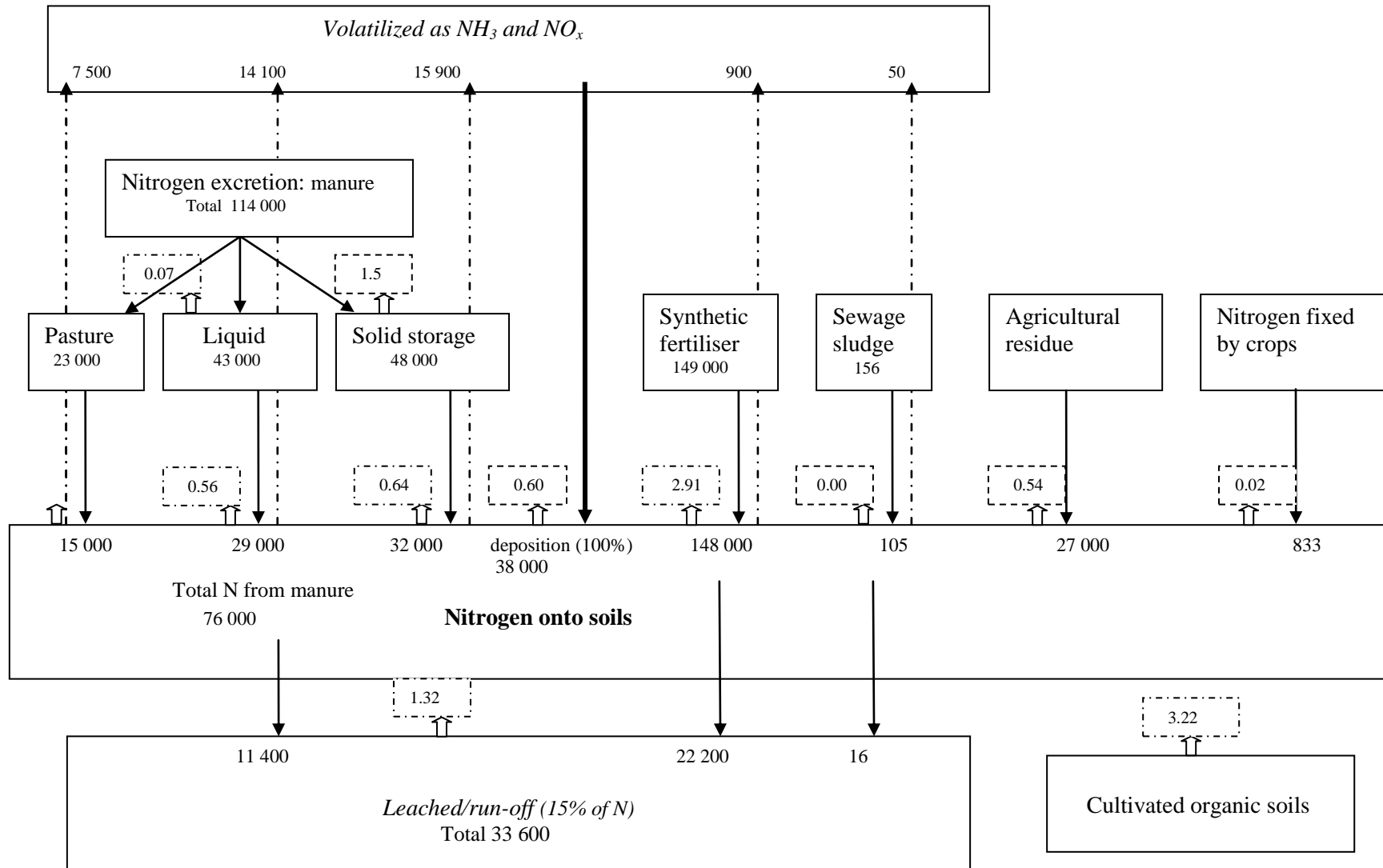


Figure 6.1_4. Nitrogen Flow in Agriculture 2007 (Bulk arrows stand for N_2O emissions, thin arrows for nitrogen flow and broken arrows mean nitrogen volatilization during application on soil. Nitrogen amounts are in Mg/year and emissions (fragmental line) in Gg/year (rounded values))

6.2 Enteric Fermentation (CRF 4.A)

6.2.1 Source category description

Methane emissions from enteric fermentation of domestic livestock comprised 28% of total agricultural emissions in Finland, being 1.6 Tg CO₂ equivalents in 2007.

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 been estimated since a default method for the estimation of these emissions is lacking. Emissions from fur animals are included in the inventory for the first time (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

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 being resident 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 296,069 in 2007. Emissions from other livestock decreased during 1990-2001 but have been increasing slightly since 2002 due to the growing number of swine and horses (Table 6.2_2).

Table 6.2_2. CH₄ emissions (Gg) from enteric fermentation in 1990-2007 by animal type.

Year	Cattle					Other livestock							Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	P	F	R	
1990	47.6	0.9	8.5	11.4	14.6	2.1	0.7	0.0	0.8	NE	0.5	4.8	91.9
1991	43.7	1.3	8.3	11.3	14.6	2.0	0.7	0.0	0.9	NE	0.3	5.2	88.2
1992	42.1	1.7	8.2	11.0	13.9	1.9	0.7	0.0	0.9	NE	0.3	4.6	85.4
1993	42.3	2.1	8.0	11.4	13.3	1.9	0.8	0.0	0.9	NE	0.3	4.3	85.2
1994	42.3	2.1	8.3	11.4	13.0	1.9	0.8	0.0	0.9	NE	0.3	4.3	85.3
1995	41.0	1.8	6.3	10.1	12.9	2.1	1.1	0.0	0.9	NE	0.3	4.1	80.7
1996	40.5	2.0	6.7	10.8	12.6	2.1	1.0	0.0	0.9	NE	0.4	4.2	81.1
1997	41.2	2.1	6.9	10.7	12.6	2.2	1.0	0.0	1.0	NE	0.4	4.0	82.2
1998	40.5	2.0	6.5	10.5	12.5	2.1	0.9	0.0	1.0	NE	0.4	3.9	80.4
1999	40.1	1.9	6.7	10.3	12.0	2.0	0.7	0.0	1.0	NE	0.4	3.9	79.1
2000	40.5	1.8	6.6	10.3	11.6	1.9	0.7	0.0	1.0	NE	0.4	4.0	79.0
2001	40.1	1.8	6.5	10.2	11.6	1.9	0.7	0.0	1.1	NE	0.3	3.7	77.9
2002	40.0	1.8	6.9	10.1	11.3	2.0	0.7	0.0	1.1	NE	0.4	4.0	78.2
2003	38.8	1.8	7.1	10.0	11.0	2.1	0.7	0.0	1.1	NE	0.3	3.9	76.9
2004	38.3	2.0	6.9	9.7	10.7	2.0	0.8	0.0	1.1	NE	0.4	4.0	75.9
2005	37.8	2.3	6.7	9.5	10.6	2.1	0.7	0.0	1.1	NE	0.4	4.1	75.4
2006	37.2	2.6	7.0	9.6	10.4	2.2	1.0	0.0	1.2	NE	0.4	3.9	75.4
2007	36.2	2.9	6.9	9.5	10.2	2.2	1.0	0.0	1.2	NE	0.3	3.8	74.3
Share of total (%) in 2007*	48.7	3.9	9.4	12.7	13.7	2.9	1.3	0.0	1.6	NE	0.5	5.2	

DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sw=Swine, Sh=Sheep, G=Goats, Ho=Horses, P=Poultry, F=Fur animals, R=Reindeer, NE=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).

CH₄ 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. CH₄ 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.mmmtike.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 (cattle, swine, and poultry) and it has been reported consistently over the time series.

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.

Table 6.2_3. Number of livestock and fur animals in Finland in 1990-2007 (x 1 000).

Year	Cattle ¹	Horses ²	Swine	Sheep	Goats	Poultry ³	Reindeer	Fur animals ⁴
1990	1 359.7	45.4	1 381.4	103.3	5.90	9 662.5	239.1	5 157.2
1991	1 309.9	48.1	1 344.3	106.7	5.35*	8 928.9	259.6	3 282.5
1992	1 273.2	49.1	1 297.9	108.4	4.80	9 356.1	231.6	2 596.8
1993	1 252.3	49.0	1 272.7	120.4	4.80	9 639.2	215.3	2 848.6
1994	1 233.0	48.3	1 298.3	121.1	5.70	9 905.7	214.3	2 880.3
1995	1 147.9	49.9	1 400.3	158.6	6.00	10 357.7	208.1	3 284.1
1996	1 145.6	52.0	1 395.4	149.5	6.50	9 951.4	212.9	3 748.6
1997	1 142.4	54.6	1 467.0	150.1	8.00	10 826.6	202.6	4 151.6
1998	1 117.1	56.1	1 401.0	128.3	8.10	11 049.6	196.1	4 321.6
1999	1 086.8	56.2	1 351.3	106.6	7.90	11 033.6	195.4	3 967.8
2000	1 056.6	57.4	1 297.6	99.6	8.60	12 569.5	203.4	3 705.1
2001	1 037.3	56.6	1 260.8	96.0	7.40	10 553.6	185.7	3 360.5
2002	1 025.4	58.6	1 315.0	95.9	6.60	10 734.0	199.7	3 540.5
2003	1 000.1	60.2	1 375.0	98.4	6.80	10 997.1	196.7	3 410.3
2004	969.2	61.1	1 364.6	108.9	7.30	10 405.1	201.1	3 668.0
2005	959.0	63.8	1 401.0	89.7	6.9	10 538.2	207.2	3 530.0
2006	949.3	66.1	1 436.5	116.7	6.7	10 239.0	197.8	3 785.7
2007	926.7	68.0	1 448.0	119.3	6.2	9 791.1	193.3	3 447.8

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 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.

⁴ 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.

Emission factors and other parameters

IPCC default emission factors were used for calculating CH₄ emissions from enteric fermentation of swine, goats and horses (Tier 1 method). For fur animals the Norwegian emission factor was used (0.1 kg/animal/yr). The emission factor was derived by scaling the 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 247 in 1990 to 311 in 2007 resulting in a change in the emission factor being 97.1 in 1990 and 122.3 kg CH₄/animal/yr in 2007 (Figure 6.2_1.).

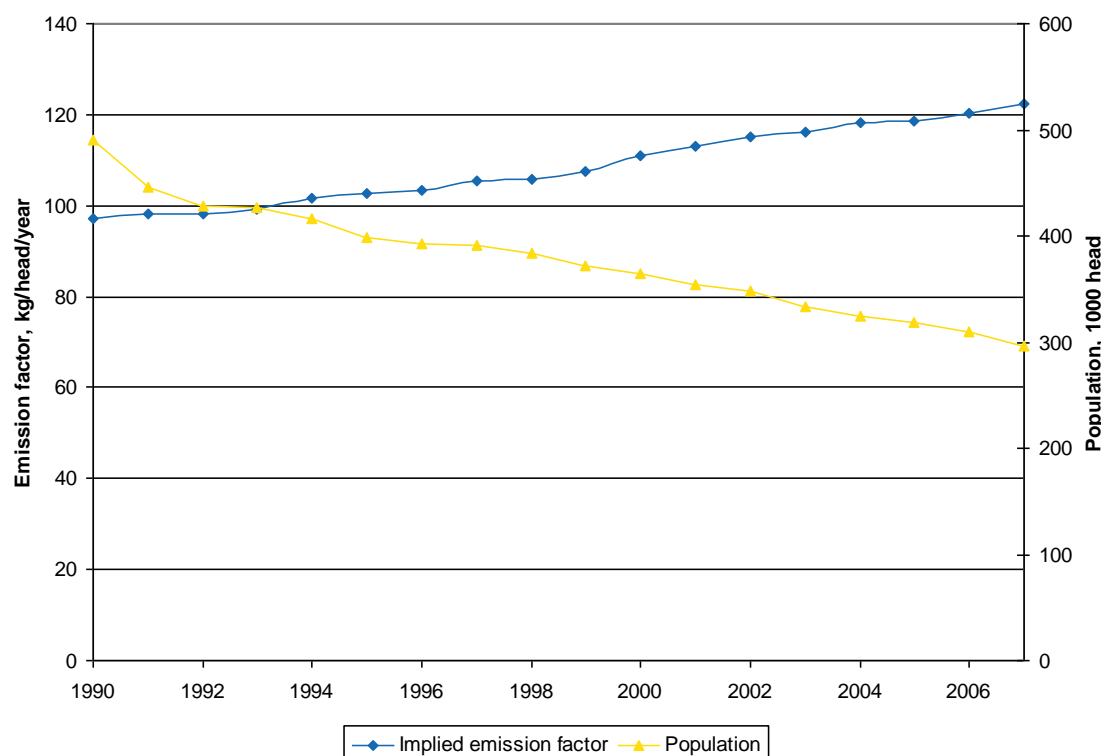


Figure 6.2_1. Development of emission factor and population of dairy cows, 1990-2007

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 2007 used for calculating CH₄ emissions from enteric fermentation.

Animal type	Emission factor (kg CH ₄ / animal/yr)	EF type	Method for calculating EF
Dairy cow	122.25	National	IPCC, Tier 2
Suckler cow	66.29	National	IPCC, Tier 2
Bull	63.30	National	IPCC, Tier 2
Heifer	56.82	National	IPCC, Tier 2
Calf	32.76	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

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. 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.).

The number of cattle by subcategory is presented in Table 6.2_5. Cattle weights and mature weights of dairy cow, suckler cow and bull are presented in Table 6.2_6 (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_7. Data on milk production (l/animal/yr) 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/yr for the whole time series. The milk production of suckler cow has been estimated to remain constant in 1990-2007, being 1,620 kg/yr (Source: Nousiainen, J. pers.comm., MTT Agrifood Research Finland). Average daily weight gain for cattle was estimated to remain constant in 1990-2007, 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., pers.comm., MTT Agrifood Research Finland)).

Table 6.2_5. Number of cattle in subcategories in 1990-2007 (Source: Information Centre of the Ministry of Agriculture and Forestry).

Year	Dairy cows Number (x 1 000)	Suckler cows Number (x 1 000)	Bulls (>1 year) Number (x 1 000)	Heifers Number (x 1 000)	Calves (<1 year) Number (x 1 000)
1990	489.9	14.2	148.9	218.8	487.9
1991	445.6	21.2	144.1	213.5	485.5
1992	428.2	27.9	143.3	211.1	462.7
1993	426.4	33.1	139.2	216.7	436.9
1994	416.7	32.6	143.5	214.8	425.4
1995	398.5	29.2	109.3	188.9	422.0
1996	392.2	31.1	114.7	201.1	406.5
1997	390.9	32.4	120.5	196.8	401.8
1998	383.1	30.6	114.8	190.3	398.3
1999	372.4	29.6	118.1	187.5	379.2
2000	364.1	27.8	114.9	185.0	364.8
2001	354.8	27.2	111.3	181.7	362.3
2002	347.8	28.1	115.3	180.0	354.2
2003	333.9	28.1	115.5	178.5	344.1
2004	324.4	30.8	110.5	173.1	330.4
2005	318.8	34.6	107.8	168.8	329.0
2006	309.4	38.9	112.5	170.8	317.7
2007	296.1	43.3	109.8	166.5	311.1

Table 6.2_6. Cattle live weights and mature weights in 1990-2007 (Source: MTT Agrifood Research Finland).

Year	Dairy cow		Suckler cow		Bull (>1 yr)		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	503	553	573	622	455	826	367	184
1991	506	547	578	628	468	853	371	186
1992	511	565	583	634	467	861	370	187
1993	517	569	589	640	468	860	373	190
1994	522	567	594	646	477	863	380	192
1995	527	570	599	652	476	878	382	194
1996	533	580	605	657	482	883	387	198
1997	538	582	610	663	478	891	398	200

Year	Dairy cow		Suckler cow		Bull (>1 yr)		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)
1998	541	588	616	669	477	917	403	203
1999	544	606	621	675	481	928	410	206
2000	550	611	626	681	488	943	417	209
2001	557	624	632	687	501	958	428	211
2002	563	635	637	692	521	981	429	212
2003	560	651	642	698	538	983	431	214
2004	568	653	648	704	552	986	432	216
2005	572	663	650	706	550	1000	434	217
2006	576	667	651	708	561	1007	435	221
2007	582	674	656	713	570	1018	445	223

Table 6.2._7. Data of milk properties used for calculating CH₄ emissions from enteric fermentation in 1990-2007.

Year	Fat content of milk ¹ (%)	Milk production/ dairy cow ² (kg/yr)
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

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 2006 (Coefficient 1.03 used to express l/animal/yr as kg/animal/yr).

6.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in CH₄ 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).

Uncertainty in the category could probably be reduced by producing more country-specific parameters taking into account boreal climate and agricultural practices. Another possibility is to develop a more straightforward calculation method using the real energy intake of cattle based on knowledge on the energy content of forage used in Finland.

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.

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 will be checked annually if new data for updating emission factors has been published. New national data will be compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances will be evaluated.

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 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.

6.2.5 Source-specific recalculations

A small correction to the milk production and CH₄ emissions of dairy cows was made for year 2006. As the time series of methane production of fur animals is now included has the annual total amount of methane produced changed accordingly.

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 1.60 Gg and 13.5 Gg in 2007, respectively, and their emissions as CO₂ equivalents were 0.8 Tg altogether. Nitrous oxide emissions from manure management were about 9% and methane emissions about 5% of total agricultural emissions in 2007.

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	CH ₄ , N ₂ O
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
4.B 11	Anaerobic Lagoons	NO
4.B 12	Liquid Systems	N ₂ O
4.B 13	Solid Storage and Dry Lot	N ₂ O
4.B 14	Other AWMS	NE

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 25% over the time period 1990-2007 (Table 6.3_2 and Figure 6.3_1). Methane emissions from manure management have been fluctuating during 1990-2007 but overall there is an increase of 23% in the emissions in 2007 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).

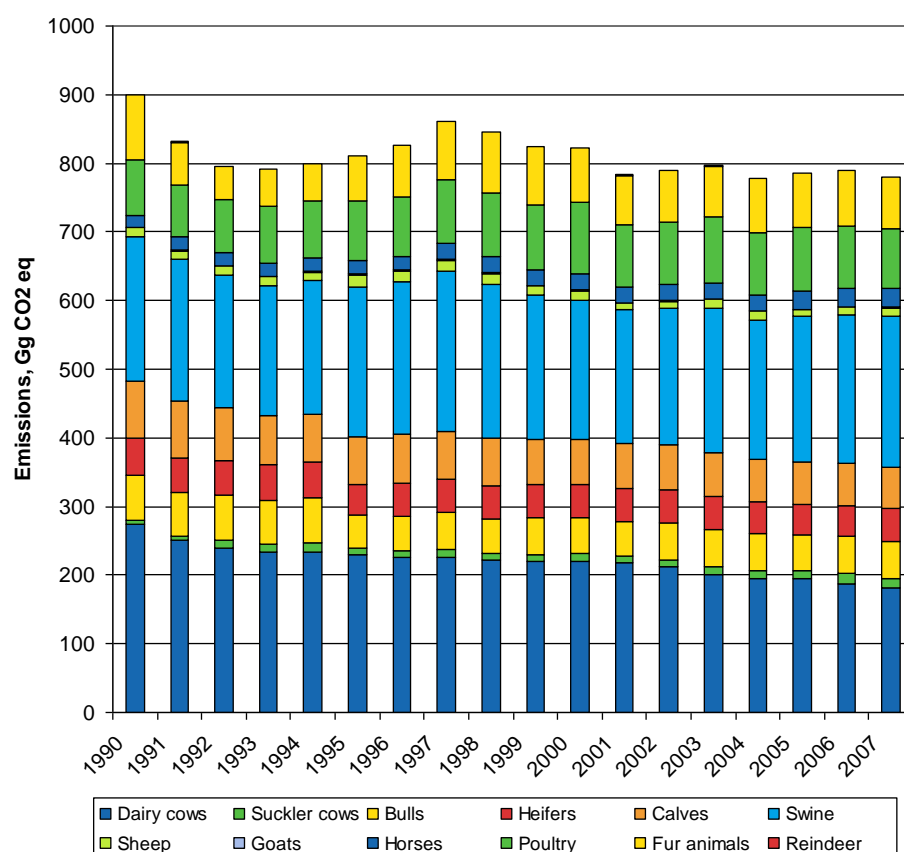


Figure 6.3_1. Total emissions of manure management by animal type in 1990-2007, Gg CO₂ eq.

Table 6.3_2. N₂O emissions (Gg) from manure management in 1990-2007 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	P	F	R**	
1990	0.67	0.02	0.18	0.14	0.22	0.42	0.02	0.00	0.05	0.16	0.26	0	2.12
1991	0.61	0.02	0.17	0.13	0.22	0.40	0.02	0.00	0.06	0.15	0.17	0	1.95
1992	0.58	0.03	0.18	0.13	0.20	0.36	0.02	0.00	0.06	0.15	0.13	0	1.84
1993	0.55	0.04	0.17	0.13	0.19	0.34	0.02	0.00	0.06	0.16	0.15	0	1.80
1994	0.55	0.04	0.18	0.13	0.18	0.34	0.02	0.00	0.06	0.16	0.15	0	1.81
1995	0.54	0.03	0.12	0.11	0.18	0.38	0.02	0.00	0.06	0.16	0.18	0	1.79
1996	0.52	0.03	0.13	0.12	0.18	0.40	0.02	0.00	0.06	0.16	0.21	0	1.83
1997	0.51	0.03	0.14	0.12	0.18	0.42	0.02	0.00	0.07	0.17	0.24	0	1.91
1998	0.49	0.03	0.13	0.12	0.18	0.40	0.02	0.00	0.07	0.17	0.25	0	1.87
1999	0.48	0.03	0.14	0.12	0.17	0.37	0.02	0.00	0.07	0.17	0.24	0	1.80
2000	0.47	0.03	0.14	0.12	0.17	0.36	0.02	0.00	0.07	0.19	0.22	0	1.78
2001	0.45	0.03	0.13	0.12	0.17	0.34	0.02	0.00	0.07	0.17	0.20	0	1.70
2002	0.42	0.03	0.14	0.12	0.17	0.33	0.02	0.00	0.07	0.17	0.21	0	1.68
2003	0.38	0.03	0.14	0.12	0.17	0.35	0.02	0.00	0.07	0.18	0.21	0	1.66
2004	0.35	0.03	0.14	0.12	0.16	0.33	0.02	0.00	0.07	0.17	0.22	0	1.62
2005	0.34	0.03	0.14	0.11	0.16	0.35	0.02	0.00	0.08	0.18	0.22	0	1.63
2006	0.32	0.04	0.14	0.11	0.16	0.35	0.02	0.00	0.08	0.17	0.23	0	1.63
2007	0.29	0.04	0.14	0.12	0.16	0.35	0.02	0.00	0.08	0.17	0.21	0	1.58
Share of total (%) in 2007*	18.6	2.4	9.0	7.3	10.0	22.1	1.4	0.1	5.3	10.7	13.1	0	

* The sum of the shares differs from 100 due to rounding. ** All manure deposited on pastures. DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sw=Swine, Sh=Sheep, G=Goats, Ho=Horses, P=Poultry, F=Fur animals, R=Reindeer

Table 6.3_3. CH₄ emissions from manure management in 1990-2007 by animal type (Gg).

Year	Cattle					Other livestock							Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	P	F	R**	
1990	3.13	0.02	0.49	0.51	0.65	3.84	0.02	0.001	0.06	1.51	0.69	0.03	10.94
1991	2.93	0.03	0.48	0.51	0.67	3.90	0.02	0.001	0.07	1.40	0.44	0.03	10.47
1992	2.88	0.04	0.48	0.51	0.66	3.91	0.02	0.001	0.07	1.46	0.35	0.03	10.41
1993	2.96	0.04	0.47	0.54	0.65	3.99	0.02	0.001	0.07	1.51	0.38	0.03	10.66
1994	3.02	0.04	0.49	0.56	0.66	4.22	0.02	0.001	0.07	1.55	0.38	0.02	11.04
1995	2.99	0.04	0.46	0.51	0.67	4.72	0.03	0.001	0.07	1.77	0.44	0.02	11.72
1996	3.07	0.05	0.48	0.54	0.66	4.71	0.03	0.001	0.07	1.70	0.50	0.02	11.83
1997	3.24	0.06	0.50	0.54	0.65	4.95	0.03	0.001	0.08	1.85	0.55	0.02	12.47
1998	3.31	0.06	0.48	0.52	0.65	4.73	0.02	0.001	0.08	1.89	0.57	0.02	12.33
1999	3.38	0.07	0.49	0.52	0.62	4.56	0.02	0.001	0.08	1.88	0.53	0.02	12.18
2000	3.54	0.07	0.48	0.52	0.61	4.37	0.02	0.001	0.08	2.14	0.49	0.02	12.34
2001	3.70	0.07	0.47	0.51	0.60	4.25	0.02	0.001	0.08	1.80	0.45	0.02	11.98
2002	3.89	0.07	0.50	0.51	0.59	4.63	0.02	0.001	0.08	1.83	0.47	0.02	12.62
2003	3.96	0.08	0.51	0.50	0.57	4.84	0.02	0.001	0.09	1.88	0.45	0.02	12.93
2004	4.10	0.09	0.50	0.49	0.55	4.81	0.02	0.001	0.09	1.78	0.48	0.02	12.92
2005	4.24	0.10	0.49	0.47	0.55	4.93	0.02	0.001	0.09	1.80	0.47	0.02	13.18
2006	4.31	0.11	0.51	0.48	0.54	5.13	0.02	0.001	0.09	1.75	0.50	0.02	13.47
2007	4.32	0.13	0.51	0.48	0.53	5.24	0.023	0.001	0.10	1.70	0.46	0.02	13.51
Share of total (%) in 2007*	32.00	0.95	3.74	3.55	3.93	38.81	0.17	0.01	0.72	12.57	3.40	0.17	

* 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, P=Poultry, F=Fur animals, R=Reindeer

6.3.2 Methodological issues

6.3.2.1 Methods

Nitrous oxide

Nitrous oxide emissions from manure management have been calculated 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. The manure management systems reported in the inventory are slurry, solid storage and pasture (Table 6.3_7). N excretion during the year per animal (cattle, sheep, swine, horses, poultry, and fur animals) and the distribution of manure management systems are national values (Tables 6.3_4-6.3_7). 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 130 days for suckler cows, 120 days for dairy cows, heifers, calves, sheep, goats and horses, 365 for reindeer and 0 for bulls, swine, poultry and fur animals. Note that emissions from pasture are calculated under manure management, but are reported under *pasture, range and paddock manure* in CRF 4.D.

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 CH₄ 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 (see Table 6.2_3). The distribution of different manure management systems was received from published literature (MKL 1993; Seppänen & Matinlassi, 1998) and by expert judgement (Kyntäjä, J. & Nopanen, A. pers.comm and Lehtonen, H., pers.comm.). Annual N excretion per animal for cattle, sheep, swine, horses, poultry and fur animals has been calculated by animal nutrition experts of MTT Agrifood Research Finland (Nousiainen, J. pers.comm.). Values for annual N excretion (Nex) are based on calculations on N intake-N retention for typical animal species in a typical forage system (Tables 6.3_4-6.3_6). For goats, the national value for Nex (17 kg head⁻¹ year⁻¹) (Ministry of the Environment 1998) has been kept as such because new data were not available. For reindeer, the value for goats has been used because no national data were available. 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. Need to update the N excretion rates is evaluated annually in cooperation with the animal nutrition experts.

Table 6.3_4. Annual average N excretion per animal (kg N/animal/year) for cattle. (Nousiainen, J. pers.comm.)

Year	Dairy cow		Suckler cow		Bull (>1 year)		Heifer		Calf (<1 year)	
	Nex (kg N)	Number (x1 000)	Nex (kg N)	Number (x1 000)	Nex (kg N)	Number (x1 000)	Nex (kg N)	Number (x1 000)	Nex (kg N)	Number (x1 000)
1990	84.6	489.9	58.3	14.2	52.8	148.9	41.4	218.8	29.8	487.9
1991	85.8	445.6	58.6	21.2	53.7	144.1	42.4	213.5	30.0	485.5
1992	85.6	428.2	58.9	27.9	54.4	143.3	42.2	211.1	30.4	462.7
1993	82.9	426.4	59.3	33.1	55.1	139.2	42.2	216.7	30.9	436.9
1994	85.7	416.7	59.6	32.6	56.0	143.5	43.3	214.8	31.2	425.4
1995	88.9	398.5	59.9	29.2	56.7	109.3	43.6	188.9	31.6	422.0
1996	89.8	392.2	60.3	31.1	57.6	114.7	44.0	201.1	32.3	406.5
1997	91.8	390.9	60.6	32.4	58.2	120.5	45.2	196.8	32.8	401.8
1998	92.6	383.1	60.9	30.6	59.0	114.8	45.6	190.3	33.4	398.3
1999	96.1	372.4	61.3	29.6	59.8	118.1	46.3	187.5	33.9	379.2
2000	99.3	364.1	61.6	27.8	60.7	114.9	47.0	185.0	34.6	364.8
2001	104.1	354.8	61.9	27.2	61.6	111.3	48.2	181.7	35.0	362.3
2002	105.2	347.8	62.2	28.1	62.5	115.3	48.3	180.0	35.4	354.2
2003	105.2	333.9	62.6	28.1	63.3	115.5	48.5	179.0	35.8	344.1
2004	108.3	324.4	62.9	30.8	64.1	110.5	49.0	173.1	36.2	330.4
2005	116.1	318.8	63.0	34.6	65.0	107.8	49.0	168.8	36.0	329.0
2006	119.1	309.4	64.0	38.9	65.7	112.5	48.7	170.8	36.8	317.7
2007	121.9	296.1	63.9	43.3	66.4	109.8	50.3	166.5	37.6	311.1

Table 6.3_5. Average annual N excretion per animal for swine and fur animals (kg N/animal/year) (Nousiainen, J. pers.comm.).

Year	Swine		Mink and fitch		Fox and racoon	
	Nex (kg N)	Number (x1 000)	Nex (kg N)	Number (pelts produced Annually x1 000)	Nex (kg N)	Number (pelts produced Annually x 1 000)
1990	16.8	1 394.1	1.2	3 161.9	2.1	1 995.3
1991	17.1	1 344.3	1.3	1 804.9	2.2	1 477.6
1992	16.8	1 297.9	1.3	1 505.2	2.3	1 091.6
1993	16.8	1 272.7	1.3	1 576.2	2.2	1 272.3
1994	17.4	1 298.3	1.3	1 659.5	2.2	1 220.8
1995	18.9	1 400.3	1.3	1 639.4	2.2	1 644.7
1996	19.8	1 395.4	1.3	1 944.7	2.3	1 803.9
1997	19.8	1 467.0	1.3	1 807.7	2.3	2 343.9
1998	19.8	1 401.0	1.3	1 828.2	2.3	2 493.4
1999	18.9	1 351.3	1.3	1 646.0	2.3	2 321.8
2000	19.5	1 297.6	1.3	1 732.7	2.3	1 972.3
2001	18.6	1 260.8	1.3	1 497.9	2.3	1 862.6
2002	18.6	1 315.0	1.3	1 496.6	2.3	2 043.9
2003	18.6	1 375.0	1.3	1 407.7	2.3	2 002.6
2004	18.1	1 364.6	1.3	1 426.0	2.3	2 242.0
2005	18.7	1 401.0	1.3	1 355.0	2.3	2 174.7
2006	18.6	1 436.5	1.3	1 465.8	2.3	2 320.0
2007	18.7	1 448.0	1.3	1 422.4	2.3	2 025.4

Table 6.3_6. Average annual N excretion per animal for sheep and horses (kg/animal/year) (Nousiainen, J. pers.comm.).

Year	Sheep		Horses	
	Nex (kg N)	Number (x1 000)	Nex (kg N)	Number (x1 000)
1990	7.2	103.3	57.3	45.4
1991	7.2	106.7	57.3	48.1
1992	7.2	108.4	57.2	49.1
1993	7.2	120.4	57.3	49.0
1994	7.2	121.1	57.3	48.3
1995	7.0	158.6	57.3	49.9
1996	7.3	149.5	57.3	52.0
1997	7.2	150.1	57.4	54.6
1998	7.3	128.3	57.4	56.1
1999	7.6	106.6	57.7	56.2
2000	7.7	98.9	57.8	57.6
2001	8.0	96.0	57.9	58.6
2002	8.0	95.9	57.9	59.1
2003	8.1	98.4	57.9	60.2
2004	8.1	108.9	58.3	61.1
2005	8.9	89.7	58.2	63.8
2006	9.1	116.7	58.1	66.1
2007	9.0	119.3	58.8	68.0

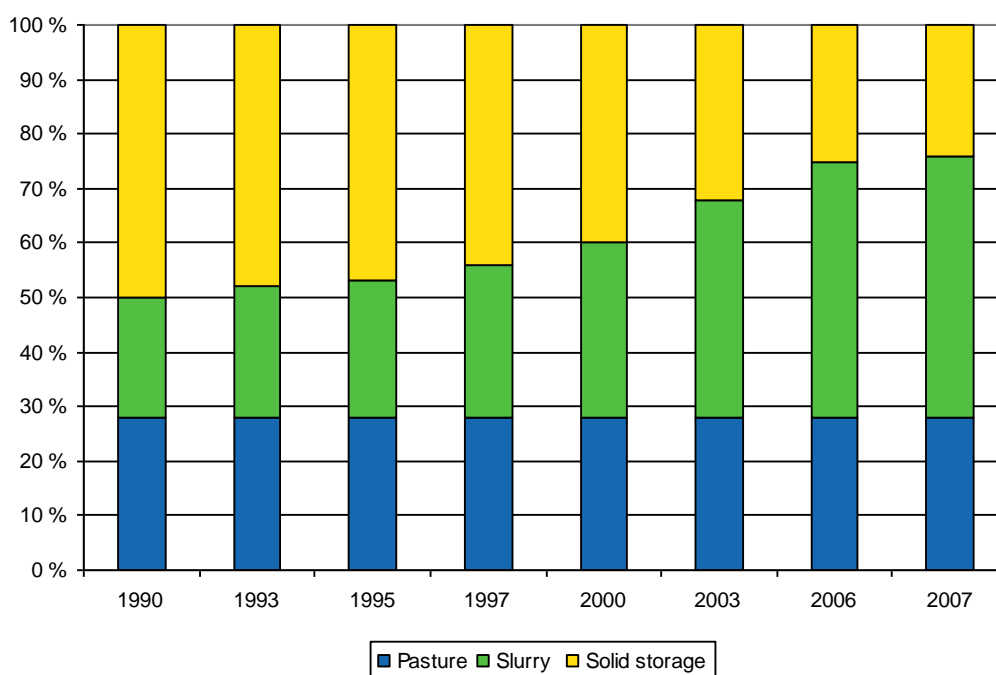


Figure 6.3_2. Fraction of manure of dairy cows in different manure management systems. (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgrida); MTT Agrifood Research Finland).

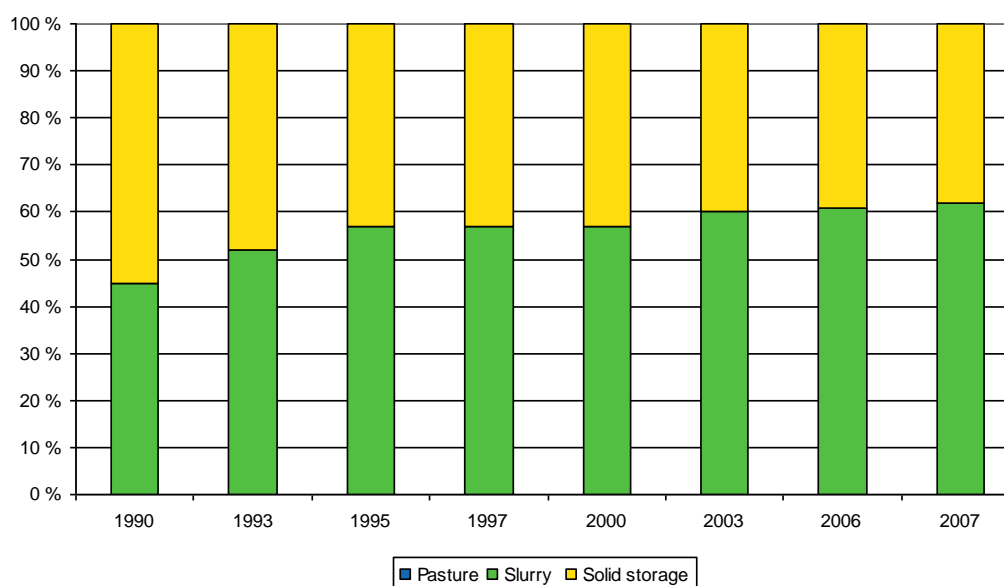


Figure 6.3_3. Fraction of manure of swine in different manure management systems. (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgrida); MTT Agrifood Research Finland).

Table 6.3_7. Fraction of manure managed in each manure management system (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgrida); MTT Agrifood Research Finland).*

	1990	1995	2000	2006	2007
Cattle					
Dairy cows					
Pasture	0.28	0.28	0.28	0.28	0.28
Slurry	0.22	0.25	0.32	0.47	0.48
Solid storage	0.50	0.47	0.40	0.25	0.24
Suckler cows					
Pasture	0.36	0.36	0.36	0.36	0.36
Slurry	0.03	0.03	0.16	0.20	0.20
Solid storage	0.61	0.61	0.48	0.44	0.44

	1990	1995	2000	2006	2007
Bulls (age over 1 year)					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.30	0.40	0.40	0.40	0.4
Solid storage	0.70	0.60	0.60	0.60	0.6
Heifers					
Pasture	0.33	0.33	0.33	0.33	0.33
Slurry	0.20	0.24	0.24	0.24	0.25
Solid storage	0.47	0.43	0.43	0.43	0.43
Calves (under 1 year)					
Pasture	0.33	0.33	0.33	0.33	0.33
Slurry	0.20	0.26	0.26	0.26	0.26
Solid storage	0.47	0.42	0.42	0.42	0.42
	1990	1995	2000	2006	2007
Other livestock					
Swine					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.45	0.57	0.57	0.61	0.62
Solid storage	0.55	0.43	0.43	0.39	0.38
Sheep					
Pasture	0.33	0.33	0.33	0.33	0.33
Slurry	0.00	0.00	0.00	0.00	0.003
Solid storage	0.67	0.67	0.67	0.67	0.67
Goats					
Pasture	0.33	0.33	0.33	0.33	0.33
Slurry	0.00	0.01	0.01	0.01	0.01
Solid storage	0.67	0.67	0.67	0.67	0.67
Horses					
Pasture	0.33	0.33	0.33	0.33	0.33
Slurry	0.00	0.00	0.00	0.00	0.00
Solid storage	0.67	0.67	0.67	0.67	0.67
Reindeer					
Pasture	1.00	1.00	1.00	1.00	1.00
Slurry	0.00	0.00	0.00	0.00	0.00
Solid storage	0.00	0.00	0.00	0.00	0.00
	1990	1995	2000	2006	2007
Poultry					
Laying hens					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.02	0.02	0.00	0.02
Solid storage	1.00	0.98	0.98	1.00	0.98
Chickens					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.02	0.02	0.02	0.02
Solid storage	1.00	0.98	0.98	0.98	0.98
Cockerels					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.01	0.01	0.02	0.01
Solid storage	1.00	0.99	0.99	0.98	0.99
Broiler hens					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.01	0.01	0.01	0.01
Solid storage	1.00	0.99	0.99	0.99	0.99
Broilers					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.01	0.01	0.01	0.01
Solid storage	1.00	0.99	0.99	0.99	0.99
Turkeys					
Pasture	0.00	0.00	0.00	0.00	0.00

	1990	1995	2000	2006	2007
Slurry	0.00	0.01	0.01	0.01	0.01
Solid storage	1.00	0.99	0.99	0.99	0.99
Other poultry					
Pasture	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.01	0.00
Solid storage	1.00	1.00	1.00	0.99	1.00

*The sum of fractions may differ from 1 due to roundings.

6.3.2.3 Emission factors and other parameters

Nitrous oxide

The IPCC default emission factors have been used for each manure management system. The manure management systems included in the inventory are pasture, solid storage and slurry (Table 6.3_8).

Table 6.3_8. IPCC default emission factors for N₂O 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)
Solid storage	0.02	-85% /+15% (beta)	Monni & Syri (2003)
Slurry	0.001	-50% / +100% (lognormal)	Penman et al. (2000)

Methane

The national emission factor for each cattle subcategory has 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_9.

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. 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_9. National emission factors used for calculating CH₄ emissions from manure management.

Animal category	Emission factor (kg CH ₄ /head/year)
Dairy cows	14.6
Suckler cows	2.98
Bulls	4.60
Heifers	2.88
Calves	1.71

Animal category	Emission factor (kg CH ₄ /head/year)
Swine	3.62
Sheep	0.19
Goats	0.12
Horses	1.42
Poultry	0.17
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 5. 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 N₂O 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 N₂O 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 CH₄ 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 N₂O.

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, B₀ 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 there are no changes in the calculation methods during 1990-2006, 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.

6.3.4 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.

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 will be checked annually if new data for updating emission factors has been published. New national data will be compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances will be evaluated.

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.

6.3.5 Source-specific recalculations

The nitrogen excretion rates of poultry were corrected for the time series since 1991 and for fur animals since 1990. These changes had no impact on emissions. For poultry corrections were made for nitrogen excretion per AMWS since 1994 because of a calculation error that appeared (broiler hens) and a small correction was also made for year 2006 (other poultry). For fur animals there was a small error in the share of solid storage since 1994 which was corrected. These corrections resulted in small changes in the reported emissions of nitrous oxide, fur animal error also affecting slightly atmospheric deposition and leaching and runoff. For dairy cows errors in the nitrogen excretion on pasture for years 2004, 2005 and 2006 were corrected and VS for the year 2006 for dairy and non-dairy cattle was also corrected. It resulted to a small change in methane production for dairy cows for the year 2006. For non-dairy cattle a small correction was made to nitrogen excretion per AMWS (calves) and that slightly affected total nitrogen excretion for year 2006. All MCF's and 'Allocation by climate region to different AMWS' tables were corrected. In NIR sheep N₂O emissions were corrected to Table 6.3_2.

6.3.6 Source-specific planned improvements

The distribution of different manure management systems should be updated regularly. However, little information about the distribution of different manure management systems exists in Finland and the data collecting methodology should be improved. Efforts will be made to improve data availability in the future. Discussions between MTT Agrifood Research Finland, the Information Centre of the Ministry of Agriculture and Forestry and Statistics Finland have been initiated to meet this objective.

An effort to revise the distribution of manure to different management systems was made in cooperation with the Finnish Environment Institute in a project that produced a new calculation model for ammonia and N₂O emissions from agriculture. The new model will be applied in the next submission.

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 almost 58% of total agricultural emissions in 2007, being 3.2 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 N volatilised as NH₃ and NO_x as well as N leached from synthetic fertilisers, manure and sewage sludge applied to soils (see Figure 6.4_1).

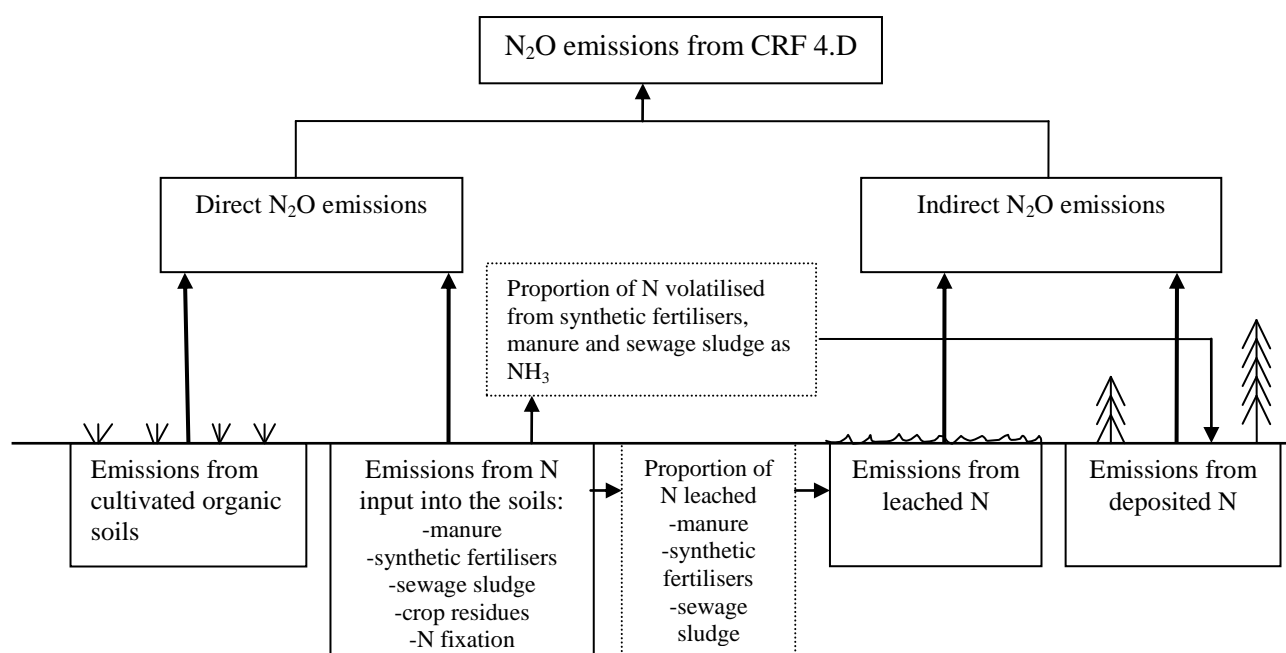


Figure 6.4_1. N₂O emissions from agricultural soils.

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 N 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 26%, from 13.9 Gg in 1990 to 10.3 Gg in 2007 (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, the fall in the amount of synthetic fertilisers sold annually and the decrease in the area of cultivated organic soils. Some parameters, such as the annual crop yields affecting the amount of crop residues produced, cause the fluctuation in the time series but this fluctuation does not have much effect on the overall N₂O 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	4.46	1.24	0.53	0.60	0.01	4.55	0.03	0.63	1.82	13.87
1991	3.95	1.17	0.53	0.49	0.04	4.47	0.02	0.58	1.64	12.91
1992	3.19	1.13	0.51	0.44	0.04	4.39	0.02	0.55	1.40	11.67
1993	3.28	1.12	0.49	0.51	0.05	4.32	0.02	0.55	1.42	11.76
1994	3.30	1.14	0.49	0.49	0.02	4.24	0.03	0.57	1.43	11.71
1995	3.82	1.15	0.48	0.49	0.02	4.16	0.02	0.59	1.59	12.31
1996	3.51	1.18	0.48	0.50	0.02	4.08	0.02	0.61	1.50	11.91
1997	3.31	1.23	0.48	0.52	0.02	4.00	0.02	0.64	1.46	11.68
1998	3.32	1.21	0.47	0.37	0.01	3.92	0.01	0.63	1.45	11.38
1999	3.18	1.18	0.47	0.42	0.01	3.85	0.01	0.61	1.40	11.11
2000	3.27	1.18	0.48	0.53	0.02	3.77	0.01	0.60	1.42	11.27
2001	3.23	1.15	0.48	0.51	0.02	3.69	0.01	0.58	1.41	11.08
2002	3.13	1.17	0.48	0.54	0.02	3.61	0.01	0.59	1.38	10.94
2003	3.11	1.17	0.47	0.50	0.02	3.53	0.01	0.59	1.37	10.77
2004	3.02	1.15	0.47	0.45	0.01	3.45	0.01	0.59	1.34	10.49
2005	2.92	1.19	0.48	0.52	0.01	3.37	0.00	0.60	1.32	10.43
2006	2.89	1.21	0.48	0.52	0.01	3.30	0.00	0.61	1.32	10.35
2007	2.91	1.20	0.48	0.54	0.02	3.22	0.00	0.60	1.32	10.28
Share of total in 2007 (%)*	28.2	11.7	4.7	5.3	0.16	31.3	0.02	5.9	12.8	

* The sum of the shares differs from 100 due to rounding. S=synthetic fertilisers, MS= manure applied to soils, MP=manure deposited on pastures, C=crop residues, N=N-fixation, O=cultivation of organic soils, SW=sewage sludge application, A=atmospheric deposition, L=leaching and run-off

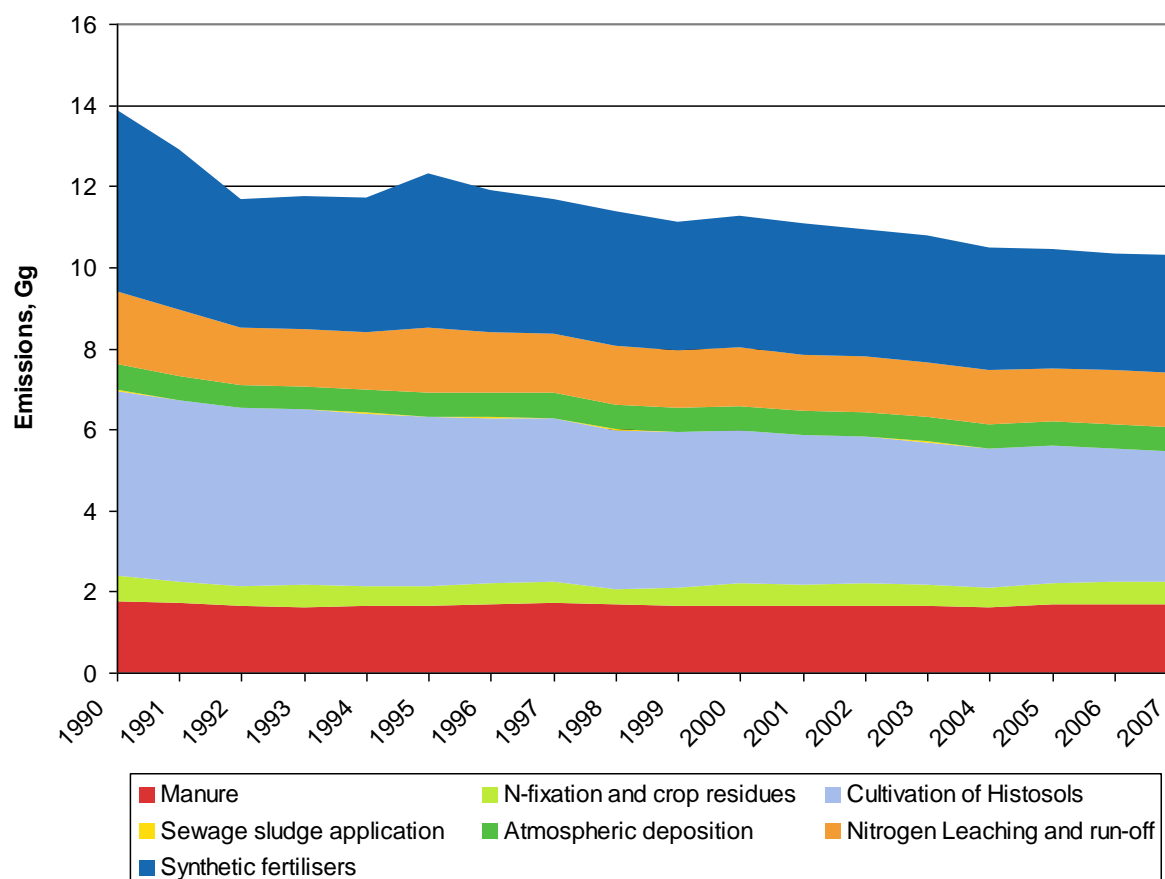


Figure 6.4_2. Nitrous oxide emissions from agricultural soils (atmospheric deposition, nitrogen leaching and run-off are indirect emissions, all other direct), Gg

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.

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), excluding the fraction used as feed and the fraction used as construction material. The calculation methodology has been developed towards a mass-flow approach in order to avoid double-counting. The N lost as NH_3 and NO_x ($\text{Frac}_{\text{GASF}}$, $\text{Frac}_{\text{GASM}}$) is subtracted from the amount of N in synthetic fertilisers and manure applied to soils, as well from manure deposited on pastures and sewage sludge application. The N emitted and leached is used for calculating the indirect N_2O emissions from atmospheric deposition and leaching and run-off and the N remaining in the soil for calculating the direct N_2O emissions. For leaching and run-off $\text{Frac}_{\text{GASF}}$ and $\text{Frac}_{\text{GASM}}$ have been subtracted before applying $\text{Frac}_{\text{LEACH}}$. N_2O emissions from crop residues (burned amount reduced), N-fixation and cultivation of organic soils are also included in the direct emissions. The N excretion is national data for most animal species. Nitrous oxide emissions from cultivated organic soils have been calculated by dividing the area into cereals and grasses 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 N in sewage sludge) and MTT Agrifood Research Finland (area of cultivated organic soils). Animal numbers are the same as those used for calculating CH_4 emissions from enteric fermentation and CH_4 and N_2O emissions from manure management (Table 6.2_3). Emissions from reindeer and fur animals are also

included. The distribution of different manure management systems has been received from published literature (Seppänen & Matinlassi, 1998) and by expert judgement. The amount of nitrogen excreted per animal is national data for cattle, swine, sheep, horses, poultry and fur animals and the same as those used for calculating nitrous oxide emissions from manure management (Source: MTT Agrifood Research Finland). 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 have been received from literature (Horticultural Enterprise Register) and Yearbook of Farm Statistics (Table 6.4_6). The amount of nitrogen in crop residue burned is now reduced from the nitrogen input to soil. The area of cultivated organic soils has been obtained from MTT Agrifood Research Finland (Table 6.4_7) and has been estimated on the basis of Myllys & Sinkkonen (2004) and Kähäri et al. (1987).

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
N 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)
Model for ammonia emission estimate	VTT Technical Research Centre of Finland, Savolainen et al. (1996), agricultural experts (updated in 2005)
Area of cultivated organic soils	MTT Agrifood Research Finland

Table 6.4_4. Nitrogen input to soils via synthetic fertilisers, manure and sewage sludge application (Mg N a^{-1}) (the fraction lost as NH_3 and NO_x has not been subtracted).

Year	Synthetic fertilisers ¹	Manure ²	Sewage Sludge ³
1990	228 470	117 641	2 202
1991	202 462	111 928	1 749
1992	163 229	107 412	1 532
1993	168 199	106 185	1 404
1994	169 138	108 168	2 063
1995	195 460	110 071	1 316
1996	179 529	112 874	1 548
1997	169 345	116 990	1 696
1998	169 928	115 112	575
1999	162 700	112 243	644
2000	167 276	112 054	513
2001	165 621	109 615	725
2002	160 403	111 341	616
2003	159 288	110 849	754
2004	154 708	109 763	437
2005	149 562	113 248	143

Year	Synthetic fertilisers ¹	Manure ²	Sewage Sludge ³
2006	148 161	114 676	156
2007	148 784	113 821	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 1990-2007 (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	6 73.1	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 1990-2007 (Gg a⁻¹).

Year	Garden pea	White cabbage	Cauliflower	Carrots	Red beet	Swede	Celeriac	Total
1990	5.8	21.1	4.4	31.4	10.7	9.3	1.7	84.3
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

Table 6.4_7. Area of cultivated organic soils in Finland in 1990-2007 (ha).

Year	Total area of cultivated organic soils, ha	Organic soils on cereals, ha	Organic soils on grass, ha
1990	368 929	184 464	184 464
1991	362 571	181 286	181 286
1992	356 214	178 107	178 107
1993	349 857	174 929	174 929
1994	343 500	171 750	171 750
1995	337 143	168 571	168 571
1996	330 786	165 393	165 393
1997	324 429	162 214	162 214
1998	318 071	159 036	159 036
1999	311 714	155 857	155 857
2000	305 357	152 679	152 679
2001	299 000	149 500	149 500
2002	292 643	146 321	146 321
2003	286 286	143 143	143 143
2004	279 929	139 964	139 964
2005	273 571	138 375	138 375
2006	267 214	133 607	133 607
2007	260 857	130 429	130 429

6.4.2.3 Emission factors and other parameters

IPCC default emission factors have been used for calculating N₂O 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 amount of nitrogen applied to soils has been corrected with the fraction of nitrogen volatilised as NH₃ and NO_x from the synthetic fertilisers (Frac_{GASF}) and the fraction of nitrogen volatilised as NH₃ and NO_x from manure and sewage sludge (Frac_{GASM}) (Table 6.4_9). The amount of nitrogen volatilised has been used for calculating indirect N₂O emissions from atmospheric deposition. The amount of nitrogen leached has been used for calculating indirect N₂O emissions from leaching and run-off. The values for Frac_{GASF}, Frac_{GASM} and Frac_{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 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). Besides, according to the report, most of the leaching was caused by tree felling and ditching and not by fertilising (and by deposition).

The value for Frac_{GASM} has been obtained from the ammonia model of VTT Technical Research Centre of Finland (Savolainen et al. 1996). In the model, annual N excreted by each animal type has been divided between different manure management systems typical of each animal group. Ammonia volatilisation during stable, storage and application was included with a specific emission factor in each phase. Frac_{GASM} is the

proportion of total $\text{NH}_3\text{-N}$ of the total N excreted. Emission factors describing the amount of NH_3 volatilised in each phase have been taken from ECETOC (1994), Grönroos et al. (1998). Support for using these values is found, for example, from Esala and Larpes (1984), Rekolainen (1989), Niskanen et al. (1990), Pipatti (1992), Savolainen et al. (1996), Grönroos et al. (1998), Rekolainen et al. (1995), Pipatti et al. (2000), Kulmala & Esala (2000) and Mattila & Joki-Tokola (2003).

The country-specific $\text{Frac}_{\text{GASF}}$ value is based on the NH_3 emission factor given in the report by ECETOC (1994) for NPK fertilisers, which is 1% of the nitrogen content in the fertilisers. In the same report the ammonia emissions from placement fertilisation are said to be negligible. Support for this is also found from Niskanen et al. (1990) and Pipatti (1992). In Finland, about 90% of the fertilisers used are NPK fertilisers. Urea fertilisation is used in Finland only in very small amounts (in 1990 about 1% of the nitrogen in fertilisers came from urea). The nitrogen in urea is in a form that volatilises easily as ammonia, the emission factor given in the ECETOC report is 15% of the nitrogen content. Placement fertilisation where the fertiliser is placed approximately 7-8 cm below the soil surface is the common method (around 80-90%) used in applying the fertilisers in the soils in Finland. In urea fertilisation, the fertiliser is applied on the surface. The $\text{Frac}_{\text{GASF}}$ is calculated using the assumption that 80% of the nitrogen in synthetic fertilisers in Finland is applied using the placement method. The emission factor for placement fertilisation is assumed to be 50% of surface application (conservative assumption).

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 $\text{N}_2\text{O-N/kg N}$	IPCC (2000), Table 4.17
Animal wastes applied to soils	0.0125 kg $\text{N}_2\text{O-N/kg N}$	IPCC (2000), Table 4.17
N-fixing crops	0.0125 kg $\text{N}_2\text{O-N/kg dry biomass}$	IPCC (2000), Table 4.17
Crop residue	0.0125 kg $\text{N}_2\text{O-N/kg dry biomass}$	IPCC (2000), Table 4.17
Cultivation of organic soils on cereals	11.7 kg $\text{N}_2\text{O-N/ha/yr}$	Monni et al. (2007)
Cultivation of organic soils on grass	4.0 kg $\text{N}_2\text{O-N/ha/yr}$	Monni et al. (2007)
Indirect emissions		
Atmospheric deposition	0.1 kg $\text{N}_2\text{O-N/kg NH}_3\text{-N \& NO}_x\text{-N deposited}$	IPCC (2000), Table 4.18
Nitrogen leaching and run-off	0.025 kg $\text{N}_2\text{O-N/kg N/yr}$	IPCC (2000), Table 4.18
Animal production		
N excretion on pasture range and paddock	0.020 kg $\text{N}_2\text{O-N/kg N/yr}$	IPCC (1997)
Other sources		
Sewage sludge spreading	0.0125 kg $\text{N}_2\text{O-N/kg N load}$	IPCC (1997) (EF_1)

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	Frac _{LEACH}	0.15	Rekolainen (1989), Rekolainen et al. (1993) Rekolainen et al. (1995), Pipatti (2001); Pipatti et al. (2000)
Fraction of N input that volatilises as NH ₃ and NO _x from synthetic fertilisers.	Frac _{GASF}	0.006	Pipatti (2001), Keränen & Niskanen (1987), Pipatti (1992); Niskanen et al. (1990), Kulmala & Esala (2000)
Fraction of manure N input that volatilises as NH ₃ and NO _x	Frac _{GASM}	0.33	Energy model for ammonia emission estimate (VTT Technical Research Centre of Finland), Savolainen et al. (1996), Pipatti (1992), Niskanen et al. (1990)

Table 6.4_10. Residue to crop ratio, dry matter fraction and nitrogen content of crops included in the inventory.

Crop	Res./Crop _i	Frac _{DM}	Frac _{NCR}
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 5. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in N₂O emissions from agricultural soils was 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 N₂O emissions from agricultural soils were partly the same as in the calculation of N₂O 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 N₂O 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 N₂O emissions from agricultural soils.

Due to consistent use of data sources the time series can be considered relatively 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.

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 will be checked annually if new data for updating emission factors has been published. New national data will be compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances will be evaluated.

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.

6.4.5 Source-specific recalculations

The time series for N₂O emissions from crop residues was changed as the burned amount is now reduced from the total amount of residue. Nitrogen input in sewage sludge was updated for the year 2006. As corrections were made for manure nitrogen excretion there were changes in time series since 1994 for atmospheric deposition and leaching /run-off.

6.4.6 Source-specific planned improvements

The estimation of N₂O emissions from leaching will be revised in the next submission as a new model for estimating N₂O emissions will be taken into use. In the new method, Frac_{GASF} and Frac_{GASM} will not be subtracted from the nitrogen inputs before applying the Frac_{LEACH} coefficient.

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 now 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 N₂O and CH₄ 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 2007 (0.25%) is 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 1990-2006 is estimated on the basis of the annual rye yield. The trend of residue burning is assumed to follow the trend of rye crop yield as rye is the most common straw burned on fields. The rye crops fluctuate from year to year. The annual fractions of cereal residue burned are listed in Table 6.5_2. The IPCC default values were used for residue-crop ratio (1.2-1.6), fraction oxidised (0.9), carbon fraction (0.471, average of wheat and barley), nitrogen-carbon ratio (0.012), and dry matter fraction (0.83). 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

* an estimate by national experts, other values are interpolated

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 5. 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

The emissions of straw burning are included in the inventory for the first time, therefore no recalculations were made.

6.5.5 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 CH₄ 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 CH₄ 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_l*, *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, 130 days for suckler cows, 120 days for dairy cows, heifers and 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) CH_4 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 CH_4 /animal/yr.

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/yr).

4) Equations for calculating N₂O emissions from manure management

N₂O 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 Seppänen & Matinlassi (1998) and expert judgement.

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,

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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 literature (Seppänen & Matinlassi, 1998). For the MCF coefficient, the IPCC default value 10% (IPCC 1997) instead of the updated value 39% (IPCC 2000) has been used.

6) Equations used for calculating direct and indirect N_2O emissions from agricultural soils

Direct N_2O 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)

N_2O emissions from synthetic fertilisers (IPCC 2000, Eq. 4.22):

$$N_2O_{fert} = N_{fert} * (1 - Frac_{GASF}) * EF * 44/28$$

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 0.06 for $Frac_{GASF}$ has been used (See Pipatti 2001).

N_2O emissions from manure applied to soils (IPCC 2000, Eq. 4.23):

$$N_2O_{manure} = \sum_{(T)} (N_{(T)} * N_{ex(T)}) * (1 - Frac_{GASM}) * (1 - Frac_{FUEL-AM}) * EF * 44/28$$

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)

$Frac_{GASM}$ = Fraction that volatilises as NH_3 and NO_x

$Frac_{FUEL-AM}$ = Amount of manure that has been burned for fuel

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 0.33 for $Frac_{GASM}$ has been used (See Pipatti, 2001).

N_2O emissions from crop residue (IPCC 2000, Eq. 4.29, modified):

$$N_2O_{CR} = \sum_i (Crop_i * Res_i / Crop_i * Frac_{Dmi} * Frac_{NCri}) * (1 - Frac_{Burn}) * EF * 44/28$$

where,

$Crop_i$ = Crop production

$Res_i / Crop_i$ = Residue to crop product mass ratio

$Frac_{Dmi}$ = Dry matter content of the aboveground biomass

$Frac_{NCri}$ = Nitrogen content of the aboveground biomass

EF = Emission factor (0.0125 kg N_2O -N/kg N load)

$Frac_{Burn}$ = Fraction of crop residue that is burned and not left on field (kg N/kg cropres-N)

IPCC default values, and if IPCC default values were not available, national values as $Crop_i$, $Res_i/Crop_i$, $Frac_{Dmi}$ and $Frac_{NCri}$ have been used (IPCC 2000, Table 4.16, Table 6.5.8, Chapter 6.5). $Frac_{Burn}$ was counted by dividing the amount of nitrogen in burned straw with the amount of nitrogen in total residue left on the field.

N₂O 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

N₂O 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)

The amount of nitrogen applied annually in sewage sludge has been received from the Finnish Environment Institute.

N₂O 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

N₂O 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 NH₃ 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 NH₃ and NO_x

EF = Emission factor (0.01 kg N₂O-N / kg NH₄-N & NO_x-N)

N₂O emissions from leaching and run-off (IPCC 2000, Eq. 4.34, modified):

$$N_2O_{indirect-L} = [N_{fert} + \sum (N_{(T)} * Nex_{(T)}) + N_{sludge}] * Frac_{LEACH} * EF * 44/28$$

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 N₂O-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 s. 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 NOx)

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 2007 as a whole acted as a CO₂ sink of around 25 million tonnes CO₂ equivalent because total emissions arising from the sector are smaller than the total removals (Figure 7.1_1, Table 7.1_3). The sink in 2007 was approximately 32% the total national emissions without the LULUCF sector.

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 is divided into different land use categories in which the emissions/removals are reported. The land-use classes are: Forest land, Cropland, Grassland, Wetlands, Settlements and Other land. According to IPCC GPG LULUCF, the emissions/removals should be reported separately for land remaining in the land-use category and land converted to another land-use category. In Finland, emissions and removals from the LULUCF sector are not yet reported separately for land remaining in the same land-use category and land converted to another land-use category.

Finland reports carbon stock changes and greenhouse gas emissions from Forest land (CRF 5.A), Cropland (CRF 5.B), Grassland (CRF 5.C), Wetlands (CRF 5.D, peat extraction areas) and harvested wood products (CRF 5.G). In the Forest land category all the carbon pools (living biomass, dead organic matter and soil) are reported. In Cropland category C changes in living biomass are reported for the first time. In the Cropland and Grassland as well as Forest land categories carbon stock changes in soil are reported separately for mineral and organic soils. N₂O emissions from agricultural soils are reported under the Agriculture sector. In addition, CO₂ emissions from liming of agricultural soils (CRF 5(IV)), direct N₂O emissions from nitrogen fertilisation on forest land (CRF 5(I)) and CO₂, CH₄ and N₂O emissions from biomass burning (on forest land) (CRF 5(V)) are reported. Other air emissions like CO and NO_x emission from forest fires are also included in the reporting. CO₂ emissions from peat extractions areas are reported in the Wetlands category (CRF 5.D) and non-CO₂ emissions in CRF category 5 (II).

CO₂ and N₂O emissions from land-use conversions from 'Forest land converted to other land-use categories' are reported as Information Items. N₂O emissions from disturbance associated with land-use conversion to cropland is not yet reported in the category CRF 5(III) since the applied method to estimate emissions and applied activity data for conversion areas are not reliable enough for the present.

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.

Finland has prepared the 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 a 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 4.

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 2007 a net sink in living biomass on Forest land was -33 Tg CO₂. The dead organic matter pool on Forest land was also a CO₂ sink of -3.3 Tg in 2007 as well as mineral forest soils had a sink of -3.6 Tg CO₂.

On the contrary, organic forest soils were a fairly large source of emissions in 2007 (6.7 Tg CO₂). Other emission sources in the Forest land category were N fertilisation on forest land (0.017 Tg CO₂ eq) and biomass burning (0.006 Tg CO₂ eq).

In the Cropland category mineral soils were a sink of 1.5 Tg CO₂ and organic soils a source of 4.6 Tg CO₂ in 2007. Changes in woody living biomass on cropland were a small sink. In addition, emissions from liming in agricultural soils made up about 0.25 Tg CO₂ in 2007. Mineral soils in the Grassland category were a source of 4.0 Tg and organic soils a source of 0.04 Tg CO₂ in 2007. 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. Emissions from peat extraction areas, reported under the Wetland category, were in 2007 a source of 1.4 Tg CO₂ eq.

Table 7.1_1. Greenhouse gas emissions and removals from the LULUCF sector in 1990-2007 (Gg CO₂ eq.) (positive figures indicate emissions, negative removals).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Forest land																		
Biomass	-26 348	-41 050	-34 212	-31 633	-22 691	-21 364	-28 769	-21 181	-18 352	-20 140	-21 618	-26 745	-27 647	-28 337	-30 242	-35 516	-40 234	-32 666
Dead organic matter	-4 539	-4 033	-4 381	-5 288	-6 742	-8 031	-9 301	-9 404	-9 290	-9 406	-8 744	-7 689	-6 637	-5 316	-4 132	-4 172	-3 689	-3 269
Mineral soil	-2 363	-2 432	-2 501	-2 576	-2 665	-2 770	-2 890	-3 013	-3 134	-3 251	-3 357	-3 446	-3 516	-3 565	-3 595	-3 616	-3 624	-3 625
Organic soil	10 027	9 809	9 573	9 451	9 258	9 036	8 787	8 579	8 395	8 185	7 990	7 801	7 602	7 396	7 185	6 925	6 820	6 725
Cropland																		
Mineral soil	214	-1 290	-1 194	-1 265	-1 340	501	782	469	44	-176	-465	-614	-993	-1 186	-1 357	-1 573	-1815	-1 534
Organic soil	6 584	6 472	6 358	6 244	6 131	6 015	5 894	5 771	5 658	5 547	5 423	5 311	5 195	5 080	4 966	4 859	4 741	4 618
Biomass	-1	0	-1	-1	-2	-2	-2	-2	-3	-3	-3	-3	-3	-4	-4	-3	-2	-3
Grassland																		
Mineral soil	-2 232	-925	-1 163	-687	-208	-787	-982	-666	7	886	1 845	2 350	2 084	2 606	2 961	3 392	4 196	4 016
Organic soil	101	90	89	86	78	103	101	96	84	78	71	67	61	57	53	49	43	41
Wetland																		
Organic soil*	1 078	1 095	1 142	1 162	1 199	1 215	1 250	1 288	1 324	1 343	1 367	1 372	1 350	1 352	1 426	1 409	1 404	1 380
Biomass burning	8	4	12	1	9	6	5	12	2	7	4	4	8	8	4	6	16	6
N fertilisation	27	20	9	3	12	6	8	13	13	10	10	11	12	11	12	11	18	17
Liming	618	431	273	448	449	386	453	467	428	429	326	395	422	278	252	265	298	249
Harvested wood products	-946	307	-225	-93	-756	-870	-1 048	-2 122	-1 766	-2 038	-1 267	-315	-437	-889	-832	-340	-394	-1 220
Total CO₂ eq	-17 773	-31 501	-26 222	-24 147	-17 269	-16 556	-25 711	-19 693	-16 590	-18 529	-18 418	-21 501	-22 497	-22 508	-23 302	-28 306	-32 207	-25 265

*Includes CO₂, N₂O and CH₄ emissions from peat extraction areas.

The high fluctuation in biomass removals in the Forest land category during the period 1990-2007 was mainly caused by the variation in the total drain of the growing stock. The drain consists of cutting removals, harvest residues and natural mortality of trees. The variation in biomass removals is caused by the variation of the harvest of the trees, which is very much affected by the international market situation in forest industry products. The cuttings were at a low level in the first half of the 1990's, the lowest drain in the period was 44.6 mil. m³ in 1991. In the second half they increased considerably, the highest drain was 70.0 mil. 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 mill. 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 7.1_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).

Another significant factor affecting the general trends in LULUCF Forest carbon pool changes is the increase in the annual increment of the trees. It has risen from 77.7 mil. m³ in the eighth national forest inventory NFI8 (1986-1994) to 86.7 mil. m³ in NFI9 (1996-2003) and it still has increased by 14% from the NFI9 to the NFI10 (99.2 million m³ (Finnish Statistical Yearbook of Forestry 2008)). The results presented for the NFI10 are preliminary. It will take five years to complete the NFI10 measurements, now four years' measurements are available. The increased total increment has compensated the changes in cuttings, and in 2006 the sink exceeded the previous peak-values of 1991 and 2005. 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 (Table 7.2_1). When the cuttings levelled off, the decomposition of the dead organic matter also levelled off the CO₂ sink of the dead organic matter in the 2000's.

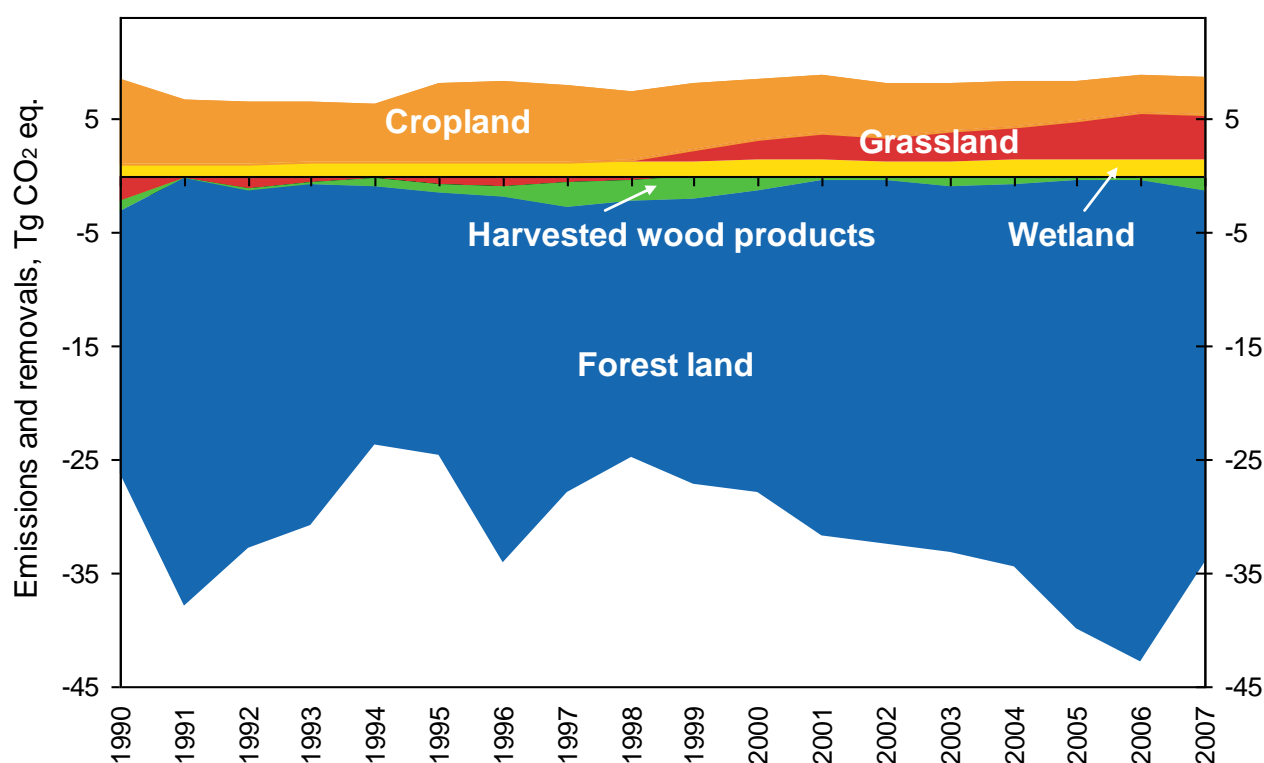


Figure 7.1_1. Net emissions and removals in the LULUCF sector in 1990-2007 by land-use category, Tg CO₂ eq. Positive figures are emissions, negative figures removals.

The increased forestry activities can also be seen as the increased CO₂ sink of the mineral soil (Figure 7.1_2). The variation in organic soil emission and sinks in the period 1990-2007 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 for the increased CO₂ sink of the organic soil is caused by the increased fine root litter production.

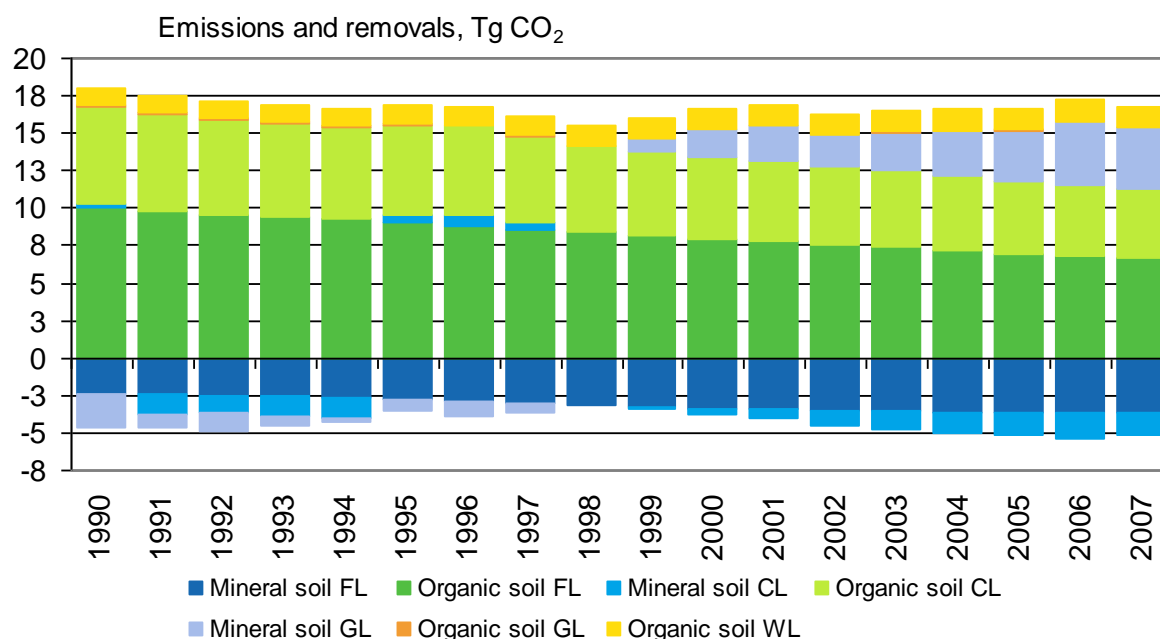


Figure 7.1_2. Emissions (positive sign) and removals (negative sign) from soil organic matter in different land-use classes during 1990-2007, Tg CO₂. (FL = Forest land, CL=Cropland, GL=Grassland, WL=Wetland = peat extraction areas).

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 total land area for years to be reported is Finland's official land area published by the National Land Survey of Finland (Table 7.1_2). Small changes occur annually due to the real changes in land and water areas and improvements in the mapping precision. According to the ERT Finland has decided to employ the same total land area for 2-5 years. Otherwise the new total area would cause recalculations of all land use areas annually. In this submission the reference date is 1 January 2006. In 2004 the Ministry of Agriculture and Forestry set up a working group one of whose tasks was to propose a follow-up system for land use and land-use changes taking into consideration the requirements of the UNFCCC reporting and the Kyoto protocol. The working group suggested in its report national definitions for all the IPCC land-use categories and summarised the potential data sources (Ministry of Agriculture and Forestry 2005:5). The recommendations of the working group are adopted in the inventory.

The area estimates of land-use categories are based on the Finnish National Forest Inventories (NFI) carried out by the Finnish Forest Research Institute. Exceptions make the area of cropland, which comes from the official statistics compiled by the Information Centre of the Ministry of Agriculture and Forestry, and the area of peat extraction, which comes from the enquiry by the Association of Finnish Peat industry (1990-2003) and a joint enquiry by Statistics Finland and Finland's environmental administration (2004-). The NFI is a sampling-based forest inventory and it covers all land-use classes, not only forest land. The sampling design is systematic cluster sampling. 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. Finnish forests have been measured by the National Forest Inventories nine times. The 10th inventory started in 2004 and the measurements were completed in 2008. A more detailed description of the National Forest Inventories, the applied methods and the data are available in Appendix_7a at the end of this chapter.

To produce the time series for land-use categories NFI8, NFI9 and NFI10 data were used. Sample plot data were classed to the IPCC land-use categories and the proportion of each six categories was estimated. The area is a product of the proportion of the land-use category and the total land area of a calculation unit. The Forestry Centre regions were used as calculation units, and the areas of these regions based on the official land area of Finland. In the NFI, IPCC cropland and grassland is assessed as a one category and therefore the

estimate for cropland area bases on the statistics. The time series for areas of peat extraction was recalculated for this submission (see Section 7.5.2). The two statistics based areas were taken into account estimating land areas.

National application of IPCC land-use categories in the Finnish inventory

Forest land. The FAO TBFRA 2000 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. Area estimates are derived from NFI data.

Cropland. Cropland refers to the official area of arable land. The area is reported by the Information Centre of the Ministry of Agriculture and Forestry and can be found in the Yearbook of Farm Statistics (2007).

Grassland. The NFI grassland area together with the difference of the arable area of the NFI and the arable area in the statistics of the Ministry of Agriculture and Forestry is classified as Grassland. The arable land concept in the NFI deviates from that applied in the official statistics on arable land (Yearbook of Farm Statistics). The arable land of the NFI includes, for example, the abandoned arable land and ditches associated with agricultural land while only the actively cultivated area is included in the statistics of the Ministry of Agriculture and Forestry. Abandoned arable land means in this context 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. Peatlands classified as Cropland or Grassland are excluded. The peat extraction area for the years 1990-2007 is received from the Association of Finnish Peat industry and from Finland's environmental administration. The area of other Wetlands is estimated from the NFI data. 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 and yards are included. Only the total area of Settlements is reported. Area estimates are derived from the NFI data.

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 and Finland's official land area are given in Table 7.1_2.

Table 7.1_2. The areas of IPCC land-use classes in 1990-2007 (1 000 ha).

	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total land area
	1 000 ha						
1990	21 770	2 271	677	3 312	1 166	1 213	30 409
1991	21 828	2 302	628	3 257	1 179	1 213	30 409
1992	21 887	2 287	626	3 204	1 191	1 214	30 409
1993	21 945	2 278	617	3 149	1 204	1 215	30 409
1994	22 003	2 302	576	3 095	1 217	1 216	30 409
1995	22 061	2 141	719	3 040	1 230	1 216	30 409
1996	22 119	2 122	718	2 987	1 244	1 219	30 409
1997	22 181	2 125	692	2 935	1 252	1 223	30 409
1998	22 243	2 166	632	2 882	1 259	1 226	30 409
1999	22 312	2 177	597	2 830	1 266	1 226	30 409
2000	22 374	2 187	561	2 780	1 274	1 233	30 409
2001	22 421	2 186	544	2 739	1 284	1 234	30 409
2002	22 446	2 204	508	2 715	1 299	1 238	30 409
2003	22 438	2 212	484	2 720	1 311	1 243	30 409
2004	22 338	2 219	466	2 811	1 316	1 259	30 409
2005	22 239	2 234	442	2 895	1 327	1 271	30 409
2006	22 139	2 259	404	2 979	1 339	1 289	30 409
2007	22 039	2 255	392	3 063	1 351	1 309	30 409

Forest land converted to other land-use categories

Finland does not report emission and removals in the categories land converted to other land in the last 20 years. The activity data for conversion areas pursuant to the IPCC land use categories is not yet available. The method to estimate converted areas is under development. Also the method to estimate emissions for all conversion categories needs to be further developed. At the moment, some area estimates of annual deforestation area are available for the years 1990-2007. Finland reports CO₂ and N₂O emissions as information items (Table 7.1_3). The included categories are transitions from forest land to cropland, to wetlands and to settlements. Area converted from forest land to cropland bases on the forest statistics on forest land area treated with fellings (Forest statistical... 2007). Only fellings made to clear forest for land-use change are included. Conversion to wetlands relate to drained forest land mires, which are restored for biodiversity reasons by removing trees and filling ditches. Areas are based on the information given by Metsähallitus, a state-owned enterprise that administers state-owned land and the main part of Finland's protected areas. Area estimates of other conversions are based on the NFI. Emissions from areas forest land converted to peat production are reported under Wetlands category.

The methods are still under development and the results presented here and the CRF tables are therefore preliminary.

Table 7.1_3. Converted areas (ha) and emissions (Gg) from category Forest land converted to other land-use categories in 1990-2007.

	Total area (ha)	Total emissions (Gg CO ₂ eq)	
		CO ₂	N ₂ O
1990	13 254	1 653	0.00
1991	12 917	1 589	0.28
1992	13 751	1 722	0.26
1993	17 169	2 191	0.31
1994	22 969	2 797	0.55
1995	15 370	1 945	0.98

Total area (ha)		Total emissions (Gg CO ₂ eq)	
		CO ₂	N ₂ O
1996	14 776	1 940	0.40
1997	14 904	1 947	0.36
1998	16 106	2 222	0.35
1999	14 838	2 132	0.43
2000	15 468	2 331	0.34
2001	18 052	3 022	0.58
2002	18 387	3 282	0.78
2003	18 418	3 169	0.81
2004	22 612	3 756	0.78
2005	16 484	3 026	1.03
2006	16 891	3 219	0.62
2007	16 922	3 310	0.67

7.1.3 Key Categories

The key categories in LULUCF sector in 2007 are summarised in Table 7.1_4.

Table 7.1_4. Key categories in LULUCF sector (CRF 5) in 2007 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
5.A 1 Carbon stock change in living biomass on Forest land	CO ₂	L, T
5.A 1 Carbon stock change in mineral soils on Forest land	CO ₂	L, T
5.A 1 Carbon stock change in organic soils on Forest land	CO ₂	L, T
5.A 1 Carbon stock change in dead organic matter on Forest land	CO ₂	L, T
5.B 1 Carbon stock change in mineral soils on Cropland	CO ₂	L, T
5.B 1 Carbon stock change in organic soils on Cropland	CO ₂	L, T
5.C 1 Carbon stock change in mineral soils on Grassland	CO ₂	L, T

7.2 Forest land (CRF 5.A)

7.2.1 Source category description

The estimation of the area of Forest land is based on the National Forest Inventory (NFI). Forest land is defined in this submission according to the FAO TBFRA 2000 definition, except the minimum area. The FAO forest is land with a tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes 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 Resources... 2000). Parks and yards, for example, are excluded regardless of whether they would meet the Forest land definition.

The old NFI data are used to estimate time series for areas, increment of growing stock and tree biomass. When the former NFIs were conducted the minimum forest stand area in South Finland was 0.25 ha and in North Finland 0.5 ha. The FAO TBFRA 2000 definition was introduced at the end of 1990's and it was implemented in the Finnish NFI in 1998, but the threshold value of 0.5 ha for the minimum area was not taken in use. A method to estimate the effect of threshold value of minimum area on the FAO forest land area derived from the old NFI is under development.

For the NFI data measured before 1998, a study was conducted to assess FAO forest, other wooded land and other land categories for all field plots. FAO Forest land includes national 'Productive forest land' where the mean annual increment of the growing stock over the rotation is at least 1 m³/ha, and part of 'Poorly productive forest land' where it is less than 1 m³/ha but more than 0.1 m³/ha. Following FAO definitions, forestry roads belong to Forest land. All forests are considered as managed in this submission. Distinction between forest land remaining forest land and areas converted to forest land is not yet made and all emissions and removals are reported in CRF 5.A 1 category Forest land remaining Forest land. Finland does not have a method to report emissions and removals for Forest land remaining Forest land and for lands converted to Forest land during the last 20 years. Finland can give some estimates on the annual bases since 1990 and they are reported in CRF Table 5/Information items (see Chapter 7.1.2). In the tables 5.A-5.F "IE" is used since all losses in tree biomass, whether occurred in Forest land or Forest land converted to another land use, is included in the statistics on the total drain of the growing stock.

The following carbon stock changes are assessed in the 2007 submission: 1) above and below ground biomass of the growing stock, 2) litter and dead wood (= dead organic matter), and 3) 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 carbon stock change in living biomass is estimated with the IPCC default method (GPG LULUCF 2003). Carbon uptake and release of the growing stock correspond to the mean annual increment and annual drain of trees.

Changes in the carbon stocks of litter, dead wood and soil organic matter were assessed using a model-based method (Yasso 2005, cf. Liski et al. 2006), with the exception of soil organic matter in organic soils where the measured emission factors were used in estimating decomposition of peat. In the modelling approach carbon stock changes of litter, dead wood and soil organic matter are driven by tree litter production and its consequent decomposition was evaluated with the Yasso model (Liski et al. 2005). The litter production was estimated separately for each tree species and it consisted of litter falling from living trees, cutting residues as well as unrecovered natural losses. On organic soils litter production by ground vegetation was also considered. The litter production was assessed using measured sample tree level data and estimated biomasses of tree compartments. The biomass estimates were calculated with Marklund's models (1988).

The time series for CO₂ changes of different pools on Forest land are given in Table 7.2._1. The removals in tree biomass have increased 24% from 26.3 Tg CO₂ in 1990 to 32.7 Tg CO₂ in 2007. That comes from the increased growth of trees. The CO₂ balance of the trees from 1990 to 2007 is presented in Table 7.2._2. 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. The demand for timber products was low at the beginning of the 1990's for which reason fellings were also at a low level and the CO₂ sink of trees was high (Figure 7.2_1). The fellings since the mid-1990 have been exceptionally high compared with a long-term average. Strong fluctuation in the CO₂ sink in the 1990's is very much affected by these facts. The decreased CO₂ release in 2005 is the result of quiet roundwood markets. The CO₂ balance differs with tree species groups. At the end of 1990's the demand of large size spruce timber increased and this is shown in Figure 7.2_2. Between the years 2006 and 2007, CO₂ removal declined by 22%, which is due to the increased total roundwood removals in 2007 compared with the year 2006. 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% (Metinfo). The removals have been quite steady on organic soils during the time series, whereas on mineral soils the removals fluctuated in the 1990's turning into gain in the 2000's. The only carbon pool being an emission is the soil organic matter in organic soils.

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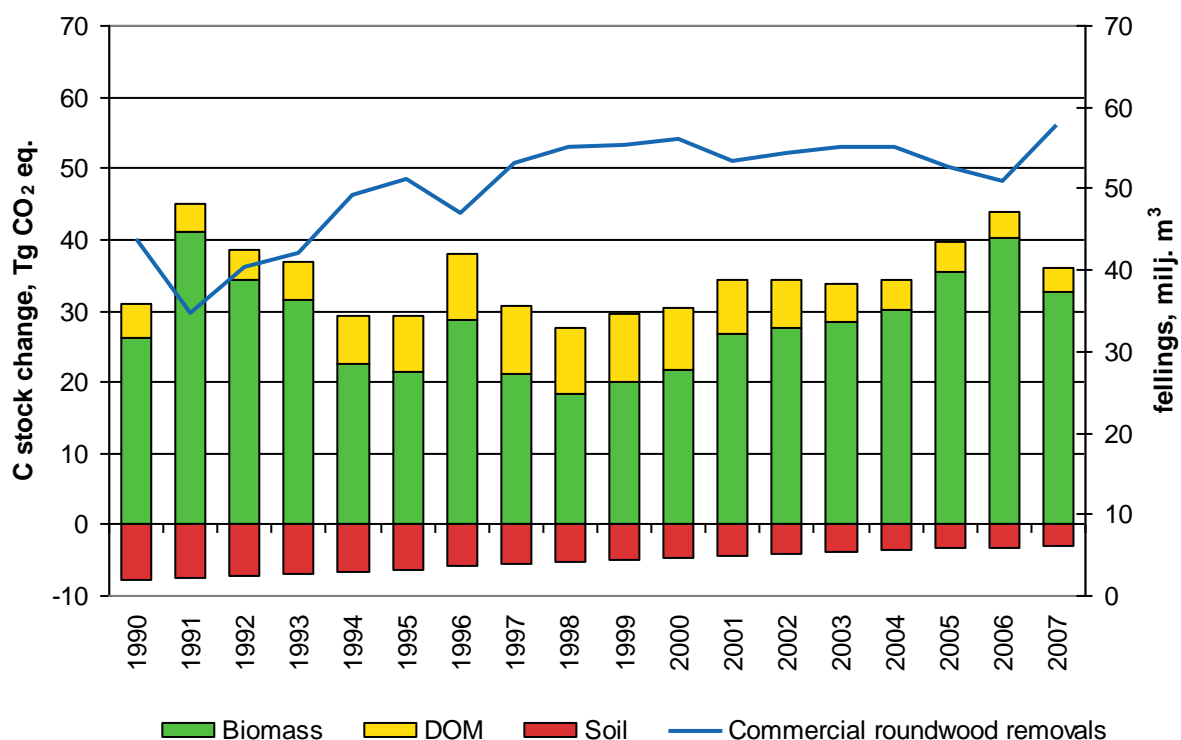


Figure 7.2_1. Commercial roundwood fellings and change in C stock by different forest land C pools in 1990-2007. Note that only commercial roundwood removals are presented in the figure (blue line). The total drain is the decrease in the growing stock due to fellings and unrecovered natural losses. Fellings consist of commercial and other roundwood removals and harvesting losses (see table 7.2_6).

Table 7.2_1. Emissions and removals from Forest land Carbon pools in 1990-2007 (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
<i>Mineral soils</i>																		
Biomass	-14.1	-26.3	-19.9	-17.5	-9.5	-8.3	-14.2	-7.5	-5.0	-6.2	-7.1	-11.5	-12.0	-12.4	-13.8	-18.2	-22.0	-15.3
Dead organic matter	-3.3	-2.9	-3.2	-4.0	-5.3	-6.4	-7.5	-7.6	-7.4	-7.5	-6.9	-6.0	-5.1	-4.0	-3.0	-3.2	-2.8	-2.5
Soil organic matter	-2.4	-2.4	-2.5	-2.6	-2.7	-2.8	-2.9	-3.0	-3.1	-3.3	-3.4	-3.4	-3.5	-3.6	-3.6	-3.6	-3.6	-3.6
<i>Total of mineral soils</i>	-19.8	-31.6	-25.6	-24.1	-17.4	-17.5	-24.6	-18.1	-15.5	-17.0	-17.4	-21.0	-20.6	-20.0	-20.5	-25.0	-28.5	-21.4
<i>Organic soils</i>																		
Biomass	-12.3	-14.8	-14.3	-14.1	-13.2	-13.0	-14.6	-13.6	-13.4	-13.9	-14.5	-15.2	-15.7	-16.0	-16.4	-17.3	-18.2	-17.4
Dead organic matter	-1.2	-1.2	-1.2	-1.3	-1.5	-1.6	-1.8	-1.8	-1.9	-1.9	-1.8	-1.7	-1.5	-1.3	-1.1	-1.0	-0.9	-0.8
Soil organic matter	10.0	9.8	9.6	9.5	9.3	9.0	8.8	8.6	8.4	8.2	8.0	7.8	7.6	7.4	7.2	6.9	6.8	6.7
<i>Total of organic soils</i>	-3.5	-6.1	-5.9	-6.0	-5.4	-5.6	-7.6	-6.9	-6.8	-7.6	-8.3	-9.1	-9.6	-9.9	-10.3	-11.3	-12.2	-11.5
<i>Total forest land</i>	-23.2	-37.7	-31.5	-30.0	-22.8	-23.1	-32.2	-25.0	-22.4	-24.6	-25.7	-30.1	-30.2	-29.8	-30.8	-36.4	-40.7	-32.8

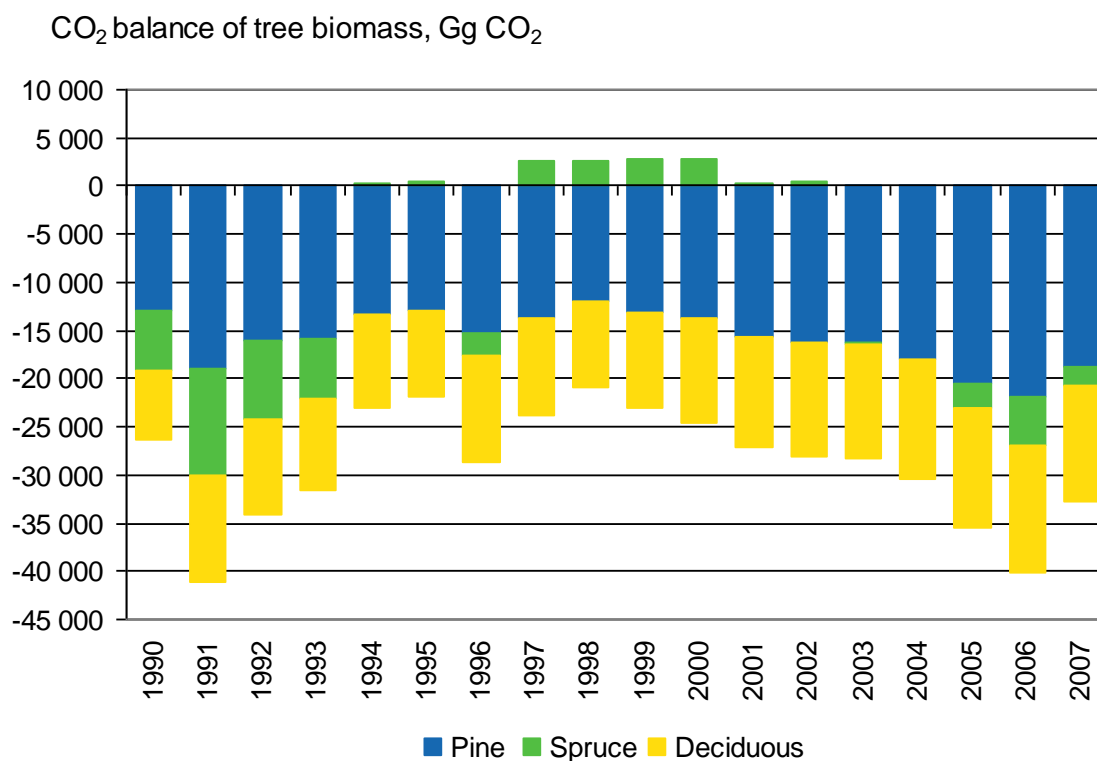


Figure 7.2_2. CO₂ balance of tree biomass by tree species groups in 1990-2007.

7.2.2 Methodological issues

7.2.2.1 Carbon stock changes in living biomass

Methods

The Finnish method applied for calculating the 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).

In the Finnish inventory the carbon uptake/loss figures are calculated from data on stem volume increment and drain (m³) based on the National Forest Inventory of Finland (NFI) and on annual statistics on cutting removals (m³)(Tomppo 2000).

$$CO_2 \text{ emissions/removals} = (\text{carbon uptake by tree growth} - \text{carbon loss due to drain}) * 44/12$$

The volume increment of the growing stock is estimated using measurements on field sample plots of the NFI. The increment figures concern increment of the tree stem volume. An average increment of five years preceding the measurement time is applied.

Tree stem volume increment and drain are converted to whole tree biomass and carbon content using the national conversion factors (Karjalainen and Kellomäki 1996, Table 7.2_3).

Table 7.2_2. Carbon dioxide uptake and release of the growing stock of tree biomass in 1990-2007 (Tg CO₂).

Year	Uptake	Release	Balance
1990	98.5	72.1	26.3
1991	99.7	58.6	41.0
1992	100.9	66.7	34.2
1993	102.1	70.4	31.6
1994	103.2	80.6	22.7
1995	104.5	83.1	21.4
1996	105.7	77.0	28.8
1997	107.1	85.9	21.2
1998	108.8	90.4	18.4
1999	110.6	90.4	20.1
2000	112.8	91.1	21.6
2001	115.0	88.2	26.7
2002	117.1	89.5	27.6
2003	119.2	90.9	28.3
2004	121.3	91.0	30.2
2005	123.3	87.8	35.5
2006	125.3	85.1	40.2
2007	127.3	94.6	32.7

Emission factors and other parameters

The country specific coefficients are used to convert the stem volume to the carbon content of total biomass (Table 7.2_3).

The conversion equation is as follows:

$$cf = ef * dw * cc,$$

where,

cf = conversion factor from stem volume on total biomass C content

ef = expansion factor from stem biomass to total tree biomass

dw = conversion factor of tree stem volume to tree stem dry biomass

cc = C-content

Table 7.2_3. The coefficients by tree species according to Karjalainen and Kellomäki (1996).

Tree species	ef	dw (Mg/m ³)	cc	cf (Mg C /m ³)
pine	1.527	0.390	0.519	0.3091
spruce	1.859	0.385	0.519	0.3715
non-coniferous	1.678	0.490	0.505	0.4152

The conversion factors depend on the site fertility and age structure of forests. However, the same factors have been used for all forests in Finland's national greenhouse gas inventory.

Activity data

Forest land area

Section '7.1 Overview of the sector', describes the way land area is allotted to IPCC land-use categories and which the information sources are. Data source for forest land is the national forest inventory (NFI). In this submission the Forest land area, as well areas of other land-use categories, are recalculated. The same method as in the previous submission was employed. Reason to the recalculation is some bugs detected in

the program applied to area estimation. The total land area bases on the state of the map database in 1 January 2006. The applied total land area of Finland is 30,408,586 ha.

NFI8, NFI9 and NFI10 sample plot data were classified according to the IPCC land-use categories. The area of forest land was estimated for Forestry Centre regions. The Forestry Centre results were dated to the inventory mid-year that refers to the year in which most of the sample plots of a Forestry Centre region were measured. Linear interpolation was used to estimate areas between mid-years. A country level estimate is a sum of regional estimates.

The area of mineral soils and organic soils on Forest land was also estimated as described above. These areas are given in Table 7.2_4.

Table 7.2_4. Areas of mineral soils and organic soils on Forest land in 1990-2007 (1 000 ha).

Year	Mineral soil	Organic soils	Total
1990	16 126	5 645	21 770
1991	16 114	5 714	21 828
1992	16 103	5 784	21 887
1993	16 092	5 853	21 945
1994	16 080	5 923	22 003
1995	16 069	5 992	22 061
1996	16 058	6 062	22 119
1997	16 053	6 128	22 181
1998	16 052	6 191	22 243
1999	16 065	6 248	22 312
2000	16 074	6 300	22 374
2001	16 082	6 339	22 421
2002	16 089	6 356	22 446
2003	16 110	6 328	22 438
2004	16 107	6 231	22 338
2005	16 105	6 134	22 239
2006	16 102	6 037	22 139
2007	16 099	5 940	22 039

Increment of the growing stock

The volume increment of the growing stock was estimated using measurements on field sample plots of the NFI. For this submission, the data come from the NFI8, NFI9 and NFI10. NFI10 comprise data measured in 2004-2007. The increment figures concern increment of the tree stem volume. An average increment of five years preceding the measurement time is applied (see Appendix_7a).

At first the increment estimates by tree species for NFI8, NFI9 and NFI10 by Forestry Centre regions were produced and set in the inventory mid-years. In the second phase the increments between inventory mid-years were interpolated linearly. The increment estimate for the whole country was a sum of increments of Forestry Centre regions. Due to the applied method, the time series for the years 1996-2006 is changed compared with the previous submission. In the 2008 submission, the growth estimates based on the measurements from the years 2004-2006, whereas for the 2009 submission the data measured in the years 2004-2007 were used.

The increment was sub-divided into the increments of tree species on mineral soils and organic soils (Table 7.2_5). Increment figures have been estimated for the entire combined national forest land and low productive forest land while the area estimates are given for FAO forest land (Table 7.1_2). FAO forest land is a subset of the previous one but in practice includes the entire increment of the growing stock. The

increment is estimated for only trees with a height of at least 1.3 m (DBH of 0 cm). This means that the increment of the trees shorter than 1.3 m is omitted.

Table 7.2_5. Increment of the growing stock in 1990-2007 (million m³/yr).

	Mineral soils			Organic soils			Total
	pine	spruce	decid.	pine	spruce	decid.	
1990	24.6	22.9	11.2	7.9	3.9	5.4	75.8
1991	25.0	22.8	11.5	8.1	4.0	5.4	76.7
1992	25.4	22.7	11.7	8.3	4.1	5.5	77.7
1993	25.8	22.6	12.0	8.5	4.2	5.5	78.6
1994	26.2	22.5	12.3	8.7	4.3	5.6	79.6
1995	26.6	22.4	12.6	8.9	4.4	5.6	80.5
1996	27.0	22.4	12.8	9.1	4.5	5.7	81.5
1997	27.5	22.3	13.1	9.3	4.6	5.7	82.6
1998	28.1	22.2	13.4	9.6	4.8	5.8	83.9
1999	28.8	22.2	13.8	9.8	4.9	5.9	85.4
2000	29.5	22.3	14.2	10.1	5.0	6.0	87.0
2001	30.3	22.4	14.6	10.4	5.1	6.1	88.8
2002	31.0	22.6	14.9	10.6	5.2	6.2	90.5
2003	31.8	22.8	15.2	10.9	5.3	6.2	92.2
2004	32.6	23.0	15.4	11.2	5.4	6.2	93.8
2005	33.5	23.1	15.6	11.5	5.5	6.3	95.5
2006	34.3	23.3	15.8	11.7	5.6	6.3	97.1
2007	35.2	23.5	16.1	12.0	5.7	6.3	98.8

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 Metsähallitus (a state-run enterprise). Since 2000 commercial removals have been 50-58 million m³ annually (Finnish Statistical Yearbook of Forestry 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). They vary from 4% to 10% for pine, from 5% to 12% for spruce and from 10% to 31% for broadleaves. In recent years, annual harvesting losses have been about 6 million m³ and fellings in total 65-69 million m³/yr 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/yr. Recently, the total drain has been 65-73 million m³/yr.

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 1990-2006. The growing stock drain is published in the Finnish Statistical Yearbook of Forestry (2007). 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 Statistical... 2007), 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_6).

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.

Table 7.2_6. The drain in 1990-2007 (million m³/yr).

Year	Mineral soils			Organic soils			Total
	pine	spruce	decid.	pine	spruce	decid.	
1990	18.7	19.6	9.2	2.3	2.7	2.6	55.1
1991	14.6	16.5	7.6	1.7	2.3	2.0	44.6
1992	17.6	18.3	8.4	1.9	2.5	2.2	51.0
1993	18.2	19.6	8.8	2.1	2.7	2.4	53.8
1994	20.6	23.8	9.1	2.4	3.3	2.5	61.7
1995	21.4	23.9	9.7	2.6	3.3	2.7	63.6
1996	20.3	22.1	8.8	2.4	3.0	2.4	59.0
1997	22.0	25.4	9.6	2.7	3.5	2.6	65.8
1998	24.1	25.3	10.4	3.1	3.5	2.9	69.4
1999	23.9	25.5	10.3	3.1	3.6	3.0	69.4
2000	24.3	25.8	10.2	3.1	3.6	2.9	70.0
2001	23.7	24.3	10.2	3.1	3.4	3.0	67.7
2002	24.2	24.7	10.3	3.2	3.4	3.0	68.7
2003	25.1	24.5	10.5	3.2	3.4	3.1	69.9
2004	24.8	24.9	10.4	3.2	3.5	3.1	69.9
2005	23.7	23.5	10.6	3.1	3.3	3.1	67.3
2006	23.8	22.1	10.4	3.1	3.1	3.0	65.4
2007	27.2	24.3	11.2	3.5	3.4	3.3	72.9

7.2.2.2 Carbon stock changes in soil, litter and dead wood

Methods

Mineral soils

The carbon stock changes of litter, dead wood and soil organic matter (SOM) were driven by tree litter production and were estimated with the Yasso model (Liski et al. 2005, Liski et al. 2006), which has been developed for general forestry applications concerning decomposition of forest litter (Fig 7.2_3). Mathematical formulations of the processes are described in Appendix_7b. The Yasso simulations were made separately for South and North Finland.

Since model application was used in estimating carbon stock changes in all soil pools, those pools were also defined congruent with used model as follows:

- *Soil organic matter* included organic carbon in soils. The examined soil depth was not defined, instead the SOM stock was assumed to be described with the model compartments humus 1 and humus 2.
- *Litter* included all non-living biomass with a diameter less than 10 cm in various states of decomposition. Again, the examined soil layers were not defined, and the litter stock was assumed to be described with the model compartments fine woody litter, coarse woody litter, extractives, celluloses and lignin-like compound.
- *Dead wood* included the rest of the non-living biomass not contained in the litter. The inventory of dead wood was made with separate simulation with only coarse woody litter input (larger than 10 cm in diameter) coming from natural mortality of trees and harvesting residues.

Before the Yasso simulation three steps of preliminary preparations had to be done:

- calculation of input data and division into three different decomposition compartments (non-woody litter, fine woody litter and coarse woody litter), separately for each tree species
- estimation of the parameters to each decomposition compartment with the environmental condition concerned (southern and northern parts of Finland)
- estimation of the initial values of model state variables.

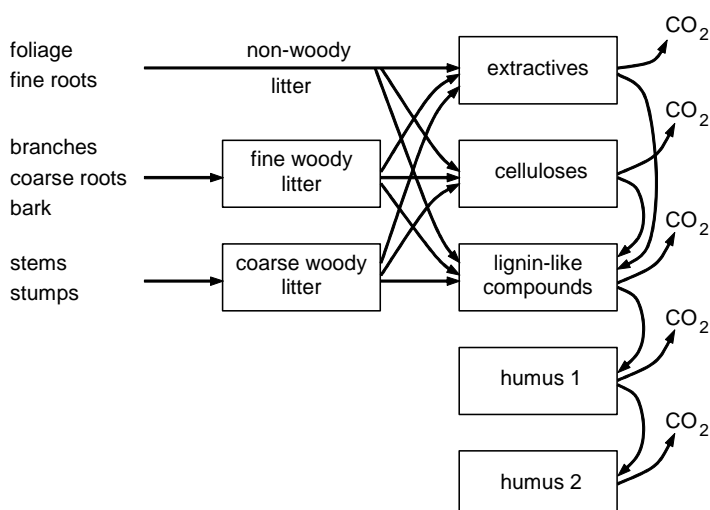


Figure 7.2_3. Flow chart of the Yasso model.

Input data for the model consisted of annual litter production from living tree biomass, unrecovered natural losses and harvesting residues. Litter production from living trees was estimated using biomass compartments of living trees and litter production rate coefficients, biomass compartments being calculated from NFI tree level data with Marklund's models (1988). Unrecovered natural losses were estimated from permanent NFI plots and converted to biomass compartments with Lehtonen et al. (2004a) biomass

expansion factors (BEFs). Harvesting residues were assessed from cutting removals and harvesting losses, both converted from volumes to biomass compartments with Lehtonen et al. (2004a) BEFs. Part of the harvesting residues is utilised in industrial energy consumption and this reduction was taken into account in litter input (Finnish Statistical Yearbook of Forestry 2007). In mineral soils the litter production from ground vegetation was ignored.

Model parameterisation included assessment of the decomposing properties of different biomass compartments and also the temperature effect on decomposition rate. The initial state of the model was estimated with a 100-year initiating period, with reasonable and smoothly increasing litter input. Stock changes in forest soil carbon were reported as 5 years' moving averages.

Organic soils

Description of decomposition of peat is significant part of estimation of carbon stock changes in the managed organic soils (peatlands) in Finland, and these below ground change estimates were made using emission coefficients. Above ground changes in organic soils were estimated with the Yasso model similarly as in the mineral soils. Overall, carbon stock changes in organic soils (litter, dead wood and SOM) were assessed only in drained peatlands, while these carbon stocks in undrained peatlands were assumed to be unchanged. 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.

Stock changes in below ground SOM in drained peatlands were estimated as the difference between annual below ground litter inputs and annual decomposition emissions of SOM (heterotrophic soil respiration):

Change in below ground SOM = below ground litter input – emission from soil.

Litter inputs to below ground SOM consisted of annual litter production from roots of trees, shrubs and graminoids and roots of trees subjected to cuttings or natural losses. The decomposition of below ground SOM was estimated by multiplying the site-type-specific emission values (Minkinen et al., 2007) by the corresponding area estimates provided by the NFI. Similarly as in mineral soils, tree litter production from trees was produced from biomass compartment data concerning drained peatlands. Annual litter production from ground vegetation was estimated according to Laiho et al. (2003)

Emission factors and other parameters

The litter production from each tree biomass compartment was calculated using litter production rate coefficients (Table 7.2_7) as follows

$$litter_i = r_i * W_i,$$

where r_i is the litter production rate of compartment i and W_i is biomass of compartment i (kg). The litter production from ground vegetation in the organic soils was estimated according to Laiho et al. (2003, Table 7.2_8). In mineral soils litter production from ground vegetation was not assessed due to the uncertainties related to the estimation of ground vegetation biomass and it changes between sequential years.

Table 7.2_7. Litter production rates from biomass compartments of trees (Liski et al. 2006, Starr et al. 2005, Lehtonen et al. 2004b, Muukkonen et al. 2004). 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

Tree species	Needles	Branches	Bark of stems	Bark of stumps	Roots >2mm	Fine roots
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_8. Litter production of ground vegetation in drained organic soils (peatlands) ($\text{g C m}^{-2} \text{a}^{-1}$) (Laiho et al. 2003).

Species group	Above ground	Below ground
Shrubs	5.0	56.8
Herbs and grasses	13.1	53.7
Mosses	101.2	

The decomposition of below ground SOM in drained organic soils was estimated by multiplying the site-type-specific emission values (Minkkinen et al., 2007, Table 7.2_9) by the corresponding area estimates provided by the NFI (Table 7.2_10).

Table 7.2_9. Carbon emissions ($\text{g C m}^{-2} \text{a}^{-1}$) due to heterotrophic soil respiration from drained organic soils (peatlands) (Minkkinen et al., 2007). For 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

Parameterisation of the Yasso model used in the inventory was based on the studies of Liski et al. (2005, 2006) and Peltoniemi et al. (2004) (Table 7.2_10). Different decomposition rates due to temperature differences were accounted for by simulating south and north Finland separately. 50 years' average temperature was used in the parameterisation. The initial state of the model was estimated with a 100-year initiating period starting from 1823 with the assumption of having then a 5% smaller growing tree biomass stock than observed in 1923. Straightforwardly litter production from living trees and natural losses were also assumed to be 5% smaller in 1823. Harvesting intensity in 1823 was assumed to be half of the level observed in 1923. At the beginning of the initiating period the model was in equilibrium state. The increase in the growing stock and harvesting intensity was assumed to be constant in the initiating period. From the year 1923 onwards the model was run with litter input estimated on the basis of activity data.

Table 7.2_10. Parameters used in the Yasso model simulations (Liski et al. 2005, Liski et al. 2006, Peltoniemi et al. 2004).

Parameter	Pine	Spruce	Deciduous
a fwl	0.5385	0.5385	0.54
a cwl	0.077	0.077	0.077
k ext	0.48	0.48	0.82
k cel	0.3	0.3	0.3
k lig	0.22	0.22	0.22
k hum1	0.012	0.012	0.012
k hum2	0.0012	0.0012	0.0012
c nwl-ext	0.27	0.06	0.38
c nwl-cel	0.51	0.54	0.36
c nwl-lig	0.22	0.4	0.26

Parameter	Pine	Spruce	Deciduous
c fwl-ext	0.03	0.03	0.03
c fwl-cel	0.66	0.61	0.65
c fwl-lig	0.31	0.36	0.32
c cwl-ext	0.03	0.01	0.01
c cwl-cel	0.69	0.69	0.77
c cwl-lig	0.28	0.3	0.22
s hum1	0.6	0.6	0.6
s hum2	0.6	0.6	0.6
p ext	0.2	0.2	0.2
p cel	0.2	0.2	0.2
p lig	0.2	0.2	0.2
p hum1	0.2	0.2	0.2

Activity data

Biomass data for each tree compartment (except fine roots) were produced using measured sample tree level data on the NFI field plots (NFI8, NFI9 and NFI10). Compartment level biomass models of Marklund (1988) were applied for measured time points, and for the years between the measurements linear interpolation was used. The function for estimation of deciduous leaf biomass $W_{d,lf}$ (kg) was fitted according studies of Parviainen (1999) and Ilomäki et al. (2003), being formulated as follows

$$W_{d,lf} = 1.6324 * d_{bh}^{-0.5954} * W_{d,br},$$

where d_{bh} is diameter at breast height (cm) and $W_{d,br}$ is branch biomass of deciduous trees (kg).

Tree biomass for the years 1990-2006 were re-estimated by reason of bugs found in the programme used to the biomass estimation, and the new data added in the end of the time series.

Fine root biomass was estimated using coefficients that describe the relation between root and leaf biomass (Helmisaari, 2007). Biomass data with the details mentioned above were produced separately for mineral and organic soils.

Unrecovered natural losses were assessed from NFI measurements (see Section 7.2.2). The data consisted of stem volumes, which were converted to biomass with BEFs presented by Lehtonen et al. (2004a). Harvesting residues (tree compartments left in forest in cuttings) were calculated from cutting removals, including also estimates of domestic use of firewood, and harvesting losses (Finnish Statistical... 2007, see Section 7.2.2). The biomasses of the harvesting residues were produced from volume data with Lehtonen et al. (2004a) BEFs. Industrial energy consumption of harvesting residues was taken into consideration as a reduction in litter input for the years 2000-2006 (Finnish Statistical Yearbook of Forestry 2007). Both unrecovered natural losses and harvesting residues data were produced separately for mineral and organic soils.

Area of drained peatlands was estimated basing on NFI data (NFI8, NFI9 and NFI10) (Table 7.2_11).

Table 7.2_11. Areas of drained organic soils (peatlands) by site type (1 000 ha).

Year	Herb-rich type (Rhtkg)	Vaccinium myrtillus type (Mtkg)	Vaccinium vitis-idaea type (Ptkg)	Dwarf shrub type (Vatkg)	Cladina type (Jätkg)
1990	696	1 141	1 428	832	10
1991	698	1 154	1 460	837	13
1992	699	1 167	1 493	842	16
1993	701	1 180	1 526	847	19
1994	702	1 193	1 558	851	22
1995	704	1 205	1 591	856	26
1996	706	1 218	1 624	861	29

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)
1997	711	1 236	1 649	859	31
1998	717	1 252	1 670	857	35
1999	723	1 266	1 689	854	38
2000	729	1 275	1 709	851	40
2001	731	1 276	1 729	850	41
2002	733	1 270	1 738	854	42
2003	729	1 254	1 731	864	42
2005	736	1 219	1 721	879	41
2006	744	1 185	1 711	893	40
2007	752	1 150	1 700	908	39

7.2.3 Uncertainty and time series' consistency

7.2.3.1 Uncertainty for Carbon stock changes in living biomass

Quantitative estimates of uncertainty are provided in Annex 5. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

This section explains the preliminary assessment of uncertainty for the CO₂ sink which is due to carbon stock changes in living biomass. The analysis of uncertainty will be revised after completion of an ongoing research project at the Finnish Forest Research Institute.

The assessment takes place in three phases:

1. Estimate carbon uptake and its variance.
2. Estimate carbon release and its variance.
3. Use the estimates from steps 1 and 2 to calculate an estimate for net carbon uptake and its variance.

A numerical illustration of the method is given in Table 7.2_12 and described below.

First (Step 1.1 in Table 7.2_12), age class specific biomass expansion factors (BEFs) developed by Lehtonen et al. (2004a), and stem volume estimates from the NFI, are used to calculate increments in the dry biomass. Note that the BEFs used here are not the ones which were used in the actual calculations for living biomass; the newer BEFs by Lehtonen et al. (2004a) are used here because their uncertainties are given by the authors. For conversion coefficients applied in the calculations, Karjalainen and Kellomäki (1996) did not give any uncertainty estimates. The calculation yields age class specific mass increments (*INC*) and their variances for forests where Pine, Spruce and deciduous trees dominate. The approximate mean and variance of the dry biomass increment – *DW* and *V*[*DW*], respectively – are obtained using the analytic method for transformation of random variables (see, for instance, Bernardo & Smith, 1994) and the assumption that the off-diagonal elements of the covariance matrix are zero. This method and the assumption of independence are used throughout this assessment. It follows from the functional form of *DW* and the assumption that the mean of *DW* is simply the product of the *BEF* and the *INC* for each age class *i* and dominant species *j*. The variance is given by

$$V[DW_{ij}] \approx BEF_{ij}^2 V[INC_{ij}] + INC_{ij}^2 V[BEF_{ij}]. \quad (1)$$

The sum of these variances over age classes

$$V[DW_j] = \sum_{i=1}^{12} V[DW_{ij}] \quad (2)$$

gives the variance of the dry biomass increment for each dominant species.

This result is then used in Step 1.2, where conversion from dry biomass increment to carbon uptake is done by multiplying DW_j with species-specific carbon contents. The variances of carbon uptake for each dominant species are obtained similarly as the variances calculated above using equation (1). And the variance of the sum over dominant species is obtained analogously to Equation (2).

The simple sum of variances is also used in Step 2.1 where the variance of the drain estimate is calculated.

In Step 2.2, the drain is converted to carbon release using average BEFs and CCs from Steps 1.1 and 1.2. The estimate of the mean of the drain is simply the product of the three variables ($DRAIN$, BEF and CC). $DRAIN$ and $V[DRAIN]$ obtained from Step 2.1. The average BEF for the three dominant species is obtained by dividing the DW calculated in Step 1.2 by the sum of the stem volume increments calculated in Step 1.1. The variance of the average BEF is given by

$$V[BEF] \approx \frac{1}{INC^2} V[DW] + \frac{DW^2}{INC^4} V[INC]. \quad (3)$$

The average carbon content CC is obtained by dividing the carbon uptake calculated in Step 1.2 by DW calculated in that same step. $V[CC]$ is calculated similarly, with the necessary changes, as $V[BEF]$ in equation (3). The variance of the carbon release is then given by

$$V[C_{release}] \approx DRAIN^2 BEF^2 V[CC] + BEF^2 CC^2 V[DRAIN] + CC^2 DRAIN^2 V[BEF]. \quad (4)$$

In Step 3, the intermediary results from Steps 1 and 2 are combined. Net carbon uptake is obtained as a difference of carbon uptake and release. The variance of the difference is simply the sum of the variances $V[C_{uptake}]$ and $V[C_{release}]$.

Finally, Step 4 summarises the results.

This method produced following relative standard errors and corresponding standard errors (Gg, C) for C gains and losses in 1990 and in 2007.

	RSE	SE	
		1990	2007
C-gain	3.6%	964	1 246
C-loss	4.0%	781	1 024
Net C-uptake	21.7%	1 558	1 932

Table 7.2_12 Calculation explaining the uncertainty estimate for the net carbon sink due to tree growth and fellings in 2007.

Step 1. Estimate C-uptake and its variance.

Step 1.1. Start with the age class specific biomass expansion factors (Lehtonen 2004a et al.) and stem volume increment estimates from the NFI.

Age-class	Pine								Spruce								Deciduous			
	BEF	V[BEF]	INC	V[INC]	DW	V[DW]	BEF	V[BEF]	INC	V[INC]	DW	V[DW]	BEF	V[BEF]	INC	V[INC]	DW	V[DW]		
	Mg/m ³	(Mg/m ³) ²	1000 m ³	(1000 m ³) ²	Gg	(Gg) ²	Mg/m ³	(Mg/m ³) ²	1000 m ³	(1000 m ³) ²	Gg	(Gg) ²	Mg/m ³	(Mg/m ³) ²	1000 m ³	(1000 m ³) ²	Gg	(Gg) ²		
1-19	0.697	0.0038	2 778	4 348	1 936	31 272	0.862	0.0338	1 635	2 611	1 409	92 350	0.544	0.0030	1 245	2 376	677	5 421		
20-29	0.705	0.0010	8 293	20 663	5 847	82 289	0.860	0.0072	1 670	2 818	1 436	22 308	0.551	0.0017	1 675	2 982	923	5 760		
30-39	0.710	0.0008	8 870	20 989	6 298	70 906	0.841	0.0033	2 756	5 335	2 318	28 545	0.554	0.0009	1 662	3 441	921	3 482		
40-49	0.702	0.0012	7 366	16 006	5 171	73 661	0.820	0.0009	2 995	6 731	2 456	12 561	0.556	0.0005	1 855	3 189	1 031	2 587		
50-59	0.701	0.0008	5 972	11 205	4 187	35 547	0.816	0.0008	2 810	5 044	2 293	9 835	0.552	0.0006	1 327	2 174	733	1 799		
60-69	0.710	0.0008	4 778	8 489	3 393	21 518	0.791	0.0006	3 342	5 088	2 644	10 206	0.554	0.0010	1 042	2 244	577	1 795		
70-79	0.708	0.0006	4 525	8 503	3 204	17 126	0.784	0.0005	3 002	4 359	2 354	7 371	0.545	0.0005	594	1 162	323	537		
80-89	0.707	0.0008	3 871	6 806	2 737	15 265	0.777	0.0005	2 502	4 085	1 944	5 732	0.545	0.0005	372	698	203	283		
90-99	0.704	0.0008	2 744	4 075	1 931	8 169	0.782	0.0007	1 748	2 372	1 367	3 573	0.544	0.0008	256	584	139	227		
100-119	0.703	0.0005	3 144	4 697	2 210	7 170	0.784	0.0005	2 101	3 196	1 647	3 986	0.544	0.0008	190	423	104	155		
120-139	0.698	0.0008	1 580	1 687	1 103	2 937	0.782	0.0013	881	1 105	689	1 672	0.544	0.0008	45	180	24	55		
140-	0.690	0.0008	2 247	6 460	1 550	7 216	0.788	0.0007	1 457	4 966	1 148	4 616	0.544	0.0008	11	9	6	3		
			56 168	113 928	39 567	373 076			26 899	47 710	21 705	202 755			10 274	19 462	5 661	22 104		

Step 1.2. Use the estimates calculated for different species in Step 1.1 and the estimates for carbon content (Karjalainen & Kellomäki 1996) and its variance (assumed RSE = 5%), to get estimates for C-uptake and its variance.

Dominant species	INC	V[INC]	DW	V[DW]	CC	V[CC]	C-uptake	V[C-uptake]
	1 000 m ³	(1 000 m ³) ²	Gg	(Gg) ²				
Pine	56 168	113 928	39 567	373 076	0.519	0.00067	20 535	1 149 409
Spruce	26 899	47 710	21 705	202 755	0.519	0.00067	11 265	370 256
Deciduous	10 274	19 462	5 661	22 104	0.505	0.00064	2 859	26 147
Total	93 341	181 100	66 933	597 935			34 659	1 545 812

Table 7.2_12 continues

Table 7.2_12 continues

Step 2. Estimate C-release and its variance.

Step 2.1. Start with the drain estimates and their variance (Finnish Statistical Yearbook of Forestry 2008 and Sevola 2005).

Drain component	1 000 m ³	V(1 000 m ³) ²
Commercial fellings	57 742	0.334
Contract sawing	961	0.003
Firewood	5 151	0.066
Harvesting losses	6 318	0.400
Natural mortality	2 760	0.076
Total	72 932	0.879

Step 2.2. Convert drain to biomass and then to C-release using average BEF and CC from Steps 1.1 and 1.2.

Drain 1 000 m ³	V(drain) (1 000 m ³) ²	BEF Mg/m ³	V[BEF] (mg/m ³) ²	CC	V[CC]	C-release Gg	V[C-release] (Gg) ²
72 932	0.879	0.717	0.00008	0.518	0.00038	27 081	1 154 736

Step 3. Estimate net C-uptake and its variance using intermediate results from Steps 1 and 2.

C-uptake Gg	V[C-uptake] (Gg) ²	C-release Gg	V[C-release] (Gg) ²	net C-uptake Gg	V[net C-uptake] (Gg) ²
34 659	1 545 812	27 081	1 154 736	7 578	2 700 548

Step 4. Conclusions.

Step 1, 2 and 3 yield the following relative standard errors:

for carbon uptake by increment in living tree biomass (C-uptake)	3.6%
for carbon release caused by decrease in tree biomass (C-release)	4.0%
for net carbon stock change in living tree biomass (net C-uptake)	21.7%

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 few years' 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. Here a long initiating period before actual simulations was used and lower deviation thus assumed for simulated results. 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 2006.

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_9), was added to the total variance estimate yielding 78% relative standard error for carbon stock change in organic soils in year 2006. The rate of decomposition of moss litter, being formed partly from the Sphagnum species and partly from other moss species, is not known well enough and the parameters applied in the Yasso model may result in overestimated rates of decomposition.

7.2.3.3 Time series' consistency

Areas of land-use categories and growing stock increment estimates are based on NFI assessments. The definitions of national land classes (see Appendix_7a) and tree measurement techniques have remained the same in different inventories. However, there is some uncertainty in the Forest land area time series. After two years' measurements in the NFI9, the FAO definition for forest was added as a variable assessed in field. For those field plots for which field assessment was not available, it was determined by rules based on the NFI9 field assessment and measurements. This means that some land areas might have been misclassified. Any research on how reliable the results are, has not been done yet.

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.

Quality control procedures named in IPCC Good Practice Guidance for LULUCF (IPCC, 2003) Table 5.5.1 were done for all calculations. Calculations concerning Forest Land were compared with similar calculations made for Finnish National Forest Program 2015, in which greenhouse gas emissions/removals were estimated in nationally defined forest (productive forest land and poorly productive forest land).

National Forest Inventory data have gone through the following QC measures:

1. Field gauges and instruments were checked and calibrated.
2. New instruments were tested to find possible differences in measurement results compared with the old ones.
3. Before field surveying, field personnel has had a training period to ascertain
 - that measurers are able to use the equipment correctly
 - that measurers do measurements and classifications correctly
 - that the guidelines and instructions are understood correctly.
4. Verification measurements were carried out during field seasons.

5. From field data it was checked

- that all sample plots are measured
- that no required information is missing
- to find errors (if found, they were corrected)
- the compatibility with different data variables
- the compatibility with sample plot, tally tree and sample tree data.

6. Calculated results were compared with the results of previous inventories. If big or unexpected changes were found, reasons for them were clarified and explained.

The NFI team applies a quality manual and QA/QC measures to all work stages. Documentation is in Finnish, but brief descriptions of NFI methods and measurements are available on the Internet www.metla.fi/ohjelma/vmi/info-en.htm.

The data based on forest statistics were produced by the Finnish Forest Research Institute, Forest Information Service. Data descriptions are available (at the moment in Finnish) including the applied definitions, methods of data compilation, reliability and comparability.

It was confirmed that all data used in this section cover whole land area of Finland.

7.2.5 Source-specific recalculations

The reasons for recalculations were

- New forest inventory data was available for years 2004-2007, so the time series was recalculated
- Bugs were found in the programs used for area and biomass estimation.

The former Forest land area, new estimated area and the difference between them are given in Table 7.2_13. All changes have an effect on the results, but the effect of each has not evaluated separately.

Table 7.2_13. The difference in forest land area between 2008 and 2009 submissions (1 000 ha).

Year	Forest land area		
	2008 submission	2009 submission	Difference 2009-2008
1990	21 762	21 770	8
1991	21 819	21 828	9
1992	21 876	21 887	11
1993	21 934	21 945	11
1994	21 991	22 003	12
1995	22 048	22 061	13
1996	22 106	22 119	13
1997	22 167	22 181	14
1998	22 229	22 243	14
1999	22 300	22 312	12
2000	22 367	22 374	7
2001	22 419	22 421	2
2002	22 449	22 446	-3
2003	22 440	22 438	-2
2004	22 342	22 338	-4
2005	22 244	22 239	-5
2006	22 146	22 139	-7

Time series for the increment of growing stock were recalculated. In this submission, NFI10 data from the years 2004-2007 were used. New estimates for Forestry Centre regions were estimated and added in the end of the time series. This procedure affected in the results from the year 1997 onward (Table 7.2_14).

Table 7.2_14. The difference in CO₂-uptake in tree biomass between the 2008 and 2009 submissions (Gg CO₂).

Year	2008 submission	2009 submission	Difference 2009-2008
1990	98 490	98 490	0
1991	99 679	99 679	0
1992	100 869	100 869	0
1993	102 059	102 059	0
1994	103 248	103 248	0
1995	104 493	104 493	0
1996	105 738	105 738	0
1997	107 224	107 115	-109
1998	109 043	108 776	-267
1999	111 063	110 587	-476
2000	113 617	112 757	-860
2001	116 328	114 977	-1 351
2002	119 003	117 116	-1 887
2003	121 650	119 247	-2 403
2004	124 096	121 263	-2 833
2005	126 542	123 279	-3 262
2006	127 039	125 296	-1 743

Time series for carbon stock changes in soil, litter and dead wood were recalculated due the changes in Forest land area, growing stock volumes and tree biomass. The CO₂ emissions from drained organic forest land soils was recalculated since the Forest land area changed and as the area of organic soils.

7.2.6 Source-specific planned improvements

For the 2010 submission Finland will improve the area estimation and estimation of carbon stock changes from forests. Finnish Forest Research Institute has an ongoing project which objectives are

- To produce a method to estimate areas for all land-use changes and carbon stock changes on these land areas. The method will produce area estimates for areas remaining in same use and for converted areas for the UNFCCC reporting as well as a method for reporting under the Kyoto Protocol.
- To enhance the estimation of carbon stock changes in living tree biomass applying the country specific biomass models.
- To improve the uncertainty estimation on carbon stock changes in living tree biomass.

Finland aims for to employ the FAO definition for forest. This resolve is not fully in use, since also older NFI data from the 1980's are needed to estimate time series for Forest land area and carbon stock changes. The main difficulty is the minimum area for forest, which has been 0.25 ha in South Finland in the previous NFIs compared with the FAO's 0.5 ha. One of the above mentioned projects is to solve this problem and produce consistent time series.

At the moment Finland defines organic soils in Forest land according to the NFI definition for peatlands. This definition will be reviewed and consolidated with the definition for organic soils used in the Agriculture sector.

7.3 Cropland (CRF 5.B)

7.3.1 Source category description

Under the Cropland category carbon stock changes in soils and living biomass are reported. In addition emissions from liming are reported under this category. The total net emissions from croplands in 2007 were 3.3 Tg and in 1990 7.4 Tg. The sink of mineral agricultural soils was 1.5 Tg which is 6% of the total sink (excluding emissions) of the LULUCF sector in 2007. The emissions from cultivated organic soils were 4.6 Tg. For the first time carbon stock change in woody living biomass on cropland was estimated. The sink from woody biomass on cropland is very small, 2.8 Gg CO₂ in 2007.

The area of cropland comprises of the area under cereals, grass (≤ 5 years), other arable crops, set-aside and permanent horticultural crops. Greenhouses and kitchen gardens are also classified as Croplands although emissions from them are not reported. The CO₂ emissions from cultivation of mineral and organic soils and agricultural lime application are reported under the category CO₂ emissions from cropland remaining cropland. Only emissions from cropland remaining cropland have been calculated since no reliable estimates for areas converted to cropland are available.

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 a decreasing source. Emissions from liming have decreased slightly as the usage of lime has declined (Figure 7.3_1).

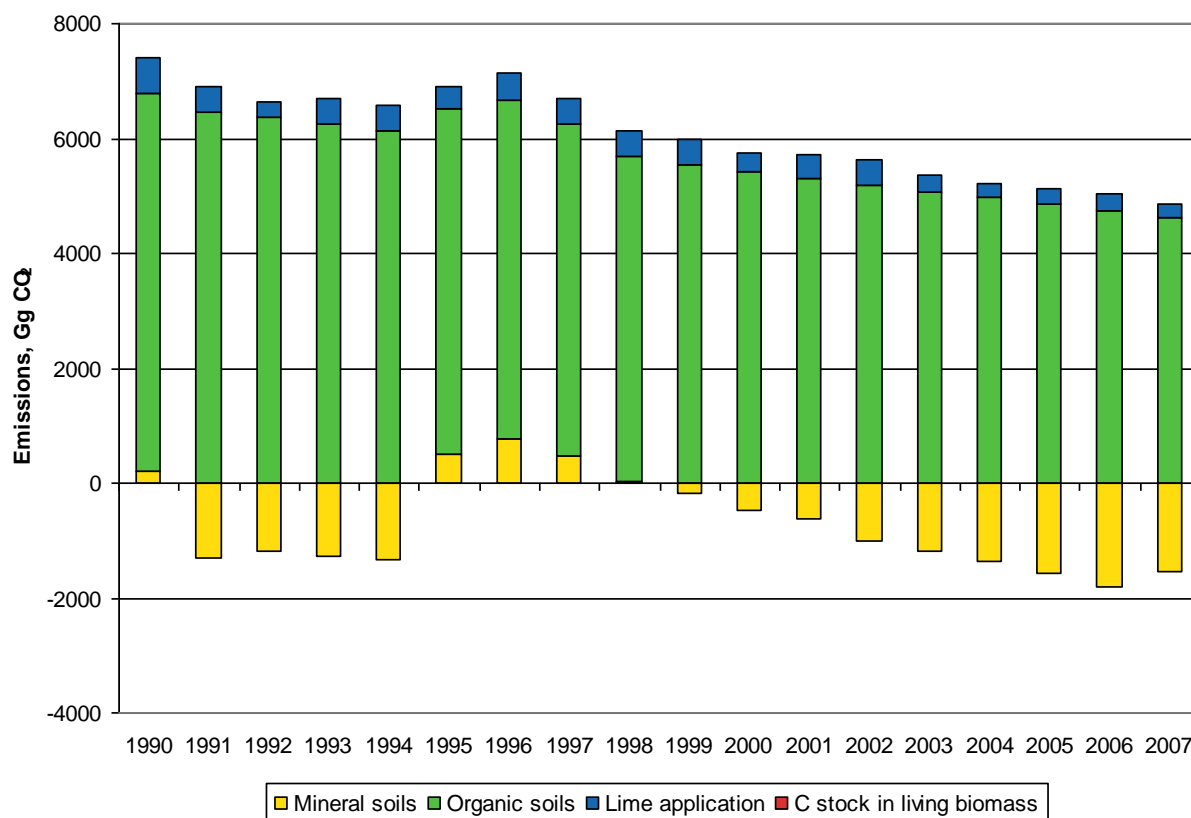


Figure 7.3_1. Emissions and removals in cropland 1990-2007, Gg CO₂.

7.3.2 Methodological issues

7.3.2.1 Carbon stock changes in living biomass

Methods

The annual carbon stock changes of living biomass of the most important perennial woody crops on cropland have been included in the inventory for the first time. The biomass of apple trees and currants was 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 as thinnings and removals of old plants. The emissions were allocated to cropland remaining cropland.

$$\Delta CC_{LB} = \sum_i (C_{ai} - C_{di})$$

$$B_{hi} = d_i * w_i * Frac_{Dm} * Frac_C$$

$$G_i = B_{hi} / H_{ci}$$

$$C_{ai} = A_i * G_i$$

$$C_{di} = A_{ci} * B_{hi}$$

Where,

i denotes the plant species (currants, dwarfish apple trees, vigorously growing apple trees)

ΔCC_{LB} = Annual change in carbon stocks in living biomass, tonnes C/yr

C_{ai} = Carbon accumulation in a year

C_{di} = Carbon decline in a year

B_{hi} = Aboveground biomass carbon stock at harvest, tonnes C/yr

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/yr

H_{ci} = Harvest cycle, yr

A_i = Area of growing plants

A_{ci} = Size of cleared area (plants removed)

Emission factors

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: Tahvonon, 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 expert judgment

(Tahvonen 2008) which has been interpolated for years 1998-2006. The dwarfish trees have started to come to the market after the year 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 (yr)	Biomass accumulation rate (tn C/ha/yr)	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

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 1990-2007, 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	452	0	1 772
1998	441	23	1 793
1999	431	48	1 867
2000	430	76	1 976
2001	425	106	2 259
2002	420	140	2 373
2003	417	179	2 451
2004	403	217	2 485
2005	388	258	2 443
2006	349	286	2 342
2007	325	325	2 264

7.3.2.2 Carbon stock changes in soil

Mineral soils

Methods and emission factors

Calculation of CO₂ emissions from mineral soils is based on changes in the carbon stocks resulting from changes in areas, land-use and management activities over a period of 20 years (IPCC 2003). Currently the method used is close to a Tier 1 method. No other national data has been used than national values for reference carbon stocks. National 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 high variation between the years results from the lack of a proper estimate for the cropland remaining cropland. In the current calculation method the area of cropland remaining cropland in

the inventory year and 20 years prior to the inventory year are different and that results to unrealistic changes in carbon stocks.

Reference carbon stocks are based on soil analysis data from a soil survey (Mäkelä-Kurtto and Sippola 2002) made by MTT Agrifood Research Finland. On the basis of this survey consisting of 720 soil samples that represent well the agricultural soils of Finland, the mean carbon stock of high activity soils was 59.1 t ha⁻¹ and that of sandy soils 74.6 t ha⁻¹ in the top soil layer of 20 cm.

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 (Source: IPCC, 2003).

	F _{LU} ^a	F _{MG} ^b	F _I ^c
Sandy soils			
Crops			
Full tillage			
Medium input	0.71	1.0	1.0
High input	0.71	1.0	1.38
Reduced tillage	0.71	1.09	1.0
No-till	0.71	1.16	1.0
Fallow	0.82	1.0	1.0
High activity soils			
Crops			
Full tillage			
Medium input	0.71	1.0	1.0
High input	0.71	1.0	1.38
Reduced tillage	0.71	1.09	1.0
No-till	0.71	1.16	1.0
Fallow	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

Activity data

For mineral soils, the area under cultivated crops and set-aside is included in the category Cropland. Carbon stock change in soils under permanent horticultural crops, greenhouses and kitchen gardens is not estimated. The area of mineral cropland soils is the area remaining after the proportion of organic soils (derived on the basis of soil analysis) is subtracted from the cultivated area (crops and set aside) reported in the Yearbook of Farm Statistics each year. The percentage distribution of different soil types on the remaining area is estimated so that the proportion of sandy soils is constant (57%) and the rest is high activity soils (Table 7.3_4.). Thus part of the reduction in the area of organic soils is transferred to the category of high activity soils each year as the drained organic soils tend to lose organic matter. 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 (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_4. Distribution of areas of soil types, management and input on mineral cropland soils (1 000 ha) (Yearbook of Farm Statistics; Mikkola et al. 2005).

	1970	1980	1990	2000	2007
Sandy soils	1 454.4	1 340.2	1 283.1	1 235.5	1 274.2
Crops	1 427.4	1 282.4	1 179.8	1 133.2	1 143.4
Full tillage	1 427.4	1 210.5	1 036.2	895.0	805.7
Medium input	1 427.4	1 210.1	1 033.1	835.0	754.1
High input	0.00	0.38	3.1	60.0	51.6
Reduced tillage	0.00	71.6	143.1	214.7	264.8
No-till	0.00	0.30	0.51	23.6	72.9
Fallow	27.0	57.8	103.3	102.3	130.9
High activity soils	479.1	541.4	621.4	649.4	724.0
Crops	470.2	518.0	571.4	595.7	649.7
Full tillage	470.2	489.0	501.8	470.4	457.8
Medium input	470.2	488.8	500.3	439.9	428.5
High input	0.00	0.15	1.5	31.5	29.3
Reduced tillage	0.00	28.9	69.3	112.9	150.5
No-till	0.00	0.12	0.25	12.4	41.5
Fallow	8.9	23.4	50.0	53.8	74.4

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 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 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 on organic soils, national emission factors are used for organic soils under grass or other crops (Table 7.3_5).

Table 7.3_5. Emission factors used for calculating 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 development of the area estimate for organic soils for the years 1990-2006 is described in Chapter 6 Agriculture. For the years 1970-1987 the estimate is based on linear interpolation between the results of the studies of Kurki (1963) and Kähäri (1987), and for the years 1988-1989 on linear extrapolation from these data. The total area of cultivated organic soils is divided into grass and other crops based on expert judgement (Myllys 2002, pers.comm.). Grass is estimated to be grown on 50% of the organic soils and the rest is mainly cereals.

7.3.2.3 CO₂ emissions from liming

Method

The emissions reported under Cropland include liming on croplands, grasslands and forest lands. 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_6). 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_6. The amount of lime sold annually for agriculture and estimated to be applied to Finnish fields in 1990-2007 (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

Year	Limestone + briquette lime	Dolomite
2005	420.7	167.1
2006	470.4	191.5
2007	390.8	160.9

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 5. 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 Yearbook of Farm Statistics published by the Information Centre of the Ministry of Agriculture and Forestry each year and thus the time series can be considered consistent. However, there are subdivisions like areas under reduced tillage and no-till agriculture which are based on expert judgement, but the effects of these on the net carbon stock change of the whole category is of minor importance.

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. In the 2008 review there were a few comments about LULUCF which were answered.

7.3.5 Source-specific recalculations including changes made in response to the review process

Small changes were made, the area of cropland on organic soil was updated for the year 2005 and organic farming area was updated for year 2006. An estimate for living biomass on croplands has been added.

7.3.6 Source-specific planned improvements

The estimate of the emissions from the areas converted to cropland will be included as soon as the area distribution is available from the Finnish Forest Research Institute. The suitability of the Yasso –model for estimating carbon stock changes in agricultural soils will be investigated in an ongoing project. The distribution of cultivated organic soils into different crop types will be checked in 2009.

7.4 Grassland (CRF 5.C)

7.4.1 Source category description

Under Grassland category carbon stock changes in organic and mineral grassland are reported. The net emissions from grasslands were 4.1 Tg in Finland in 2007. Most of the emissions arise from mineral soils. The share of emissions on grasslands on organic soils was 0.041 Tg in 2007.

In Finland there are no large grazing land areas or permanent grasslands. Therefore Grassland-category comprises of grasslands and meadows more than five years old (Yearbook of Farm Statistics) together with the abandoned agricultural area which cannot yet be included in the Forest land category (FAO forest definition). Small roads and other small areas with tree cover less than 10% inside cropland are also placed to the Grassland category. The reason for this is that these areas fit best into the Grassland category by their characteristics. At present only soil CO₂ emissions from grasslands remaining grasslands are reported in this source category since no estimates of areas converted to grasslands are available.

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 emissions from grasslands on mineral soils have increased since 1990. The emissions of grasslands on organic soils have decreased (Figure 7.4_1). The high variation between the years results from the lack of a proper estimate for the grassland remaining grassland. In the current calculation method the area of grassland remaining grassland in the inventory year and 20 years prior to the inventory year are different and that results to unrealistic changes in carbon stocks.

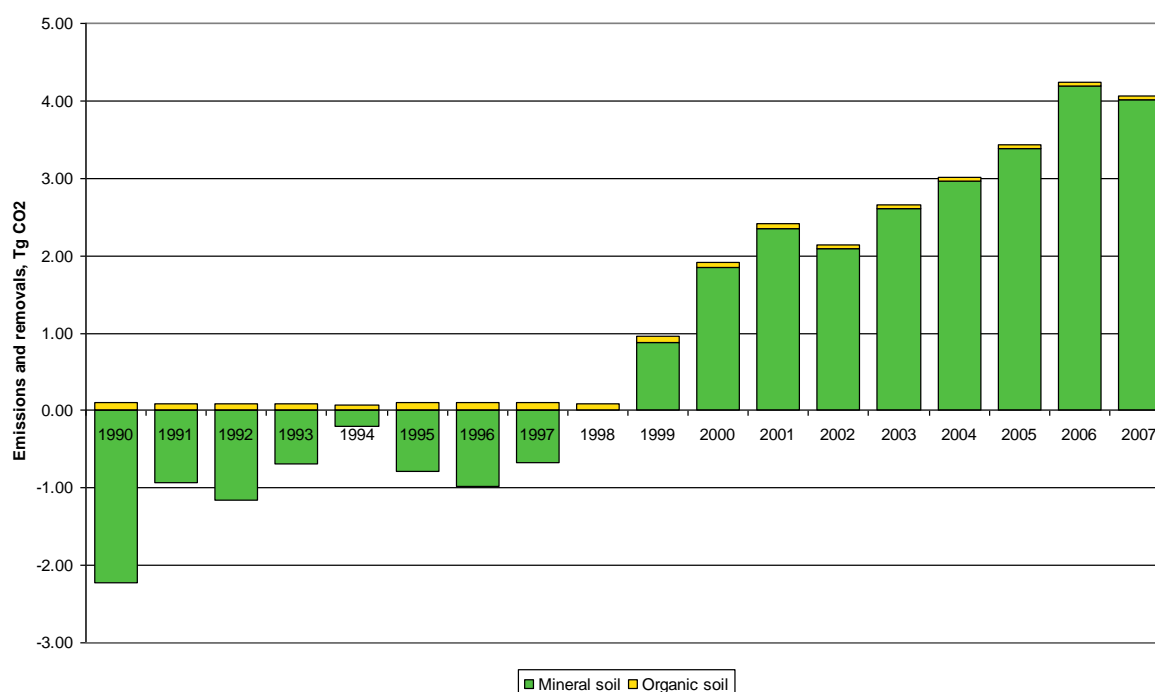


Figure 7.4_1. Emissions and removals in grassland 1990-2007, Tg CO₂

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 have not been included in the inventory yet.

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 (IPCC defaults) 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. The high variation between the years results from the lack of a proper estimate for the grassland remaining grassland. In the current calculation method the area of grassland remaining grassland in the inventory year and 20 years prior to the inventory year are different and that results to unrealistic changes in carbon stocks.

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 (IPCC, 2003). The carbon stock change factors used represent the average management of these soils which range from abandoned fields to pastures fertilised with manure. Division of grassland to different categories based on the intensity of management is currently not possible.

Activity data

Permanent grasslands and pastures are included in the source category, not grass cultivated as part of crop rotation. The abandoned agricultural areas are included in this category before their conversion to forest. The area estimate of grasslands was derived from statistics and from NFI data as follows. Originally all land in the agricultural use has been classified as agriculture in the NFI. Agriculture land includes area under grass (under and over five years old), other crops and set-aside, area needed for barnyards and outbuildings, excluding farmhouses, as well as abandoned fields and croplands. This definition covers a wider range of land than the IPCC cropland definition and is hence larger than the reported cropland area which bases on the Yearbook of Farm Statistics. NFI8, NFI9 and NFI10 sample plot data were classified to IPCC land-use categories so that abandoned agriculture land was set into the grassland category and all others into the cropland category. Cropland and grassland areas were estimated for Forestry Centre regions. The Forestry Centre results were dated to the inventory mid-year that refers to the year in which most of the sample plots of a Forestry Centre region were measured. Linear interpolation was used to estimate areas between mid-years. A country level estimate is a sum of regional estimates. The cropland area of agricultural statistics was subtracted from the NFI cropland estimate and the final grassland estimate was a sum of the difference and the NFI grassland estimate. The division to high activity and sandy soils is done according to the description in Section 7.3 Cropland and is presented in Table 7.4_1.

Table 7.4_1. Distribution of areas of soil types on grassland soils (1 000 ha).

	1970	1980	1990	2000	2007
Sandy soils	332.0	431.0	382.4	317.0	221.4
High activity soils	109.7	174.5	184.5	166.8	125.9
Organic soils	145.9	157.4	110.0	77.2	44.5
Total	587.6	762.8	676.8	561.0	391.9

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 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 organic soils the default emission factor of the IPCC (0.25 t C /ha/a) for grasslands is used, since no national emission factor is currently available (IPCC, 2003, Table 3.4.6).

The area of grasslands on organic soils is derived assuming that the percentage of organic soils is the same as that on cropland soils. The area estimates are presented in Table 7.4 1 above.

7.4.2.3 CO₂ emissions from liming

Emissions from the total amount of lime used annually in Finland are reported under 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 5. 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 not consistent as a whole. The way of producing the time series for the area of grasslands differs between the years 1970-1989 and 1990-2004 because the area of grasslands could not be separated from the area of cropland for the years 1970-1989 in the NFI. However, since the area of cropland in the NFI is also considered to include the area of grasslands during 1970-1989 there is actually no big difference in practice.

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.

7.4.5 Source-specific recalculations including changes made in response to the review process

The emissions from grassland remaining grassland were recalculated because new area estimates were available.

7.4.6 Source-specific planned improvements

The emissions from land converted to grassland will be added to the inventory as soon as the data of the area converted has been received from the Finnish Forest Research Institute. As soon as national values for carbon stock change factors are available they will be used in the calculations. The possibility to use the Yasso –model for estimating carbon stock changes in grasslands will be examined in an ongoing project

7.5 Wetland (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).

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). Non-CO₂ emissions from drainage of wetlands. 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.

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.

Emissions of 2007 from peat extraction have increased similarly as in the previous submissions, total emissions being 20% larger than in 1990 (Figure 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. Due to the new methodology the level of emissions almost doubled being 1990 1,078 Gg of CO₂ eq., while being 599 Gg of CO₂ eq. for 1990 in the previous submission.

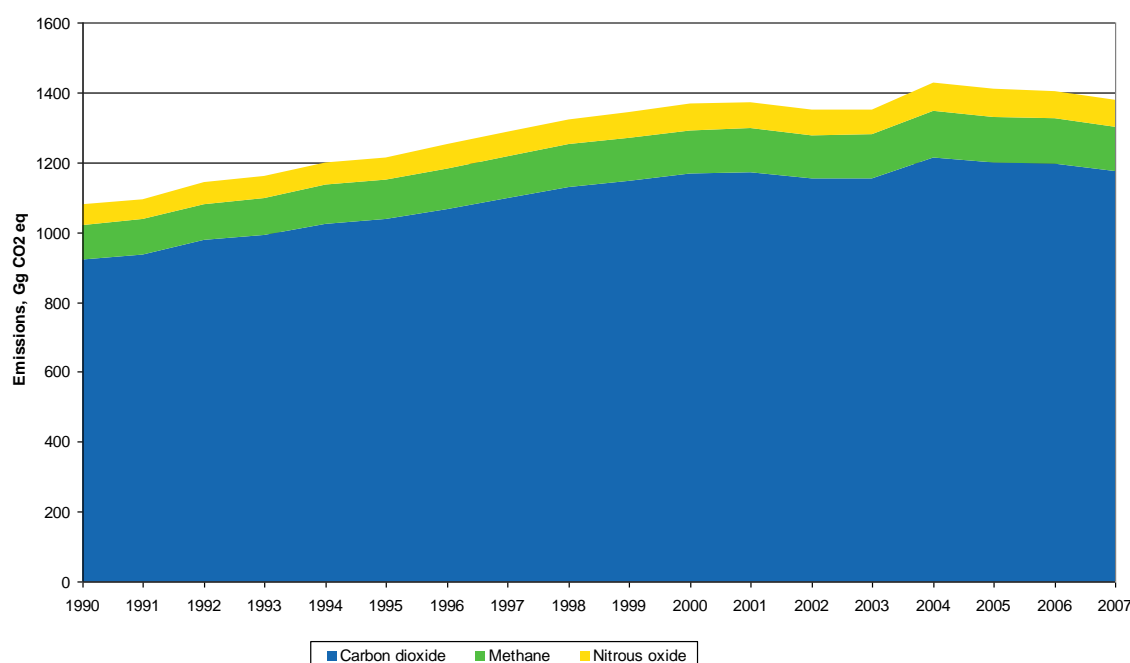


Figure 7.5_1. Emissions from the peat extraction areas between 1990 and 2007.

Table 7.5_1. Greenhouse gas emissions from peat extraction in 1990-2007 (Gg CO₂ eq.)

Year	CO ₂	CH ₄	N ₂ O	Total
1990	922	98	58	1 078
1991	936	100	59	1 095
1992	976	104	62	1 142
1993	993	106	63	1 162
1994	1 024	110	65	1 199
1995	1 037	111	66	1 215
1996	1 067	115	69	1 250
1997	1 098	119	71	1 288
1998	1 129	122	73	1 324
1999	1 146	124	74	1 343
2000	1 166	126	75	1 367
2001	1 171	126	75	1 372
2002	1 152	124	74	1 350
2003	1 154	124	74	1 352
2004	1 213	133	80	1 426
2005	1 199	132	79	1 409
2006	1 194	131	78	1 404
2007	1 174	129	77	1 380

Key categories

CO₂ emissions from peat extraction were found to be a key category in 2007 based on level assessment.

7.5.2 Methodological issues

Methods

The emissions were calculated by multiplying area estimates with national emission factors. Emissions of stockpiles and ditches are included in the inventory.

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 Alm et al. (2007) were used.

Carbon dioxide emissions from the soil is 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 and Alm et al. 2007) (corrected with IPCC 1995 GWP). 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	46	46	46	1	1	1
Production	91 %	9 860	9 460	8 400	1 518	1 518	1 518	961	961	961
Total emissions	100 %	14 615	14 250	13 282	1 509	1 509	1 509	895	895	895

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 2007 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 1990–2007 (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	76.3	9.0	85.3

7.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 (±12-16%), the contribution of winter CO₂, and non-CO₂ emissions (CH₄, N₂O) with lower emission rates can be expertly deemed to increase that uncertainty to ±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 published by 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 2007 originates directly from VAHTI system. It takes into account all peat producers, even the small ones. The area data are fluctuating in an unexpected manner in the beginning of the 2000's, which can be seen in the Table 7.5_3 and in the Figure 7.5_1. This possible temporal inconsistency in the area data, will be examined in more detailed for the next submission.

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 years 1996–2007, including the re-evaluation of the VAHTI data with completing the missing data. Also new emission factors were applied based on the latest scientific research (Alm et al. 2007). As a result of these changes the emissions from peat extractions nearly doubled compared to previous submissions. (Table 7.5_4).

Table 7.5_4. Effects of recalculations.

Year	Effect on areas			Effect on emission		
	2008 submission	2009 submission 1 000 ha	Difference	2008 submission	2009 submission Gg CO ₂ -eq	Difference
1990	64.734	64.734	0	599	1 078	479
1991	65.984	65.984	0	607	1 095	488
1992	68.856	68.856	0	633	1 142	509
1993	70.334	70.334	0	643	1 162	519
1994	72.616	72.616	0	663	1 199	536
1995	73.827	73.827	0	670	1 215	545
1996	75.766	76.321	0.555	683	1 250	567
1997	77.330	78.800	1.470	694	1 288	594
1998	77.194	80.943	3.749	693	1 324	631
1999	77.755	82.041	4.286	699	1 343	644
2000	76.891	83.337	6.446	693	1 367	674
2001	75.803	83.526	7.723	685	1 372	687
2002	78.112	82.151	4.039	708	1 350	642
2003	71.876	82.126	10.250	652	1 352	700
2004	80.535	88.348	7.813	706	1 426	720
2005	84.862	87.243	2.381	748	1 409	661
2006	84.100	86.799	2.699	742	1 404	662

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 (see 7.1 Overview of the sector, Appendix_7a). The main data source is the national forest inventory (NFI) data (Table 7.6_1). The area time series for Settlements and for Other land were recalculated for this submission. Reasons to the recalculation were a) a detected bug in the computer program, b) a corrected time series for peat extraction areas, which effected to the allocation of total land area to the land-use categories, and c) the new NFI data employed for years 1997-2006. A description of the NFIs and principles of area estimation method are given in Appendix_7a.

NFI8, NFI9 and NFI10 sample plot data were classified into IPCC land-use categories. Areas of settlements and other land were estimated for Forestry Centre regions. The Forestry Centre results were dated to the inventory mid-year that refers to the year in which most of the sample plots of a Forestry Centre region were measured. Linear interpolation was used to estimate areas between mid-years. A country level estimate is a sum of regional estimates. In the NFI, the kitchen gardens and greenhouses and peat production areas are classified as built-up lands. In the greenhouse gas inventory, the peat production areas are included into wetlands and the others into croplands. Thus, these areas are subtracted from the NFI area estimate for settlements to avoid double counting.

The emissions from land conversion to Settlements and Other land are not reported. The method to estimate land transitions from other land-use categories to Settlements and to Other land is under development.

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.

Table 7.6_1. Areas of settlements and other land in 1990-2007 (1 000 ha).

Year	Settlement	Other land
1990	1 166	1 213
1991	1 179	1 213
1992	1 191	1 214
1993	1 204	1 215
1994	1 217	1 216
1995	1 230	1 216
1996	1 244	1 219
1997	1 252	1 223
1998	1 259	1 226
1999	1 266	1 226
2000	1 274	1 233
2001	1 284	1 234
2002	1 299	1 238
2003	1 311	1 243
2004	1 316	1 259
2005	1 327	1 271
2006	1 339	1 289
2007	1 351	1 309

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. This category includes emissions from different kinds of N fertilisers applied in forests, like urea, saltpetre and nitrogen phosphorous mixtures.

N₂O emissions from fertilisation have decreased 38% from year 1990 to 2007. The trend after the slowdown in the beginning of the 1990's seems to be towards slightly increasing usage of fertilisers.

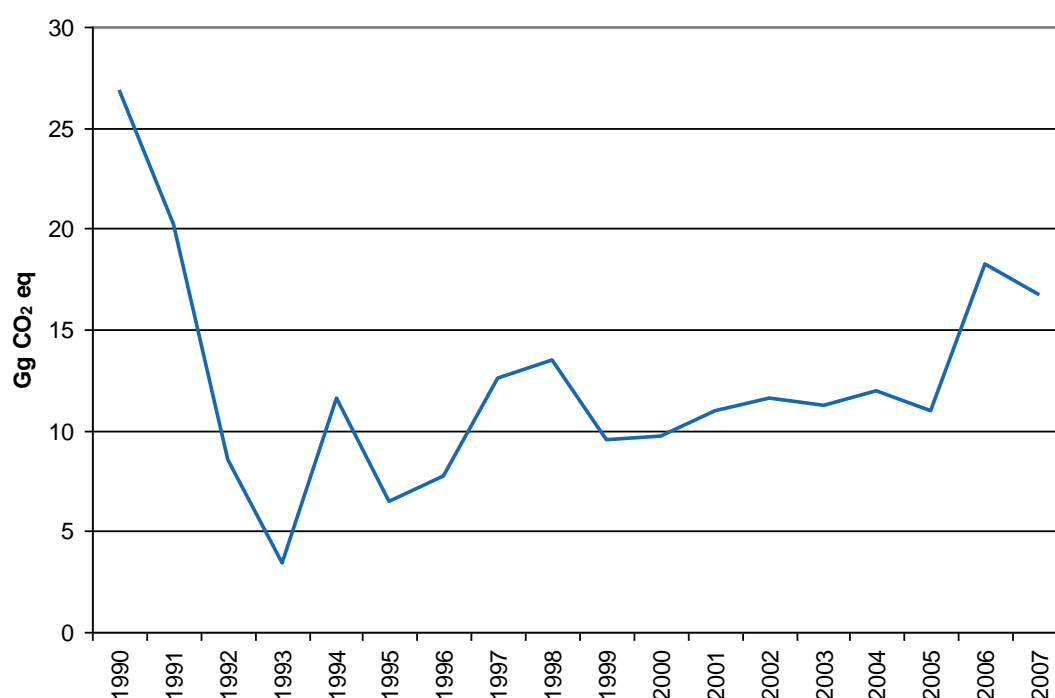


Figure 7.7_1. N₂O emissions from forest fertilisation (Gg CO₂ eq.).

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 1990-2007 (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

7.7.1.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 Statistical... 2008). It was confirmed that all data used in this section cover whole land area of Finland.

7.7.1.5 Source-specific recalculations

No recalculations have been carried out.

7.7.1.6 Source-specific planned improvements

The work in harmonizing the sale statistics of forest and agriculture fertilisers concerning the same time interval has recently begun and revisions in activity data are expected.

7.7.2 N₂O 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. Wetland. 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))

This source category is not so far included in the reporting due to lack of appropriate methods to estimate these changes. These emissions will be included in 2010 inventory submission.

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. At the moment complete statistics on burned areas are not available. 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.

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	3.26	0.19	0.0013	1.67	0.047
1991	1.71	0.08	0.0006	0.71	0.020
1992	8.27	0.14	0.0010	1.22	0.035
1993	0.00	0.05	0.0004	0.46	0.013
1994	6.21	0.11	0.0008	0.96	0.027
1995	4.13	0.09	0.0006	0.81	0.023
1996	3.75	0.07	0.0004	0.57	0.016
1997	9.36	0.10	0.0007	0.83	0.024
1998	0.77	0.04	0.0002	0.31	0.009

Year	Greenhouse gases			Other gases	
	CO ₂	CH ₄	N ₂ O	CO	NO _x
1999	5.07	0.09	0.0006	0.78	0.022
2000	3.07	0.04	0.0003	0.36	0.010
2001	1.54	0.12	0.0008	1.05	0.030
2002	4.88	0.13	0.0009	1.10	0.031
2003	5.99	0.09	0.0006	0.79	0.023
2004	2.93	0.02	0.0002	0.22	0.006
2005	4.10	0.07	0.0005	0.61	0.017
2006	13.44	0.11	0.0007	0.95	0.027
2007	4.91	0.05	0.0003	0.41	0.012

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 volume of the growing stock on forest land by tree species groups were estimated from the NFI8, NFI9 and NFI10 data (Table 7.7_3.). Volumes were converted to dry weight of biomass by stand-level biomass expansion factors (Lehtonen et al., 2004a).

Table 7.7_3. Mean volume (m³ ha⁻¹) and biomass (tonnes d.m. ha⁻¹).

	Scots pine		Norway spruce		Broad-leaved trees	
	Volume	Biomass	Volume	Biomass	Volume	Biomass
1990	37.5	20.8	30.0	20.4	14.5	8.7
1991	38.1	21.2	30.0	20.4	14.8	8.9
1992	38.7	21.5	30.0	20.4	15.1	9.1
1993	39.3	21.8	30.1	20.4	15.3	9.2
1994	39.9	22.1	30.1	20.4	15.6	9.4
1995	40.5	22.5	30.1	20.5	15.9	9.6
1996	41.0	22.8	30.1	20.5	16.2	9.7
1997	41.6	23.1	30.1	20.5	16.5	9.9
1998	42.2	23.4	30.2	20.5	16.7	10.1
1999	42.8	23.8	30.2	20.5	17.0	10.2
2000	43.4	24.1	30.2	20.5	17.3	10.4
2001	44.0	24.4	30.1	20.5	17.2	10.4
2002	44.7	24.8	30.0	20.4	17.2	10.3
2003	45.3	25.1	30.0	20.4	17.1	10.3
2004	46.0	25.5	29.9	20.3	17.0	10.3
2005	46.6	25.9	29.8	20.3	17.0	10.2
2006	47.3	26.2	29.7	20.2	16.9	10.2
2007	47.9	26.6	29.3	19.9	19.0	11.4

The biomass of understory was added to the total biomass. The used biomass of field layer was 782 kg d.m. ha⁻¹ and bottom layer 1,534 kg d.m. ha⁻¹ (Muukkonen et. al. 2006). In 2005, the estimated average biomass per hectare on burned area was 60 tonnes d.m. The combustion efficiency is based on expert judgement* and it was assumed that 7.5% ($\pm 2.5\%$) 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 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.

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 (d.m. 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 d.m. kg ha⁻¹ and for field layer 770 d.m. kg ha⁻¹ (Muukkonen et. al. 2005). It was assumed according to expert judgement* 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_4). 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.

* Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007

* Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007

Table 7.7_4. Burned forest area in 1990-2007 (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

7.7.4.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 volumes of the growing stock on forest land were re-produced basing on re-estimated Forest Land area and total growing stocks. Thereby the time series of the emissions from wildfires and controlled fires were recalculated.

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 2007, harvested wood products were a small carbon sink in Finland, 1.2 Tg CO₂ equivalent which is approximately 5% 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. During the reporting period 1990-2007 the solid wood stock was estimated to have grown by 3.7 Mt C and the paper product stock by 0.5 Mt C – or 13,567 Gg CO₂ and 1,900 Gg CO₂, respectively. The average annual removal of HWP including both solid wood and paper is thus around -830 Gg CO₂/yr during the reporting period.

Table 7.8_1. Estimated net emissions and removals of Harvested wood products by category in 1990-2007, 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

Year	Solid wood products	Paper products	Total
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

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 $= -44/12 \cdot \Delta C_{HWP\text{ in use}} \text{ (given in Gg CO}_2\text{/yr)}$.

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, $\Delta C_{HWP\ DC} = \Delta C_{HWP\ IU\ DC} + \Delta C_{HWP\ SWDS\ DC}$	Variable 1A $\Delta C_{HWP\ IU\ DC}$	Variable 1B $\Delta C_{HWP\ SWDS\ DC}$
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, his includes exported HWP to other countries, $\Delta C_{HWP\ DH} = \Delta C_{HWP\ IU\ DH} + \Delta C_{HWP\ SWDS\ DH}$	Variable 2A $\Delta C_{HWP\ IU\ DH}$	Variable 2B $\Delta C_{HWP\ SWDS\ DH}$
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 et al. 2000, 2001, 2003). For the Finnish NIR 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:

$$C(i+1) = e^{-k} * C(i) + \left[\frac{(1 - e^{-k})}{k} \right] * Inflow(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

$$\text{With } C(1900) = 0.0$$

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, yr^{-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 yr^{-1}

$\Delta C(i)$ = carbon stock change of the HWP pool during year i , Gg C yr^{-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, 2007, 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 (2007) 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 (FAO 2007). 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 (FAO 2007). 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).

7.8.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 1990-2006. 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 1990-2006 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 in Figure 7.8_1: 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 (METLA 2005, p. 184-185). 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/yr or 280 Gg CO₂/yr.
 - 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 1990-2006 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 (FAO 2007) except for the year 2006, which could be found from UNECE (2007).
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

No recalculations have been made.

7.8.6 Source-specific planned improvements

The HWP worksheet model of the 2006 IPCC Guidelines is based on primary wood products. The carbon balance of the HWP stock is estimated based on the inflow of new HWP into the pool and outflow from the pool. The decay (=outflow) of the pool is assumed to be of first-order, i.e. the decay is proportional to the stock size. There are some weaknesses of the method: In reality the decay is not of the first-order. Some physically more realistic decay functions could be applied, but in fact the decay depends on many socio-economic factors such as business cycles in construction. For instance, both demolitions of old buildings and construction of new buildings increase during economic booms. This could be difficult to describe by any physically-based decay models.

Basically, a more robust estimation method is based on the direct stock inventories applied in the Finnish HWP reporting. In this method the product half-life in the HWP worksheet model is only a fitting parameter. The model is only used to interpolate the HWP stock in the intermediate years between the inventories. The annual emission/removal from HWP could, however, be estimated more exactly in combination with the inventories (Tier 3 Method D) in case a more realistic decay model were available. For instance, the share of very short-term use of wood products, such as wood ending up as construction waste, could be defined using a separate parameter. Other decay patterns than first-order could be used. Another weakness in the worksheet model is that it is not based on final products. The trade of secondary/final products cannot be described with this kind of model. But on the other hand, there are no directly suitable statistical data for developing a model based on final products.

A more formal quantitative uncertainty analysis of the method used in this reporting could be developed, taking into account at least all the parameter uncertainties e.g. in the conversion factors. The HWP source categories could be more extensive, including furniture, roundwood stocks (which were given in this reporting as a separate emission) and the short-term wood product stock, such as packages. More empirical evidence would be required for estimation of the half-life of paper products, which now appears to be over-estimated. Estimation of HWP in solid waste disposal sites would be challenging task in the future, but most likely its uncertainty would be an order of magnitude higher than the emission/removal estimate of HWP in use.

Appendix_7a

National forest inventory

The National Forest Inventory (NFI) is a sampling-based forest inventory and it covers all land-use classes. 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 nine inventories have been completed. The 10th inventory was launched in 2004 and the field measurements will be completed in 2008. The first four NFIs were made as line surveys, whereas in latter inventories sample plots are located in clusters.

Until the 10th inventory the NFIs proceeded region by region (the region of a Forestry Centre, Fig. 1_App_7a) and the inventory cycle was 8 to 10 years. In the NFI10 the cycle is five years and measurements are carried out in the whole country every year, that is, 20% of the sample plots are measured every year (Fig. 1_App_7a). In the NFI9, the country was divided into six sampling regions, between the areas the distance between the clusters varying, as well as the number of sample plots in a cluster and the distance between the sample plots (Fig. 2_App_7a). South Finland comprises sampling regions 1, 2 and 3, and North Finland regions 4, 5 and 6. The distances between clusters and the distance between the sample plots in the NFI9 and NFI10 are given in Table 1_App_7a. The shape of clusters in the NFI 9 is presented in Figure 3_App_7a and in the NFI10 in Figure 4_App_7a.

The inventory years of the three previous NFIs are the NFI7 1977-1984, the NFI8 1986-1994 and the NFI9 1996-2003.

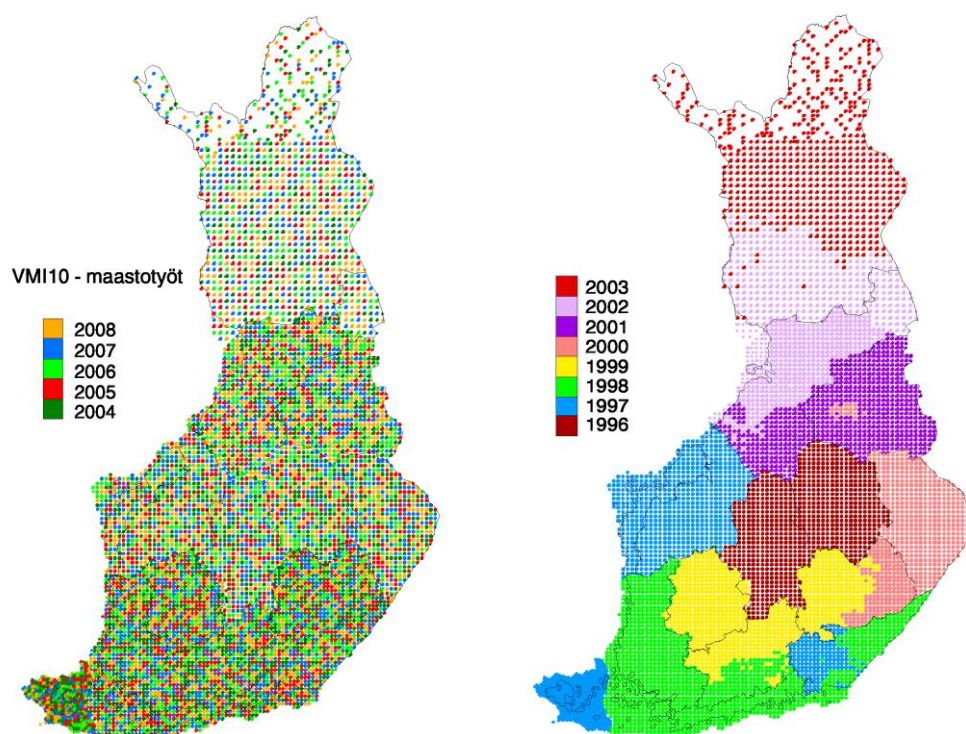


Figure 1_App_7a. Field inventory years in the NFI9 and NFI10.

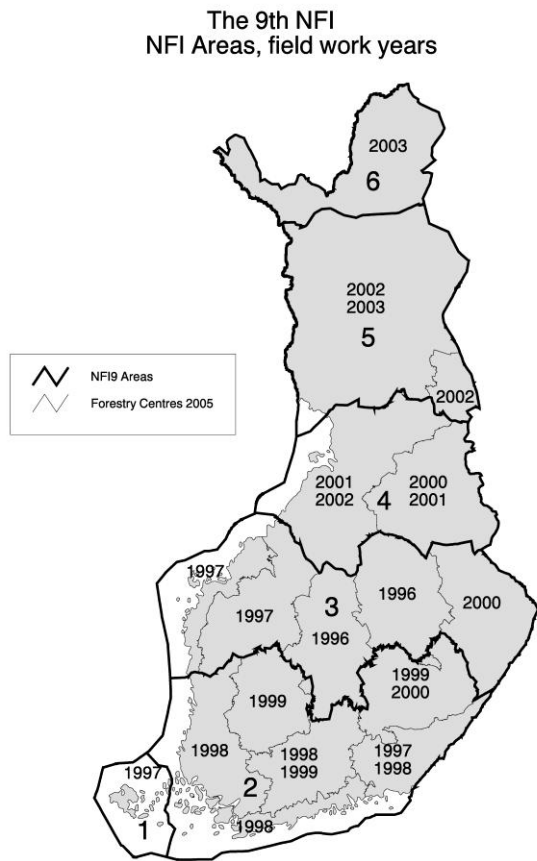


Figure 2_App_7a. Six sampling regions of the NFI9 with forestry centre boundaries and inventory years.

Table 1_App_7a. Sampling regions and their parameters in the NFI9 and NFI10.

Area	Distance between clusters	Shape of a cluster	Distance between plots within a cluster	Number of plots in a temporary (permanent) cluster
NFI9				
1. Åland	6 x 6 km ¹⁾	L-shaped	250 m	14 (10)
2. Southernmost Finland	6 x 6 km	L-shaped	250 m	14 (10)
3. Central Finland	7 x 7 km	Rectangular	300 m	18 (14)
4. Southern North Finland	7 x 7 km	L-shaped	300 m	15 (11)
5. Lapland	10 x 10 km	L-shaped	300 m	15 (11)
6. Northern Lapland	- ²⁾	L-shaped	450 m	9 (9)
NFI10				
1. Åland	To be decided	Tbd	Tbd	Tbd (10)
2. Southernmost Finland	6 x 6 km	L-shaped	250 m	12 (10)
3. Central Finland	7 x 7 km	Rectangular	300 m	14 (14)
4. Southern North Finland	7 x 7 km	L-shaped	300 m	13 (11)
5. Lapland	10 x 10 km	L-shaped	300 m	13 (11)
6. Northern Lapland	To be decided	Tbd	Tbd	Tbd (9)

1) The sampling was densified by a double number of temporary clusters.

2) Stratified sampling: a sampled area was first divided into six strata according to the percentage of forests. The stratification was based on the forest maps produced by the multi-source NFI using satellite imagery and NFI8 data.

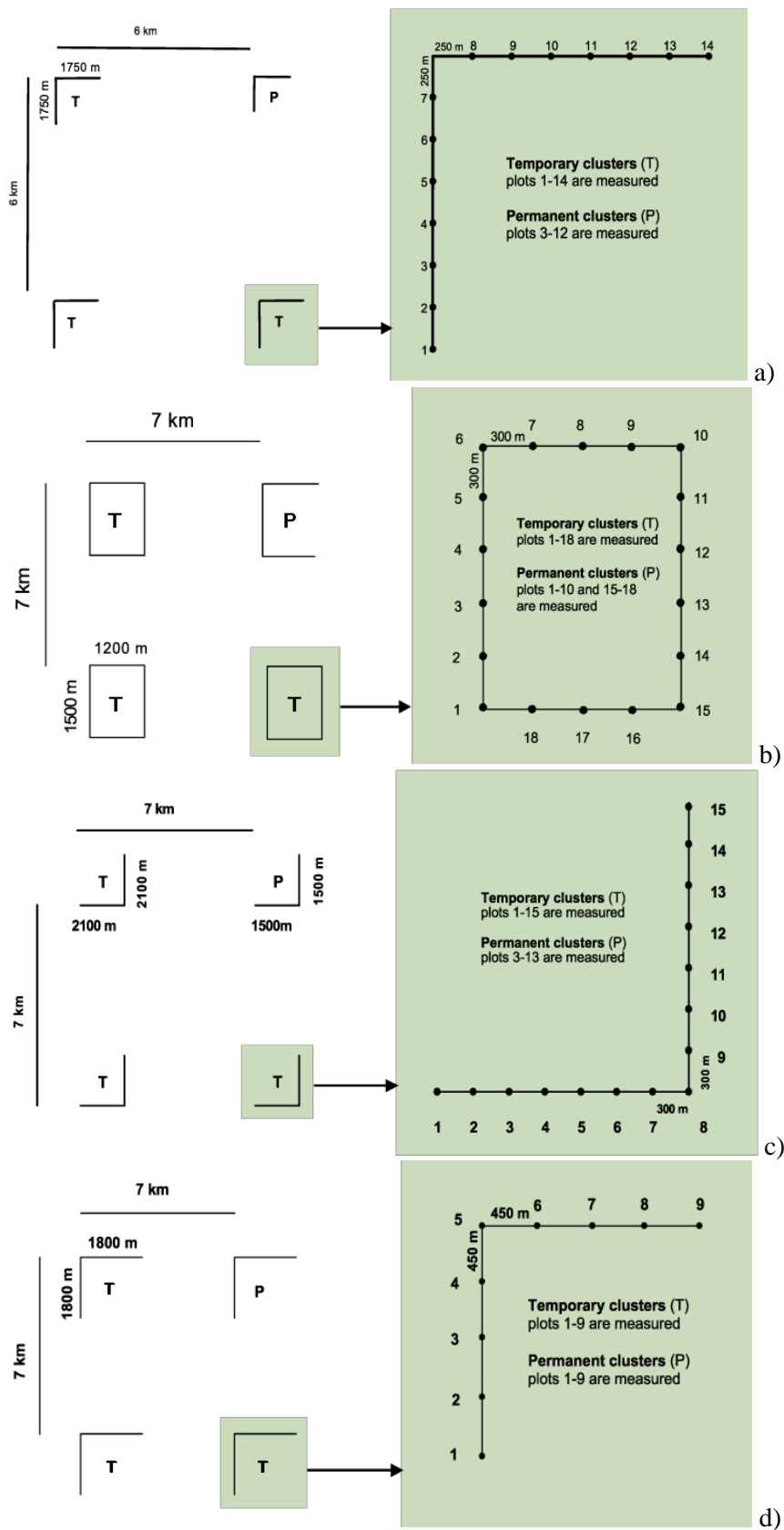


Figure 3_App_7a. Sampling design of the NFI9 in different sampling regions: a) region 2, in Åland, the design is the same but the distances are 3 km x 3 km, b) region 3, c) region 4, in region 5, the design is the same but the distances are 10 km x 10 km, d) region 6.

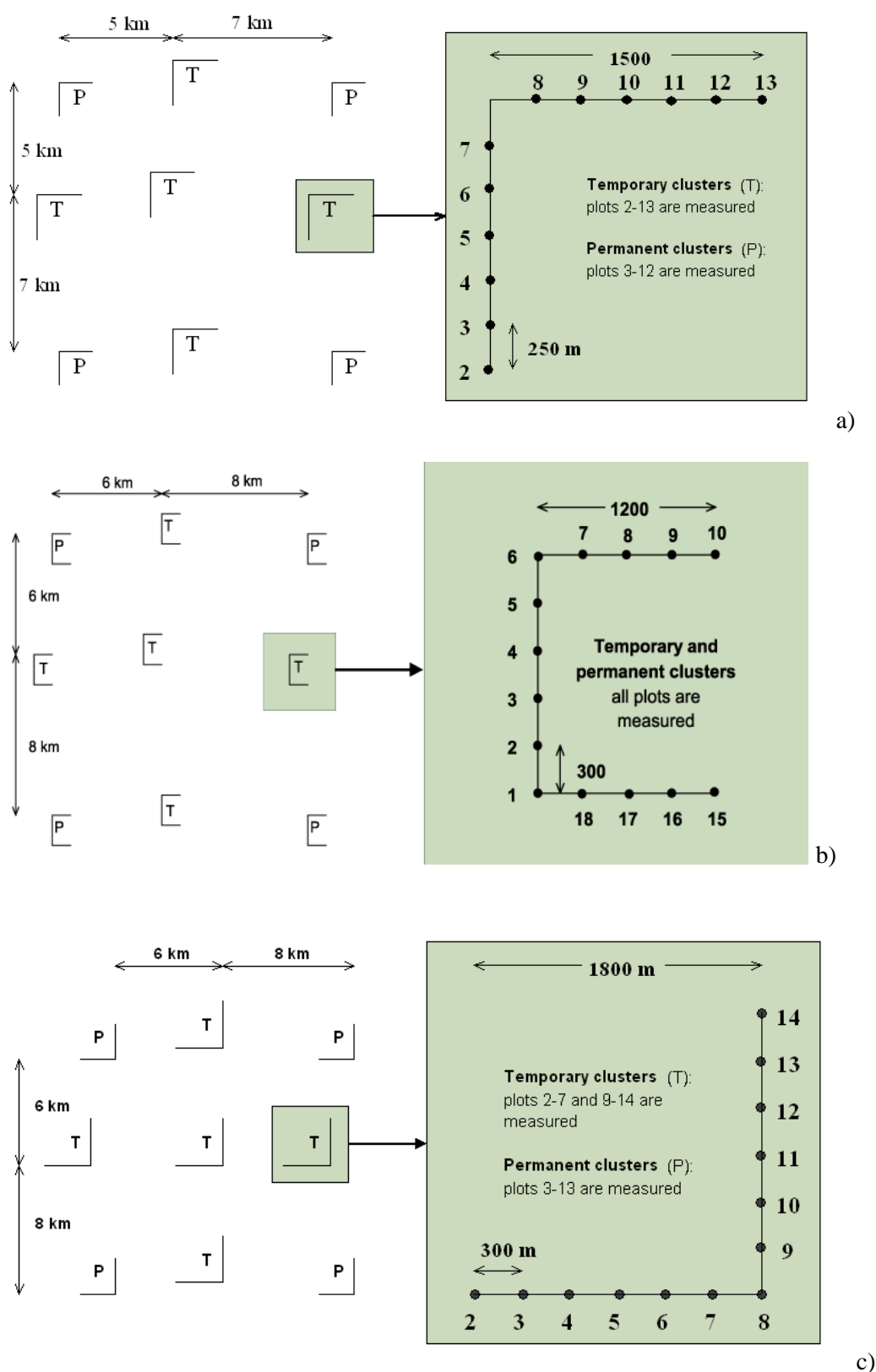


Figure 4_App_7a. Sampling design of the NFI10 in different sampling regions: a) region 2, b) region 3, c) region 4, in region 5, the design is the same but the distances are 9 km x 11 km.

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, but the method to estimate converted areas is not yet available for this greenhouse gas inventory submission. In all, over 100 stand variables are measured and assessed on a Forest land sample plot. 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. Every 7th tallied tree is measured as a sample tree. Height, diameter at 6 m, thickness of bark, 5 years' increment of diameter and height, measured of sample trees, are applied in volume and biomass estimations alongside stand variables.

Workload of the latest completed inventory, the NFI9, was:

- 70,955 field plots on forestry land
- over 150 characteristics measured or assessed
- 518,720 tallied trees.

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 et al. 1998, 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 volume of trees means tree stem volume over bark, from above the stump to the top of the tree. Volumes for sample trees are estimated as a function of diameters at a height of 1.3 m ($d_{1.3}$) and 6.0 m ($d_{6.0}$), and height (h) using taper curve models (Laasasenaho 1982). The current volume over bark is thus a function

$$v_{ob,0} = f(\text{treesp.}, d_{1.3}, d_{6.0}, h). \quad (2)$$

Volumes are estimated for tally trees using a non-parametric regression method (Tomppo et al. 1997, Tomppo et al. 1998, Tomppo 2005).

The volume increment means the increase in tree stem volume over bark, from above the stump to the top of the tree. The annual volume increment is calculated as an average over five years. Volumes five years ago are computed for sample trees using taper curve models and estimated volume per basal area ratio curve (Kujala 1980):

$$v_{ob,-5} = g(\text{treesp.}, r, v_{ob,0}, g_{ub,0}, g_{ub,-5}, h), \quad (3)$$

where

$$r = \frac{v_{ob,0}}{g_{ub,0}} \text{ from a large set of trees}$$

$g_{ub,0}$ is current basal area under bark

$g_{ub,-5}$ is basal area under bark 5 years ago.

Volume increments are estimated for tally trees by computation strata and by diameter classes using the average 5-year increments of the sample trees of the stratum and the numbers of tally trees in the stratum. The annual increment is simply the 5-year increment divided by 5. The increment of the drain is included in the final results (Salminen 1993, Tomppo et al. 1998, Tomppo 2006).

Sampling errors can be estimated for area, volume and increment estimates. The applied method is described in Heikkinen (2006).

Inventory results for South Finland and North Finland are published in the Forest Resource Reports as follows; the NFI7 by Kuusela and Salminen (1991), the NFI8 by Tomppo et al. (2001), the NFI10 by Korhonen et al. (2006, 2007). The NFI9 results for South and North Finland were published in the earlier Finnish Statistical Yearbooks.

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) defines, 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 buildings.

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 5. 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 varies 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.

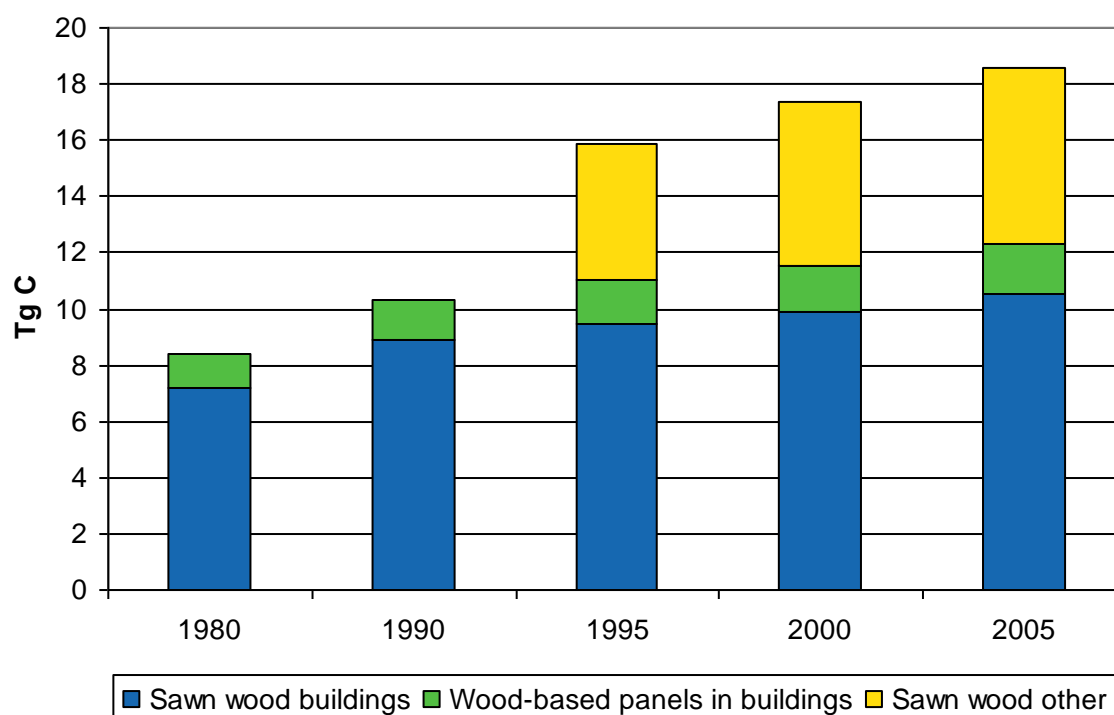


Figure 1_App_7c. Carbon storage of wooden products in Finnish construction.

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, stores	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

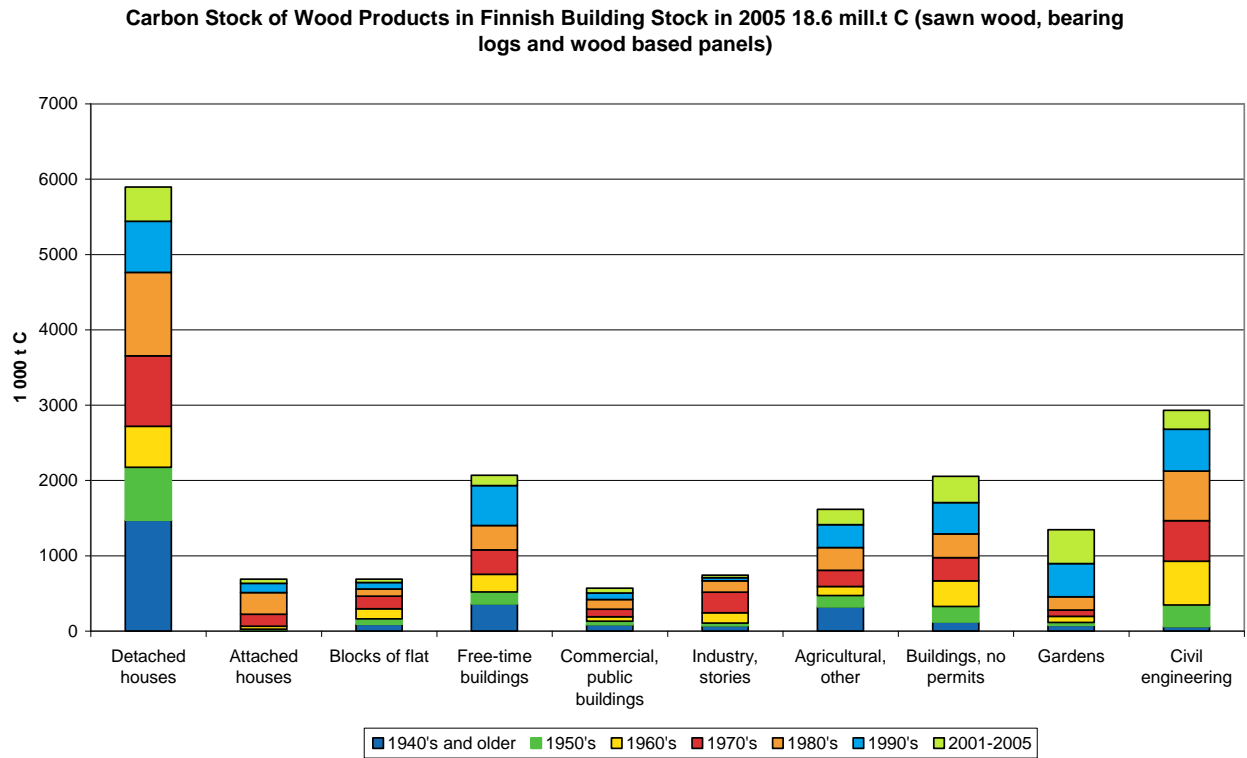


Figure 2_App_7c. Carbon stock by building types in Finland in 2005.

The Share of Carbon Stock by Decades in the Whole Finnish Buildings Stock in 2005 (18.6 mill.t C)

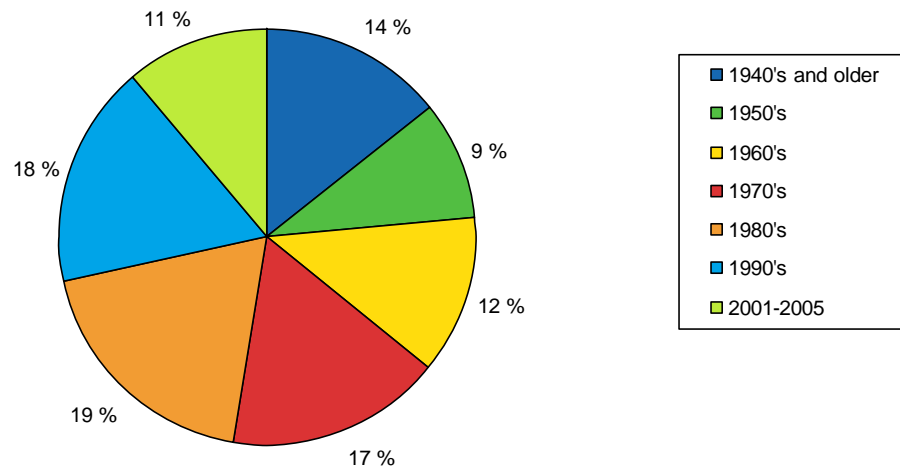


Figure 3_App_7c. Carbon stock in Finnish building stock by decades in 2005.

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, stores	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	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	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 2.4 Tg CO₂ eq. in 2007. This was over 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.

NMVOC emissions from solid waste disposal sites and wastewater handling as well as NMVOC, 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 4.

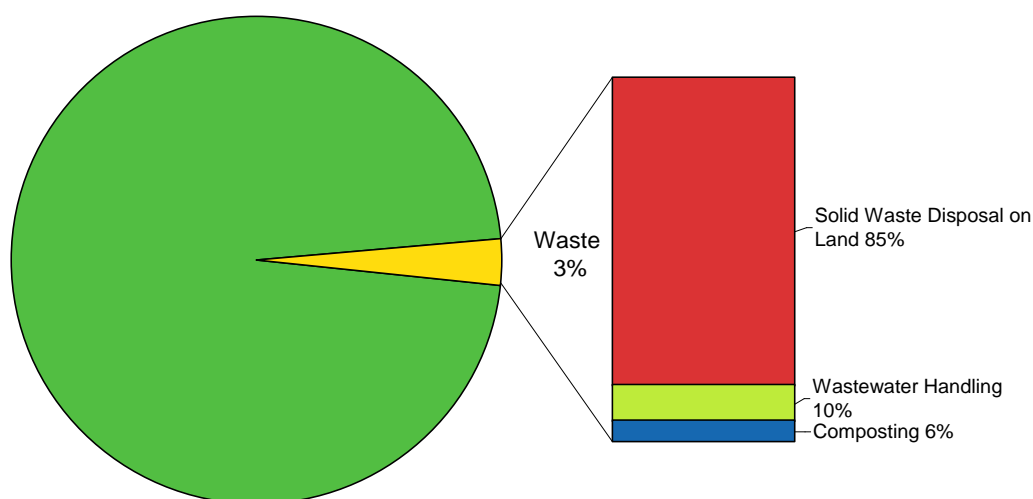


Figure 8.1_1. Greenhouse gas emissions from the Waste Sector in 2007 compared with the total greenhouse gas emissions in Finland.

CH₄ emissions from landfills are the most important greenhouse gas emissions in the waste sector. Solid waste disposal on land contributes over 85%, waste water handling about 10% and composting 6% of this sector's total emissions. Since 1990 these emissions have decreased 40%. (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 due to alternative waste treatment methods. Implementation of landfill gas recovery has significant impact on emissions. The increase of emissions in 2006 followed from (temporary) technical problems in one important landfill gas recovery plant.

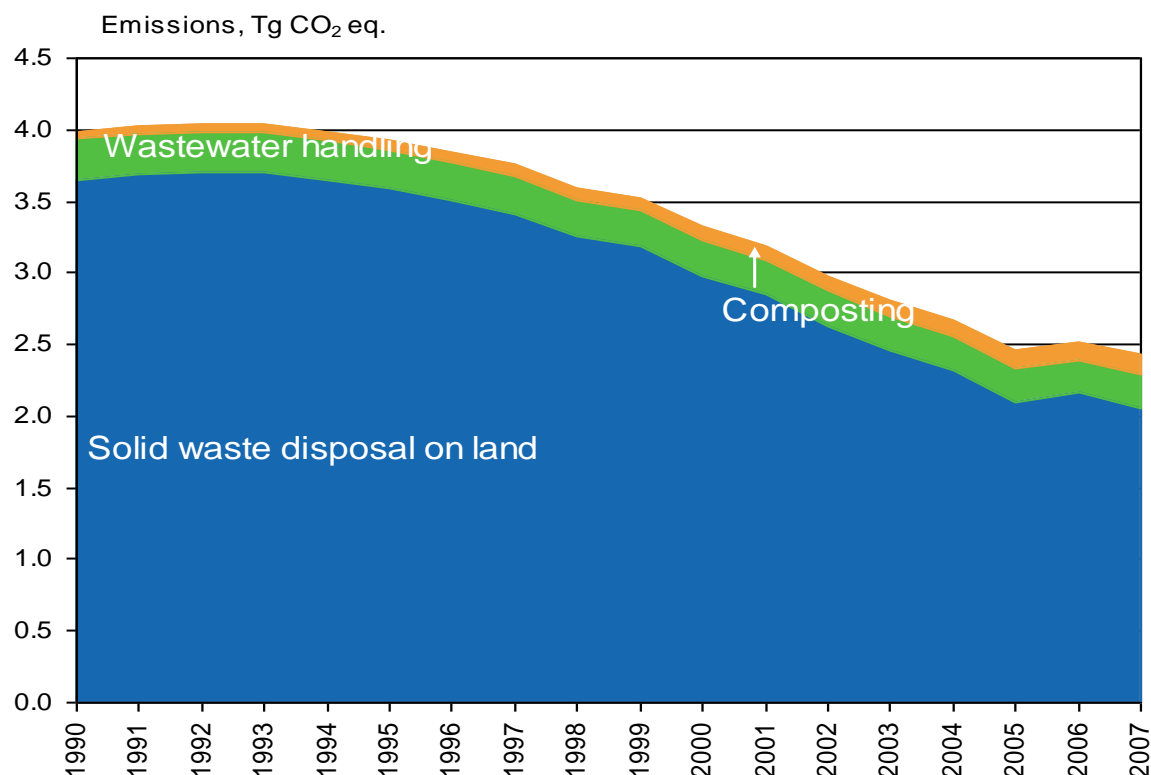


Figure 8.1_2 Trend in the Waste Sector's emissions in 1990-2007 (Tg CO₂ eq.).

The emission trend in the Waste Sector by subcategory and gas is presented in Table 8.1_2.

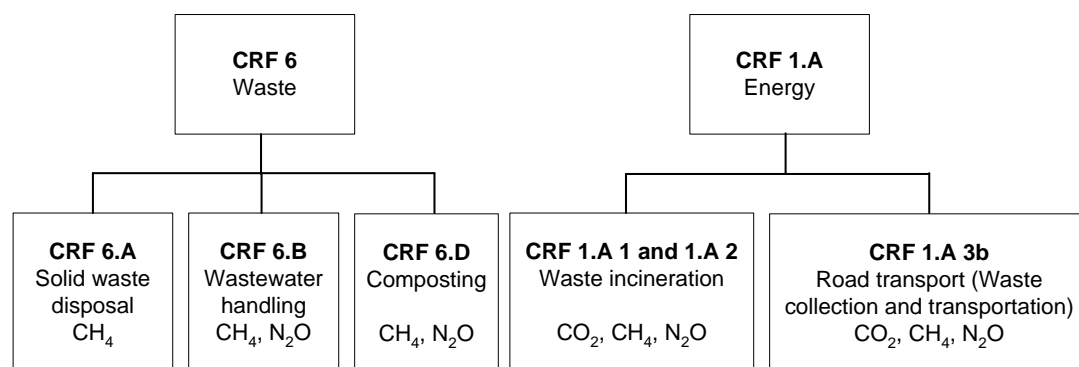


Figure 8.1_3. Emissions from waste handling and their reporting categories in the national greenhouse gas inventory.

Key categories

The key categories in the waste sector in 2007 are summarised in Table 8.1_1.

Table 8.1_1 Key categories in Waste Sector (CRF 6) in 2007 (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

Table 8.1_2. Emissions in the Waste Sector by source and gas in 1990-2007 (Tg CO₂ eq).

Source category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
6.A Solid waste disposal on land, CH₄	3.64	3.69	3.71	3.70	3.65	3.59	3.50	3.41	3.26	3.19	2.98	2.85	2.63	2.45	2.31	2.10	2.16	2.06
6.B 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
-CH ₄	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
-N ₂ O	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
6.D Composting	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
-CH ₄	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
-N ₂ O	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
Total	3.98	4.02	4.04	4.04	3.98	3.93	3.85	3.75	3.60	3.52	3.32	3.19	2.98	2.80	2.67	2.46	2.52	2.43

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	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 been decreased by 43% 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.

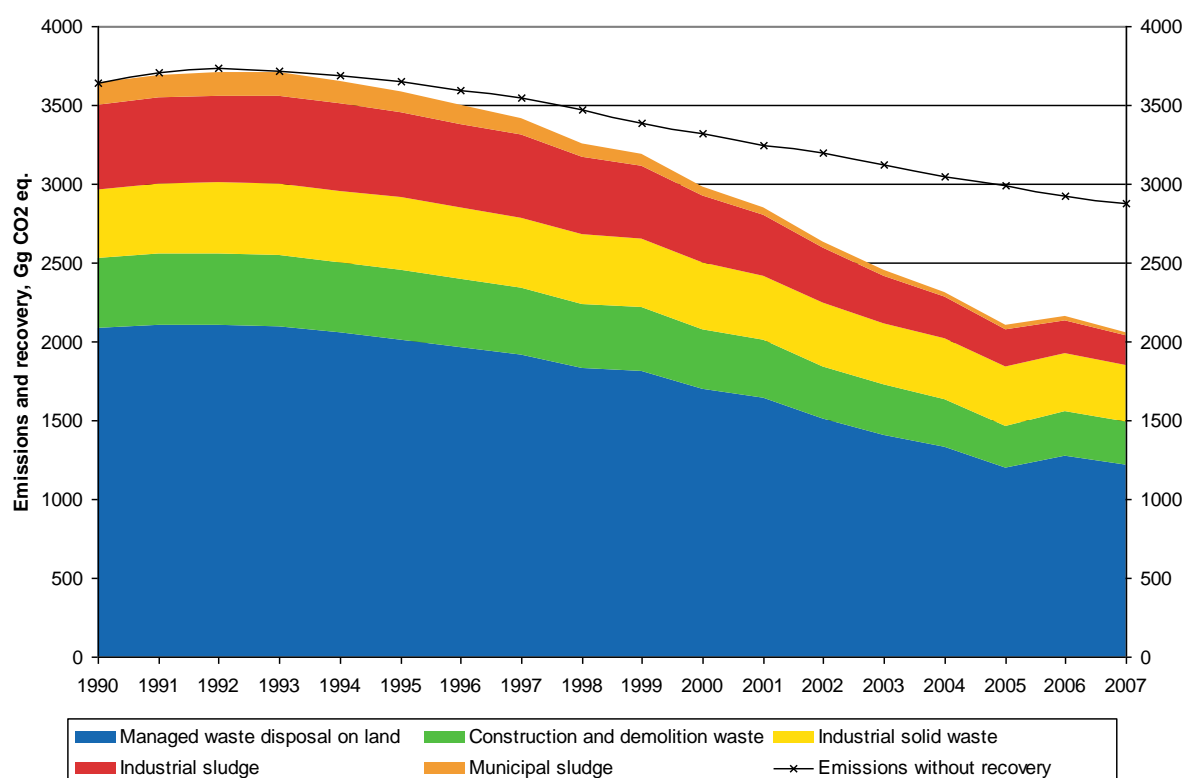


Figure 8.2_1. Methane emissions from solid waste disposal on land and in 1990-2007 (Gg CO₂ eq.)

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 1990-2007 by subcategory (Tg CO₂ eq.).

Source category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
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
Industrial sludge	0.54	0.55	0.55	0.55	0.55	0.54	0.53	0.52	0.50	0.46	0.42	0.38	0.34	0.30	0.26	0.23	0.21	0.19
Industrial solid waste	0.43	0.44	0.45	0.46	0.46	0.46	0.45	0.45	0.44	0.43	0.42	0.41	0.40	0.39	0.38	0.38	0.37	0.36
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
Total	3.64	3.69	3.71	3.70	3.65	3.59	3.50	3.41	3.26	3.19	2.98	2.85	2.63	2.45	2.31	2.10	2.16	2.06

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). 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	DOC	k	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)	0.3	0.03	Isännäinen
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	0.1	0.06	Expert knowledge
Other organic	0.1	0.1	Expert knowledge
Construction and demolition waste			
Plastics	0		IPCC 2006
Other inert	0		IPCC 2006
Asphalt	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

Waste group and subgroups	DOC	k	Reference
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 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
Paper and paperboard	14.9	18.3	21.3	16.5	18.5	22.7
Food	38.5	39.2	37.9	39.8	37.5	36.2
Garden	9.1	8.6	7.6	8.2	7.8	7.4
Plastics (inert)	5.9	6.2	6.5	6.4	7.1	7.3
Glass (inert)	1.6	1.2	1.1	1.2	1.5	0.8
Textiles	2.0	1.8	1.5	1.7	1.7	1.6
Napkins	2.5	3.1	3.3	3.5	3.8	3.6
Wood	6.1	3.7	3.0	3.4	3.2	2.6
Other – inert	15.8	14.6	14.4	15.6	16.0	15.0
Other – organic	3.6	3.4	3.4	3.7	2.9	2.8

Table 8.2_7 DOC-values of municipal solid waste.

DOC	Period												
	1990-1993	1994-1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
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

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 1990-2007 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 et al. 2008) 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.

Table 8.2_8. Landfilled waste in 1990-2007 (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)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
Municipal sludge (d.m.)	47	48	48	47	46	25	21	7	6	5	6	8	6	6	6	6	5	4
Municipal sludge (wet m.)	498	504	510	505	501	298	212	84	71	67	70	79	66	63	58	53	51	39
Industrial sludge (d.m.)	337	318	299	285	268	260	248	229	182	140	118	97	65	42	29	48	44	32
Industrial sludge (wet m.)	1 193	1 129	1 065	999	935	881	790	695	606	559	550	329	209	198	127	161	144	119
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
Constr. and demol. waste	1 262	1 110	781	667	639	637	567	473	409	373	400	401	318	304	304	319	307	297

Table 8.2_9. Landfilled waste in 1990-2007 (1 000 DOC t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Municipal solid waste	422	392	364	336	311	303	288	282	282	292	276	266	259	260	248	255	275	262
Municipal sludge	24	24	24	24	23	12	10	3	3	3	3	4	3	3	3	3	3	2
Industrial sludge	110	104	98	95	92	91	88	83	67	50	41	32	21	13	6	14	13	8
Industrial solid waste	121	115	108	97	87	77	67	56	50	38	40	34	26	20	24	22	25	22
Constr. and demol. waste	134	113	81	69	64	61	55	54	44	38	56	56	44	42	43	44	43	42

Table 8.2_10. Landfill CH₄ recovery in 1990-2007 (Gg) and the number of operating CH₄ recovery plants (Kuittinen et al. 2007).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
Number	0	1	1	2	3	4	6	8	9	10	12	13	26	27	29	33	33	33

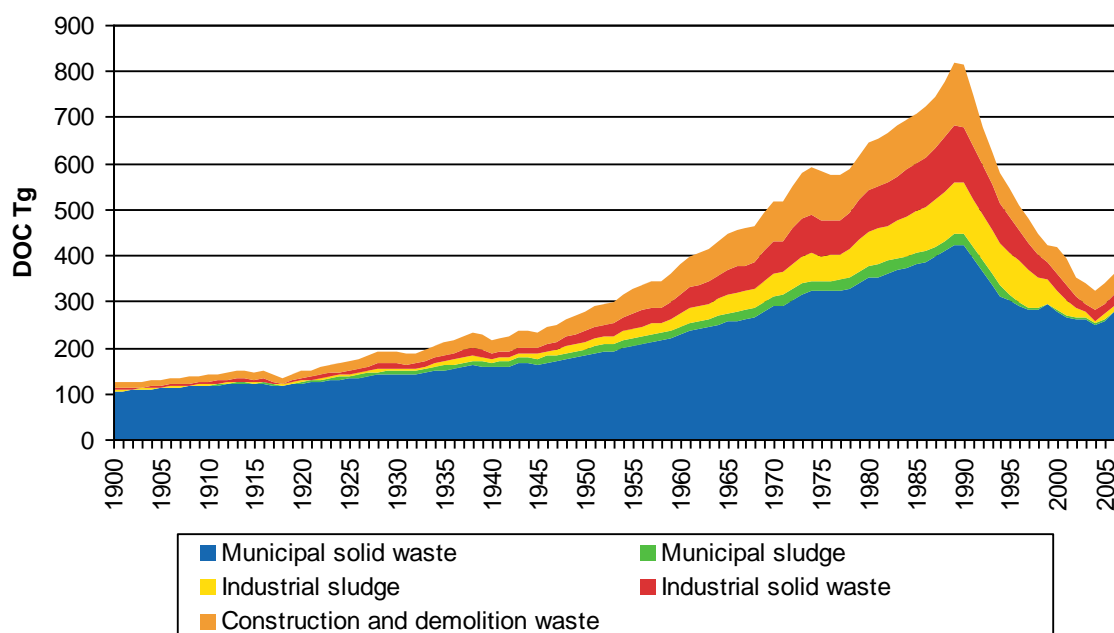


Figure 8.2_2. The DOC Tg of the five waste groups starting from the year 1900.

8.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 5. 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 activity data of the landfilled municipal solid waste for the year 2007 have been compared with the data of Statistics Finland. The activity data of the landfilled municipal solid waste are at the same level as the waste statistics delivered to Eurostat by Statistics Finland.

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 3.1).

8.2.5 Source-specific recalculations

The waste composition of MSW has been the same through the whole time series in the previous submissions. For some waste subgroups (especially paper and paper board) there are good statistics on national consumption and recycling in Finland. Top-down approach has been used for the new waste composition data. The waste composition of solid municipal waste is calculated according to the estimated

composition of generated municipal waste and separately collected waste fractions. Together with the work for the waste composition the landfilled waste amounts was re-estimated. The new waste composition data improves the accuracy of the inventory. However, these improvements to the uncertainty analysis will not be implemented until in the next inventory.

8.2.6 Source-specific planned improvements

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 21% since 1990. Emission trends by sources are presented in Figure 8.3_1.

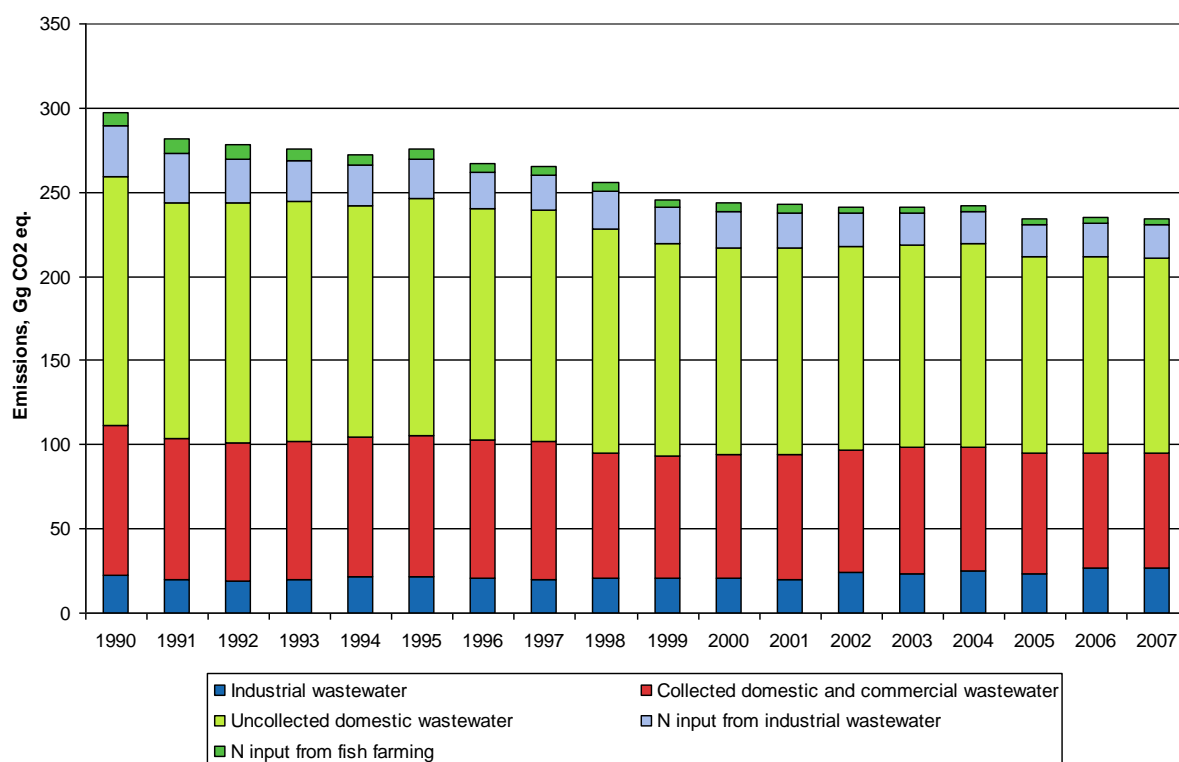


Figure 8.3_1. Emissions from wastewater handling by emission source in 1990-2007 (Gg CO₂ eq.)

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. 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. 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.

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 1990-2007 by subcategory (Tg CO₂ eq).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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	0.134	0.133	0.134	0.130	0.133	0.133
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
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	0.095	0.095	0.092	0.092	0.091
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
Nitrous oxide (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	0.107	0.103	0.102	0.101
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
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	0.026	0.025	0.025	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
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
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	0.241	0.241	0.241	0.234	0.235	0.234

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 (1998-2006) 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 2008).

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 1990-2007 (1 000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Collected BOD ₇ load (municipal wastewater)	121	118	107	109	110	113	110	112	112	118	118	118	125	127	125	130	123	132
Collected BOD ₅ load (municipal wastewater)	103	101	92	93	94	97	94	96	96	101	101	101	108	109	107	112	106	113
Uncollected BOD ₅ load (domestic wastewater)	23	22	22	23	22	22	22	22	21	20	19	19	19	19	19	18	18	18
COD load (industrial wastewater)	847	749	736	769	814	810	784	770	778	779	791	755	932	904	962	900	1 025	1 090

Table 8.3_4. N input from wastewater in 1990-2007 (1 000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
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	5.3	5.1	5.1	5.2
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
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

Table 8.3_5. Population (1000 persons) having uncollected wastewater handling system and protein consumption (g/persons/yr).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Population (1000 persons)	1 067	1 013	1 023	1 041	1 003	1 024	999	983	950	907	884	877	867	860	857	834	831	822
Protein consumption (g/persons/yr)	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	103.8	105.0	105.4	106.0	107.8

8.3.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 5. 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 2006 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 industrial wastewater and in uncollected domestic wastewater handling (2006) for more accurate activity data due to an added industrial load in Vahti system and due to preliminary information on protein consumption.

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.

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

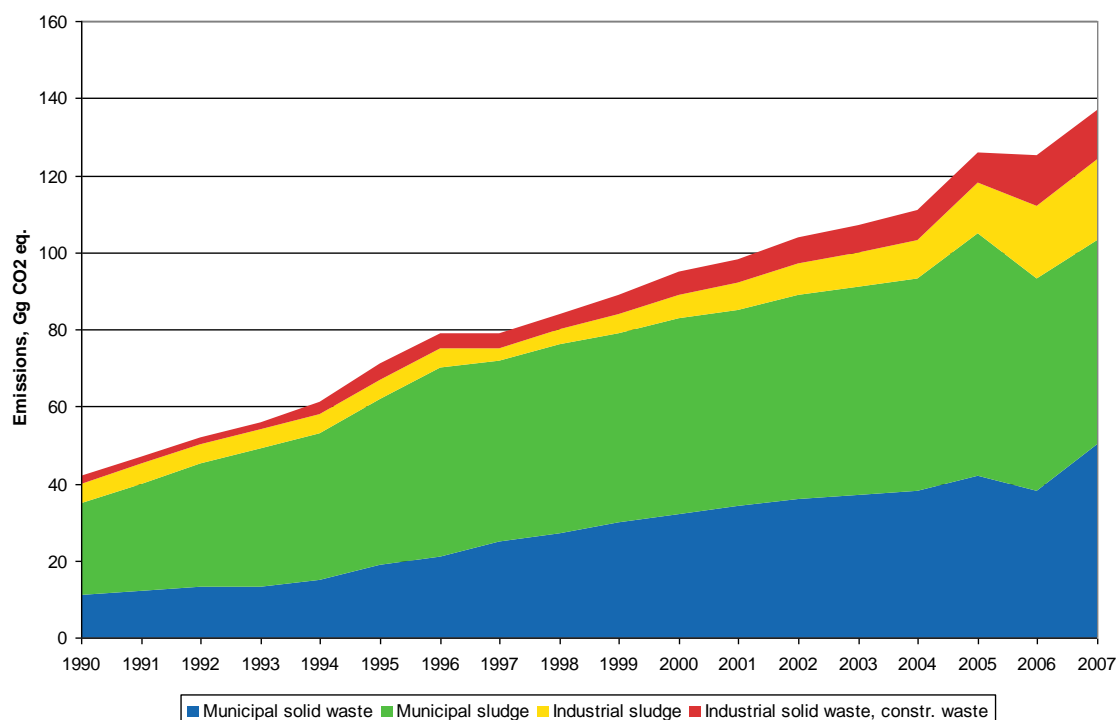


Figure 8.5_1. Greenhouse gas emissions from composting in 1990-2007 (Gg CO₂ eq.)

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 threefold since 1990, being almost 6% of the Waste sector's emissions in 2007. 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.

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 5. 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 (±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

No source-specific improvements are planned for this category.

Table 8.5_3. Emissions from composting in 1990-2007 by subcategory (Tg CO₂ eq).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
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
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
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
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
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
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
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
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
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
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
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

Table 8.5_4. Composted waste with auxiliary matter in 1990-2007 by subcategory (1 000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Municipal solid waste	60	66	72	77	83	102	122	141	154	167	180	190	199	209	218	233	213	280
Municipal sludge (d.m.)	60	72	83	90	97	110	123	120	123	125	128	131	133	136	138	159	138	135
Industrial sludge (d.m.)	13	12	12	12	12	12	12	7	10	13	15	18	21	23	26	32	47	53
Industrial solid waste	12	13	14	16	17	18	19	21	24	28	31	34	38	41	45	45	75	75

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 / yr)

$L_0(x) = MCF(t) * DOC(x) * DOC_F * F * 16 / 12$ (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))

DOC_F = 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:

$$\text{CH}_4 \text{ emitted in year } t \text{ (Gg / yr)} = [\text{CH}_4 \text{ generated in year } t - R(t)] * (1 - OX)$$

where

$R(t)$ = Recovered CH₄ in inventory year t (Gg / yr)

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 2007
(Kuittinen et al, 2008)*

Name of a plant	Volume of collected gas, 1 000 m ³
Vuosaari, Helsinki	1 545
Seutula, Vantaa	1 347
Kiertokapula, Hyvinkää	2 400
Kiertokapula, Hämeenlinna	1 100
Porvoo	760
Espoo, Ämmässuo	59 901
Espoo, Mankkaa	1 403
Tampere	6 000
Oulu	7 510
Kerava	300
Lappeenranta	338
Lohja	200
Joensuu	2 942
Pori	1 653
Simpele	200
Lahti	3 490
Jyväskylä	3 500
Nokia	1 250
Kouvola	1 000
Iisalmi	900
Järvenpää	100
Mikkeli	560
Raisio	500
Rovaniemi	1 668
Turku	1 400
Uusikaupunki	300
Kajaani	530
Myllykoski Paper, Anjalankoski	700
Kuopio, Silmäsuu	900
Kuopio, Heinälamminrinne	1 190
Anjalankoski	900
Vaasa	800
Imatra	600

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 1990-2006 can also be found in CRF tables 8(a)s1-8(a)s2 and 8(b) of the relevant years.

In the **Energy Sector (1.A)** there were three types of recalculation:

- transfer of CO₂ to PCC: the share of stored CO₂ was reported as negative emission figures in subcategory 1.A.2.f
- time series of gasoline consumption and corresponding CO₂ emissions in 1.A 3b Road Transport were slightly revised to ensure full consistency between Energy Statistics and GHG inventory
- minor corrections were made in the point sources' data (activity, combustion technology or allocation) to remove inconsistencies in plant level data (mainly 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.

In addition some preliminary fuel consumption figures for 2006 were substituted with final data.

In **Energy Sector (1.B)** there were only minor recalculations done. Flaring emission of one company was corrected. NMVOC emissions from the petrol distribution chain and refuelling of vehicles have been recalculated from year 2005 onwards. Average carbon content in NMVOC was estimated to be 80% in oil reefing based on the IPCC 2006 GL.

Under **Industrial processes** (CRF 2) emissions from cement production (2.A 1) have been recalculated to ensure the consistency of time series. Methane emissions from ethylene production (2.B 5) have been removed due to new information received in a plant visit, where it became clear that no gas is emitted from this process, because all methane is used in energy production. The calculation method of a hydrogen producing company was corrected. Small corrections have been done in amounts of used carbonates in categories 2.A 2, 2.A 3 and 2.A 7. Average carbon content in NMVOC was estimated to be 80% in road paving with asphalt, chemical and steel production based on the IPCC 2006 GL.

In the **Agriculture sector** (CRF 4) a small correction was made for year 2006 to category CRF 4.A Enteric fermentation concerning the milk production and CH₄ emissions of dairy cows for year 2006. In CRF 4.B.Manure management several small corrections were made, which had only minor impact on emissions (see sub chapter 6.3.5.). In agricultural soils category (CRF 4 D) the time series for N₂O emissions from crop residues was changed as the burned amount was reduced from the total amount of residue. Nitrogen input in sewage sludge was updated for the year 2006. As corrections were made for nitrogen excretion in manure there were changes in time series since 1994 for atmospheric deposition and leaching /run-off.

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). Two main reasons for recalculation in CRF 5.A category were bugs found in the programs used for area and tree biomass estimation and a supplement to NFII0 data. In the categories CRF 5.D and CRF 5(II) new emission factors for peat extraction areas were applied and a corrected time series for area data were used. In the category CRF 5(V) the mean volumes of the growing stock on forest land were re-produced based on re-estimated Forest Land area and total growing stocks. In CRF 5.B an estimate for living biomass on croplands was added to the time series. The area of cropland on organic soil was updated for the year 2005 and the area estimate for high input in croplands was updated for year 2006. In CRF 5.C

area estimates were updated for the time series. Also the area estimates for Settlements (CRF.5.E) and Other land categories (CRF 5.F) were recalculated (no C stock changes from these categories are reported).

In the **Waste sector** (CRF 6) recalculations have been made for nitrous oxide emissions in uncollected domestic wastewater (CRF 6.B 2) and in industrial wastewater (CRF 6.B 3) for the year 2006 to improve the accuracy of activity data. The time series of the waste composition of MSW was estimated and the landfilled waste amounts were re-estimated together with the top-down approach of the estimation of the waste composition (CRF 6.A). The new DOC and k values introduced in 2006 IPCC Guidelines were implemented (CRF 6.A 1 and 6.A 3).

Table 10.1_1. Recalculations made for the 2008 inventory submission by CRF category and their implications to the emission level in 1990 and 2006.

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 2006	in 1990	in 2006
1.A. Fuel combustion			-33.25	-367.67	-0.047	-0.469
1. Energy Industries	Corrections in plant level data (activities, technology, allocation)	Correction of errors (time series consistency)	2.04	-50.78	0.003	-0.065
2. Manufacturing industries and construction	Corrections in plant level data (activities, technology, allocation) Subtraction of transferred CO ₂	Correction of errors (time series consistency), Completeness	1.47	-132.57	0.002	-0.169
3. Transport	Correction in gasoline consumption.	Consistency between Energy Statistics and GHG inventory data.	-33.63	-6.51	-0.047	-0.008
4. Other sectors	Corrections in plant level data (activities, technology, allocation)	Correction of errors (time series consistency)	0.00	-54.35	0.000	-0.069
5. Other	Preliminary data for 2006 substituted with final data. Corrections in other subcategories are partly reflected in this subcategory.	Time series consistency; Preliminary data for 2006 substituted with final data	-3.12	-123.46	-0.004	-0.158
1.B. Energy - Fugitive emissions	Flaring in oil industry Oil and natural gas	Flaring emission of one company was corrected. NMVOC emissions from the petrol distribution chain and refuelling of vehicles have been recalculated from year 2005 onwards. Average carbon content in NMVOC was estimated to be 80% due to IPCC 2006 GL..	-5.98	0.73	-0.008	0.001
2. Industrial Processes			-62.47	-33.47	-0.088	-0.009
A. Mineral products	Cement production	Emissions from cement production were recalculated to improve the consistency of time-series. Road paving with asphalt: Average carbon content in NMVOC was estimated to be	-53.35	9.20	-0.075	0.012

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 2006	in 1990	in 2006
		80% due to IPCC 2006 GL.				
B. Chemical industry	Ethylene production and hydrogen production	Emissions of ethylene production were removed from the time-series due to new information that no emissions occur in that process. Emission calculation of one hydrogen production plant was corrected. Chemical production: Average carbon content in NMVOC was estimated to be 80% due to IPCC 2006 GL.	-9.04	-16.65	-0.013	-0.020
C. Metal Production		Steel production: Removal of double counting (2006). Average carbon content in NMVOC was estimated to be 80% due to IPCC 2006 GL.	-0.08	-26.02	0.000	-0.033
4. Agriculture			12.26	23.47	0.017	0.030
A. Enteric B. Fermentation	Time series was recalculated.	Milk production for the year 2006 was corrected and thus CH ₄ emissions of dairy cows changed. Fur animals were included in the time series.	10.83	21.55	0.015	0.027
C Manure Management	N ₂ O emissions corrected since 1994, CH ₄ emissions for year 2006	Some small calculation/transfer errors: CH ₄ emissions: VS for dairy cows for year 2006 corrected. N ₂ O emissions: poultry & fur animals corrected since 1994, calves for yr. 2006	0.00	1.55	0.000	0.002
D. Agricultural Soils	Time series changed.	Sewage sludge for year 2006 was updated. Emissions from crop residue were changed as the amount burned is now subtracted. As amount of manure was corrected since 1994, also small changes to leaching/runoff and atm. deposition.	-1.00	-0.07	-0.001	0.000
F Field Burning of Agricultural Residues		A new source category	2.43	0.44	0.003	0.001

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 2006	in 1990	in 2006
5. Land use, Land Use Change and Forestry			669.32	1 236.45		
A. Forest land	The CO ₂ uptake in living biomass: time series for growth 1997-2006 was recalculated. Tree biomass used for an input data for Yasso model was recalculated for 1990-2006. Time series for organic and mineral soils was recalculated.	Correction of bugs in the program used for the area and mean volume estimation. New NF110 data added into end of the time series.	-145.00	152.65		
B Cropland	The emissions from cropland remaining cropland were recalculated.	An estimate for living biomass on croplands has been added. Organic farming area (high input) was updated for year 2006. The area of cropland on organic soil was updated for the year 2005..	-1.44	11.47		
C. Grassland	The emissions from grassland remaining grassland were recalculated.	Area estimates were updated for the time series.	336.92	410.65		
D. Wetlands	A corrected area data for the years 1996-2006 was used. New country specific emission factors for CO ₂ , N ₂ O and CH ₄ were applied to peat extraction areas.	Since 1996 the area data are compiled electronically to a database. A project was carried out to check the correctness of the data. The result of the project was corrected areas for 1996-2006. New published country specific emission factors were available.	478.85	661.69		
6. Waste			5.70	21.09	0.008	0.027
A. Solid Waste Disposal on Land	Waste composition (DOC) and waste amounts for MSW	Estimation of the time series of waste composition for MSW was done for the first time. With the top-down approach for the waste composition the waste amounts were re-estimated.	5.70	20.34	0.008	0.026

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 2006	in 1990	in 2006
	IPCC 2006 Guidelines for DOC and k values	Waste composition for MSW includes waste categories which are not mentioned in earlier IPCC Guidelines.				
B. Wastewater Handling	N-load for industrial wastewater in 2006	More accurate activity data due to an added industrial load in Vahti system.	0.00	0.76	0.000	0.001
	Protein consumption for human sewage (uncollected wastewater)	Instead of preliminary information final data were available for 2006 protein consumption.				

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)	Fuel shift in transport models (separation of gasoil for non-road use from heating gasoil)	2010 submission (depending on the Energy statistics)
CRF 1.A 3 (Transport)	Improving the calculation of emissions from leisure boats.	2009-2010
CRF 4 (Agriculture)	CRF 4.B (Manure management) and CRF 4.D (Agricultural soils) The methods to update the distribution of different manure management systems regularly will be explored. The possibility to take a new N ₂ O model into use will be considered.	2009-2010
CRF 5 (LULUCF)	The methodology for estimating carbon stock changes in Cropland and Grassland will be reviewed. The distribution of cultivated organic soils into different crop types will be checked in 2009.	2010 submission
CRF 5 (LULUCF)	Inclusion of N ₂ O emissions from disturbance associated with land-use conversion to cropland (CRF 5 (III))	2010 submission
CRF 5 (LULUCF)	Development of methodology to identify transitions between land-use categories.	2010 submission
CRF 5 (LULUCF)	Finland do not adhere the minimum area of 0.5 ha for FAO Forest land. An investigation will be done to have correct areas for FAO forest land.	2010 submission
CRF 5 (LULUCF)	The method to estimate carbon stock changes in living biomass on Forest land is under review (CRF 5.A). When a new method has been chosen, the same biomass estimation method will be used for all biomass calculations.	2010 submission
CRF 5 (LULUCF)	At the moment Finland defines organic soils in Forest land according to the NFI definition for peatlands. This definition will be reviewed and consolidated with the definition for organic soils used in the Agriculture sector.	2010 submission
CRF 6 (Waste)	CRF 6.B (Wastewater Handling) The activity data in the Vahti system for wastewater handling will be checked	2010 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.	2010 submission

Table 10.4_2 summarises Finland's responses to the review of the initial report under the Kyoto Protocol and the 2006 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 2007 inventory submission.

CRF	Comment	Finland's response	Where in NIR
General	The QA/QC procedures need further strengthening	The quality management system forms an integral part of the national system and the annual inventory process. The description of the system and its implementation in 2008-2009 is updated,	Section 1.6
General	The ERT encouraged Finland to further improve the transparency of the NIR.	The descriptions in the NIR have been updated and improved and separate sections for key categories have been added.	For specific improvements, see below
General	The ERT recommended Finland to provide a summary of the changes of uncertainty estimates.	Finland has revised its uncertainty estimation as a whole.	Section 1.7 and Annex 5
1.A 3	The ERT noted that the NIR describes the trends at an aggregate level, but does not provide an explanation of technological changes in road transportation and of changes in the vehicle composition. The ERT encourages Finland to further improve transparency by adding more explanations of emissions trends of subcategories.	The table showing gasoline shares with catalytic converter and without has been added to the report.	Table 3.3_&
1	The ERT encourages Finland to include in its next annual submission the main results of checks performed on point source data.	The table about point source QC has been added to the report.	Table 3.2_6.
1	The checking of the N2O EF for gasoline from road transportation and the inclusion of a separate chapter in the NIR on this key category	The emission factors will be checked and updated as appropriate for the next submission.	Section 3.3.2.7
1	The ERT recommends that Finland include an explanation of the NCVs used for the entire time series in its next inventory submission.	The matter about NCV has been described in the NIR.	Section 3.2.4.
1	The ERT noted that explanations for the differences are provided for all years, but for cases the large discrepancies in the early 1990s the explanations are not sufficient. The ERT encourages Finland to continue its efforts to better explain these differences.	The text has been added to the NIR.	Section 3.8.
1	The ERT noted that annex 3 of the NIR provides a country-specific analysis of the CO ₂ EF for coal and indicates EFs that are higher than the IPCC default values. It also indicates that EF varies over time.	This has been checked and corrected except wood fuels.	Section 3.8.
1	The ERT noted that the data used by Finland to report the amount of carbon stored differ from the data provided by the Revised 1996 IPCC Guidelines. The ERT also noted that Finland uses an incorrect conversion factor for ktoe to TJ for crude oil (42.66); the correct international standard factor is 41.86. The ERT recommends that Finland provide an explanation for differences mentioned above or correct the values in the next submission.	This has been checked and corrected.	Section 3.8.
1	The ERT recommends that Finland extend the justification of the differences between the approaches (sectoral, reference and additional approach) applied in its next inventory submission.	This Annex 4 is a voluntary QA/QC procedure of energy sector's CO ₂ calculations. We are excluded it from the NIR but the procedure will be done for this submission.	Annex 4 is now removed from the NIR and explained in 3.2.4.
1	The ERT recommends that, for those fuels where variations occur, Finland include the annual NCVs in a tabular format in its next inventory submissions for transparency reasons.	Time series have been corrected.	Section 3.7
1 B	The ERT noted that the NIR provides only the method applied and the C-content value of the NMVOC emissions used and encourages Finland to further explain the reasons for this transformation.	The methodology is from 2006 GLs and C-content is estimated using literature references as mentioned in the NIR.	Section 3.6.2.1.
1	The ERT recommends that Finland report peat under fossil fuels or provide an explanation for reporting peat under other fuels in its next inventory submission.	A new explanation has been provided to NIR.	Section 3.2.2.2

CRF	Comment	Finland's response	Where in NIR
2.B 2 and 2.C 1	The ERT encourages Finland to provide additional explanation of the trends of IEFs and verification of the data (for example, for N ₂ O emissions from nitric acid production and for CO ₂ emissions from iron and steel production).	Finland couldn't give any more precise data due to confidential reasons in Nitric acid production. The quality system of measurements in the plants will be studied as a source category-specific QC procedure.	Section 4.3.2.7
2.C 1 and 1.B 2	The ERT recommends that Finland provide such relevant information (justification of such a transformation and relevant methodologies on indirect CO ₂ emissions from CH ₄) in its next inventory submission.	Methodology is from IPCC 2006 Guidelines. The explanation was attached to the NIR, section 3.6.2.1, where the calculation was first introduced.	Section 3.6.2.1.
2.A 1	The ERT welcomes further exploration of this matter (determination of calcium oxide and magnesium oxide contents of clinker) and recommends that Finland provide the findings in its next inventory submission.	The total time-series of cement production was recalculated.	Section 4.2.2.
2.B 2	The ERT recommends that Finland provide complete trends of EFs and relevant data calculations in its next inventory submission.	Finland couldn't give any more precise data due to confidential reasons in Nitric acid production. The quality system of measurements in the plants will be studied as a source category-specific QC procedure.	Section 4.3.2.7
2.C 1	The ERT recommends that Finland provide relevant verification data to demonstrate the accuracy of CO ₂ emissions from iron and steel production.	It seems impossible to get any more data to verify the emissions because all available data have been used.	Section 4.4.
2.A 4	The ERT recommends that Finland check coverage of these data and provide relevant description in its next inventory submission.	Finland checked the coverage from industrial statistics and no other sources were found.	Section 4.2.5.3.
4.A	Finland produces more than 3.7 million fur-farming animals per year, the highest production of all Annex I Parties, but has reported emissions from fur-farming livestock as NE.	Fur animals' emissions are now included in the inventory.	Section 6.2.
	Finland may wish to provide a full nitrogen balance, for manure management and agricultural soils, for the entire time series in the NIR; this will improve the transparency of the reporting.	Finland has added a diagram of nitrogen balance to the inventory with figures from the year 2007.	Section 6.1.
4.D	Finland stated that it subtracted FracGASF and FracGASM from the nitrogen inputs before applying the FracLEACH value of 0.15. The ERT noted that this is not in line with the IPCC good practice guidance, which advises that FracLEACH should be applied to total synthetic fertilizer and animal manures unadjusted for volatilization of NO _x and ammonia (NH ₃). The ERT recommend that Finland revise this emission estimation in its next inventory submission.	Finland has explained this issue in the inventory in section 6.4.	Section 6.4.2.3.
4.F	Finland stated that field burning of crop residues occurs occasionally on a small scale, but it considers emissions to be negligible and reports them as not occurring.	Burning of residues is now included in the inventory.	Section 6.5.
5.A	The ERT noted that the impact of recalculations of the changes of the areas among the different land-use categories is less than 1 per cent. On the other hand, the ERT noted that the impact of the recalculation of the CO ₂ uptake in tree biomass is quite high and varies from 2.8 per cent in 1998 to +11.9 per cent in 2004, which implies changes in methodologies applied.	The higher variation in the tree biomass compared to land areas is due to additional data in the NFI 10. This issue is explained in the NIR on page 247. Additional year with NFI measurements may fluctuate biomass increment, while land areas are typically more static. Method is equivalent between submissions.	
5.C	Finland explained that this trend [grassland remaining grassland from sink to source] was caused by an increase in the area of grassland in the 1970s and a decrease since 1990. The ERT could not fully follow the explanation in the NIR, which is based on the fact that a decreasing area causes an increasing emission; it invites Finland to explain the context more transparently.	The high variation between the year's results from the lack of a proper estimate for the grassland remaining grassland and land converted to grassland. The remaining area should be the same in the inventory year and 20 years prior to it. In the current calculation method, the area of grassland remaining grassland in the inventory year and 20 years prior to the	Section 7.4.1.

CRF	Comment	Finland's response	Where in NIR
		inventory year are different and that results in unrealistic changes in carbon stocks. The situation will be corrected as soon as the tracking system for land use changes is developed and the remaining grassland area can be separated from the area converted to grassland.	
5.C	The ERT noted that tier 1 approach applies only in the case of a change of the management regime, but Finland does not indicate such a change of the grassland management regime. The ERT recommends that Finland explore the possibilities of applying a higher tier approach for this key category, and include information on the changes in grassland management in its next inventory submission.	The possibility to use the Yasso –model, which is used for estimating carbon stock changes in forests, for estimating carbon stock changes in grasslands is being examined in an ongoing project .	Section 7.4.6.
	To further strengthen the QA/QC procedures, in particular in agriculture, in order, for example, to ensure consistent nitrogen amounts in manure management and soil emissions	Finland will endeavour to improve QA/QC procedures in agriculture.	
6.A	The ERT encourages Finland to improve the transparency of data compilation and estimation of the historical waste amount.	Data compilation and estimation of the historical waste amount is explained and presented in the NIR.	Section 8.2.2.3
6.A	The ERT recommends that Finland explain how the average MCF has been derived in the next annual submission.	Presented in the NIR.	Section 8.2.2.2
6.A	The ERT recommends that Finland update information on waste composition and the DOC corresponding to the total amount of waste	The time series of the waste composition are presented in the NIR and implemented to the calculation of methane emissions	Section 8.2.2.2
6.B	The ERT recommends that Finland explain the expert judgment of the MCF and provide description of the wastewater system	Presented in the NIR	Section 8.3.2
6.B	The ERT recommends that Finland use the IPCC method based on the maximum CH ₄ producing capacity and the weighted average MCF as provided in the IPCC Good Practice Guidance	Finland has used the mentioned IPCC method for all other subcategories except for uncollected domestic wastewater (septic tanks). For septic tanks Finland use the Check Method presented in the IPCC Good Practice Guidance, also. For MCF in septic tanks there has been no IPCC default value until IPCC 2006 Guidelines. The default value of the MCF of septic tanks in the "unofficial" IPCC 2006 Guidelines is not suitable for the conditions in Finland.	Section 8.3.2
6.	The ERT recommends that Finland implement QA procedures, at least for key categories, for the future inventory submissions.	The activity data of landfilled municipal solid waste are compared and checked with the data of Statistics Finland.	Section 8.2.4
6.	The ERT recommends that Finland provide more explanation on some uncertainty estimates based on expert judgment.	Details on 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.	
KP issues	The ERT recommends Finland to include information on its commitment period reserve in its next submission.	The commitment period reserve has not changed since the previous submissions. This information is now provided in the NIR.	Annex 7
KP issues	The ERT recommended Finland to reconsider and elaborate the voluntary reporting under Article 3, paragraphs 3 and 4	This reporting will improved when the reporting starts in 2010. Finland has not provided voluntary reporting on the issue in 2009..	

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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 2007
- 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 5 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	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	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'	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
Sum		70862.24	-17772.94	0.314	1.000		1.000	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	..	10027.37	0.062	..	..	0.198	0.198
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	..	6584.34	0.048	..	..	0.153	0.351
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	..	-26348.41	0.045	..	..	0.144	0.495
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3377.61	..	0.019	0.168	0.168	0.060	0.556
4.D.Agricultural soils: indirect emissions	N2O	922.24	..	0.018	0.161	0.329	0.058	0.614
5.C1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	..	-2231.99	0.018	..	0.329	0.056	0.670
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	..	-2363.291	0.017	..	0.329	0.055	0.725
2.B.2 Nitric Acid Production	N2O	1655.71	..	0.013	0.117	0.446	0.042	0.767
6.A. Solid Waste disposal on Land	CH4	3644.52	..	0.012	0.110	0.556	0.040	0.806
1.A. Fuel Combustion - solid fuels	CO2	14591.85	..	0.012	0.104	0.660	0.037	0.844
1.A. Fuel Combustion - liquid fuels	CO2	27779.59	..	0.006	0.055	0.716	0.020	0.863
4.A.Enteric fermentation	CH4	1928.87	..	0.005	0.044	0.759	0.016	0.879
4.B.Manure management	N2O	664.76	..	0.004	0.038	0.798	0.014	0.893
5.A.1. Forest Land remaining Forest Land - net carbon stock change in dead organic matter	CO2	..	-4539.15	0.004	..	0.798	0.011	0.904
1.A. Fuel Combustion - other fuels	CO2	5693.53	..	0.003	0.026	0.824	0.009	0.914
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	74.79	..	0.002	0.020	0.844	0.007	0.921
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.42	..	0.002	0.019	0.863	0.007	0.928
1.A.4. Other Sectors - biomass	CH4	161.28	..	0.002	0.017	0.880	0.006	0.934
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	..	214.08	0.002	..	0.880	0.005	0.939
	CO2, CH4,							
5.D2. Land Converted to Wetlands - peat production areas	N2O	..	1078.05	0.002	..	0.880	0.005	0.945
2.C.1 Iron and Steel production	CO2	1861.21	..	0.001	0.013	0.893	0.005	0.949
5 (IV) CO2 Emissions from Agricultural Lime Application	CO2	..	617.87	0.001	..	0.893	0.004	0.954
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	59.42	..	0.001	0.011	0.904	0.004	0.958
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	32.01	..	0.001	0.009	0.913	0.003	0.961
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.55	..	0.001	0.008	0.921	0.003	0.964
6.B.3. N input from industrial wastewater	N2O	30.17	..	0.001	0.008	0.929	0.003	0.967
1.A.3.b. Road Transportation - diesel	N2O	68.12	..	0.001	0.008	0.936	0.003	0.969
5.G Other (harvested wood products)	CO2	..	-945.64	0.001	..	0.936	0.003	0.972
5 (I) Direct N2O Emissions from N Fertilization	N2O	..	26.82	0.001	..	0.936	0.003	0.975
5.C1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	..	100.78	0.001	..	0.936	0.002	0.977
2.F.8 Electrical Equipment	SF6	86.52	..	0.001	0.005	0.942	0.002	0.979
1.A. Fuel Combustion - gaseous fuels	CO2	4970.23	..	0.001	0.005	0.947	0.002	0.981
1.B.2. Oil and Natural Gas - flaring	CO2	122.80	..	0.000	0.004	0.951	0.002	0.982
1.A.4. Other Sectors - liquid fuels	N2O	56.43	..	0.000	0.003	0.954	0.001	0.983

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	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'	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
1.A.4. Other Sectors - biomass	N2O	27.77	..	0.000	0.003	0.957	0.001	0.984
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	114.23	..	0.000	0.003	0.960	0.001	0.985
2.A.1 Cement Production	CO2	733.59	..	0.000	0.003	0.963	0.001	0.986
1.A.3.b. Road Transportation - gasoline	CH4	77.85	..	0.000	0.003	0.965	0.001	0.987
4.B.Manure management	CH4	229.81	..	0.000	0.003	0.968	0.001	0.988
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.43	..	0.000	0.002	0.970	0.001	0.989
6.B.3. N input from Fish Farming	N2O	8.28	..	0.000	0.002	0.973	0.001	0.990
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	46.87	..	0.000	0.002	0.975	0.001	0.991
1.A.1 Energy Industries - solid fuels	N2O	43.40	..	0.000	0.002	0.976	0.001	0.991
6.B.1 Industrial Wastewater	CH4	22.23	..	0.000	0.002	0.978	0.001	0.992
3. Solvent and Other Product Use	N2O	62.00	..	0.000	0.002	0.980	0.001	0.993
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	36.98	..	0.000	0.002	0.981	0.001	0.993
1.A.1 Energy Industries - other fuels	N2O	34.64	..	0.000	0.001	0.983	0.001	0.994
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	17.07	..	0.000	0.001	0.984	0.000	0.994
1.A.1 Energy Industries - liquid fuels	N2O	25.03	..	0.000	0.001	0.985	0.000	0.994
2.A.2 Lime Production	CO2	382.60	..	0.000	0.001	0.986	0.000	0.995
1.A.4. Other Sectors - liquid fuels	CH4	18.18	..	0.000	0.001	0.987	0.000	0.995
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.37	..	0.000	0.001	0.988	0.000	0.995
6.D Other: compost production	CH4	21.55	..	0.000	0.001	0.989	0.000	0.996
6.D Other: compost production	N2O	20.43	..	0.000	0.001	0.989	0.000	0.996
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.45	..	0.000	0.001	0.990	0.000	0.996
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.01	..	0.000	0.001	0.991	0.000	0.997
2.A.3 Limestone and Dolomite Use	CO2	88.02	..	0.000	0.001	0.992	0.000	0.997
1.A.1 Energy Industries - gaseous fuels	N2O	15.63	..	0.000	0.001	0.992	0.000	0.997
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.26	..	0.000	0.001	0.993	0.000	0.997
2.B.1 Ammonia Production	CO2	44.00	..	0.000	0.001	0.994	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	N2O	4.86	..	0.000	0.001	0.995	0.000	0.998
1.B.2. Oil and Natural Gas - oil refining	CH4	7.56	..	0.000	0.000	0.995	0.000	0.998
1.A.3.b. Road Transportation - diesel	CH4	11.75	..	0.000	0.000	0.995	0.000	0.998
1.A.3.e. Other Transportation - diesel	N2O	3.84	..	0.000	0.000	0.996	0.000	0.998
1.A.5. Other - liquid fuels	N2O	8.89	..	0.000	0.000	0.996	0.000	0.998
1.A.3.d Navigation - gasoline	CH4	4.13	..	0.000	0.000	0.997	0.000	0.999
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.80	..	0.000	0.000	0.997	0.000	0.999
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.56	..	0.000	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	CH4	..	4.00	0.000	..	0.997	0.000	0.999
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	24.41	..	0.000	0.000	0.998	0.000	0.999

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	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'	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
1.A.3.e. Other Transportation - gasoline & diesel	CH4	4.61	..	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
5 (V) Biomass Burning	CO2	..	3.26	0.000	..	0.998	0.000	0.999
1.A.3.c. Railways	N2O	1.51	..	0.000	0.000	0.998	0.000	0.999
1.A.4. Other Sectors - other fuels	N2O	1.47	..	0.000	0.000	0.998	0.000	0.999
1.A.1 Energy Industries - biomass	N2O	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	0.999
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.54	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - other fuels	CH4	2.47	..	0.000	0.000	0.999	0.000	1.000
1.A.5. Other - liquid fuels	CH4	2.36	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - solid fuels	CH4	2.29	..	0.000	0.000	0.999	0.000	1.000
2.C.1 Iron and Steel production	CH4	5.11	..	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	CH4	1.51	..	0.000	0.000	0.999	0.000	1.000
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	0.99	..	0.000	0.000	0.999	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	N2O	1.17	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	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	CH4	1.24	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.08	..	0.000	0.000	1.000	0.000	1.000
1.A.1 Energy Industries - gaseous fuels	CH4	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	CH4	1.01	..	0.000	0.000	1.000	0.000	1.000
1.A.1 Energy Industries - liquid fuels	CH4	0.97	..	0.000	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	N2O	0.29	..	0.000	0.000	1.000	0.000	1.000
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	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	N2O	0.59	..	0.000	0.000	1.000	0.000	1.000
5 (V) Biomass Burning	N2O	..	0.41	0.000	..	1.000	0.000	1.000
1.A.3.a Civil Aviation	CH4	0.27	..	0.000	0.000	1.000	0.000	1.000
1.A.3.c. Railways	CH4	0.23	..	0.000	0.000	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	CH4	0.39	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - gaseous fuels	N2O	0.31	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	CH4	0.22	..	0.000	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	N2O	0.22	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	CH4	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

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	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'	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.57	..	0.000	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	CH4	0.06	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	CH4	0.04	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - solid fuels	N2O	0.01	..	0.000	0.000	1.000	0.000	1.000
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	0.01	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - solid fuels	CH4	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

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 2007

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	2007 estimate, non-LULUCF	2007 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		78345.35	-25265.63	0.297	1.000		1.000	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	..	-32665.77	0.051	..	..	0.173	0.173
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	..	6725.30	0.038	..	..	0.128	0.302
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	..	4617.71	0.031	..	..	0.104	0.406
5.C1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	..	4016.30	0.029	..	..	0.098	0.504
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	..	-3624.70	0.024	..	..	0.082	0.585
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	525.10	..	0.014	0.137	0.137	0.049	0.634
4.D.Agricultural soils: indirect emissions	N2O	745.50	..	0.013	0.128	0.264	0.045	0.679
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	2442.75	..	0.013	0.119	0.384	0.042	0.722
1.A. Fuel Combustion - solid fuels	CO2	16768.36	..	0.012	0.117	0.501	0.042	0.763
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	..	-1534.30	0.011	..	0.501	0.038	0.801
2.B.2 Nitric Acid Production	N2O	1482.05	..	0.011	0.102	0.603	0.036	0.837
6.A. Solid Waste disposal on Land	CH4	2060.68	..	0.006	0.061	0.664	0.022	0.859
1.A. Fuel Combustion - liquid fuels	CO2	25769.93	..	0.005	0.050	0.714	0.018	0.876
1.A. Fuel Combustion - other fuels	CO2	11015.16	..	0.005	0.050	0.764	0.018	0.894
4.A.Enteric fermentation	CH4	1559.95	..	0.004	0.035	0.799	0.012	0.906
4.B.Manure management	N2O	497.01	..	0.003	0.028	0.827	0.010	0.916
5.A.1. Forest Land remaining Forest Land - net carbon stock change in dead organic matter	CO2	..	-3269.38	0.002	..	0.827	0.008	0.924
1.A.4. Other Sectors - biomass	CH4	179.65	..	0.002	0.019	0.846	0.007	0.931
	CO2, CH4,							
5.D2. Land Converted to Wetlands - peat production areas	N2O	..	1379.51	0.002	..	0.846	0.007	0.938
2.C.1 Iron and Steel production	CO2	2459.53	..	0.002	0.017	0.863	0.006	0.944
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	818.68	..	0.002	0.015	0.877	0.005	0.949
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	52.93	..	0.001	0.014	0.891	0.005	0.954
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	271.56	..	0.001	0.012	0.903	0.004	0.958
1.A.3.b. Road Transportation - diesel	N2O	96.43	..	0.001	0.011	0.913	0.004	0.962
5.G Other (harvested wood products)	CO2	..	-1219.67	0.001	..	0.913	0.003	0.965
1.A. Fuel Combustion - gaseous fuels	CO2	8104.42	..	0.001	0.008	0.921	0.003	0.968
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	24.91	..	0.001	0.007	0.928	0.002	0.970
6.B.3. N input from industrial wastewater	N2O	19.78	..	0.001	0.005	0.933	0.002	0.972
1.A.1 Energy Industries - other fuels	N2O	123.25	..	0.001	0.005	0.938	0.002	0.974
5 (IV) CO2 Emissions from Agricultural Lime Application	CO2	..	248.65	0.001	..	0.938	0.002	0.975
2.B.5 Other: Hydrogen Production	CO2	516.94	..	0.000	0.005	0.943	0.002	0.977
5 (I) Direct N2O Emissions from N Fertilization	N2O	..	16.69	0.000	..	0.943	0.002	0.979
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	21.87	..	0.000	0.004	0.947	0.001	0.980
1.A.2. Manufacturing Industries and Construction - biomass	N2O	81.99	..	0.000	0.003	0.950	0.001	0.981

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	2007 estimate, non-LULUCF	2007 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)
1.A.1 Energy Industries - solid fuels	N2O	82.99	..	0.000	0.003	0.953	0.001	0.982
1.B.2. Oil and Natural Gas - flaring	CO2	91.23	..	0.000	0.003	0.957	0.001	0.984
1.A.4. Other Sectors - biomass	N2O	30.17	..	0.000	0.003	0.960	0.001	0.985
4.B.Manure management	CH4	283.71	..	0.000	0.003	0.963	0.001	0.986
6.D Other: compost production	CH4	69.32	..	0.000	0.003	0.966	0.001	0.987
6.D Other: compost production	N2O	68.01	..	0.000	0.003	0.968	0.001	0.988
5.C1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	..	40.83	0.000	..	0.968	0.001	0.989
1.A.1 Energy Industries - biomass	N2O	60.47	..	0.000	0.003	0.971	0.001	0.990
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	94.00	..	0.000	0.002	0.973	0.001	0.990
2.A.1 Cement Production	CO2	599.57	..	0.000	0.002	0.976	0.001	0.991
1.A.4. Other Sectors - liquid fuels	N2O	38.19	..	0.000	0.002	0.978	0.001	0.992
6.B.1 Industrial Wastewater	CH4	26.92	..	0.000	0.002	0.979	0.001	0.993
1.A.1 Energy Industries - gaseous fuels	N2O	32.43	..	0.000	0.001	0.981	0.000	0.993
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	28.84	..	0.000	0.001	0.982	0.000	0.993
2.A.2 Lime Production	CO2	480.03	..	0.000	0.001	0.983	0.000	0.994
2.A.3 Limestone and Dolomite Use	CO2	152.27	..	0.000	0.001	0.984	0.000	0.994
1.A.1 Energy Industries - liquid fuels	N2O	27.71	..	0.000	0.001	0.985	0.000	0.995
3. Solvent and Other Product Use	N2O	36.42	..	0.000	0.001	0.986	0.000	0.995
6.B.3. N input from Fish Farming	N2O	3.44	..	0.000	0.001	0.987	0.000	0.995
1.A.3.b. Road Transportation - gasoline	CH4	24.88	..	0.000	0.001	0.988	0.000	0.996
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	11.62	..	0.000	0.001	0.989	0.000	0.996
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	18.19	..	0.000	0.001	0.990	0.000	0.996
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	16.58	..	0.000	0.001	0.990	0.000	0.996
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	25.41	..	0.000	0.001	0.991	0.000	0.997
1.B.2. Oil and Natural Gas - oil refining	CH4	10.71	..	0.000	0.001	0.992	0.000	0.997
1.A.4. Other Sectors - liquid fuels	CH4	12.19	..	0.000	0.001	0.992	0.000	0.997
2.F.4 Aerosols	HFCs	75.32	..	0.000	0.001	0.993	0.000	0.997
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	60.65	..	0.000	0.000	0.993	0.000	0.998
2.F.8 Electrical Equipment	SF6	7.36	..	0.000	0.000	0.994	0.000	0.998
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	10.03	..	0.000	0.000	0.994	0.000	0.998
1.A.3.a Civil Aviation	N2O	3.88	..	0.000	0.000	0.995	0.000	0.998
1.A.3.e. Other Transportation - diesel	N2O	3.76	..	0.000	0.000	0.995	0.000	0.998
1.A.2. Manufacturing Industries and Construction - biomass	CH4	8.66	..	0.000	0.000	0.995	0.000	0.998
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	3.40	..	0.000	0.000	0.996	0.000	0.998
1.A.3.d Navigation - gasoline	CH4	4.51	..	0.000	0.000	0.996	0.000	0.998
1.A.1 Energy Industries - biomass	CH4	7.19	..	0.000	0.000	0.996	0.000	0.999
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	37.09	..	0.000	0.000	0.997	0.000	0.999
1.A.1 Energy Industries - other fuels	CH4	6.81	..	0.000	0.000	0.997	0.000	0.999
1.A.3.e. Other Transportation - gasoline & diesel	CH4	6.45	..	0.000	0.000	0.997	0.000	0.999

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	2007 estimate, non-LULUCF	2007 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)
1.A.5. Other - liquid fuels	N2O	6.19	..	0.000	0.000	0.997	0.000	0.999
5 (V) Biomass Burning	CO2	..	4.91	0.000	..	0.997	0.000	0.999
1.A.3.b. Road Transportation - diesel	CH4	5.43	..	0.000	0.000	0.998	0.000	0.999
1.A.1 Energy Industries - gaseous fuels	CH4	4.36	..	0.000	0.000	0.998	0.000	0.999
2.A.7 Other - Glass Production	CO2	21.92	..	0.000	0.000	0.998	0.000	0.999
1.A.4. Other Sectors - other fuels	N2O	1.40	..	0.000	0.000	0.998	0.000	0.999
2.F.2 Foam Blowing	HFCs	8.14	..	0.000	0.000	0.998	0.000	0.999
1.A.1 Energy Industries - solid fuels	CH4	3.24	..	0.000	0.000	0.998	0.000	0.999
2.C.1 Iron and Steel production	CH4	9.08	..	0.000	0.000	0.999	0.000	0.999
1.B.2. Oil and Natural Gas - gas distribution	CH4	33.60	..	0.000	0.000	0.999	0.000	0.999
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	..	-2.81	0.000	..	0.999	0.000	1.000
1.A.3.e. Other Transportation - gasoline	N2O	0.96	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.33	..	0.000	0.000	0.999	0.000	1.000
1.A.3.c. Railways	N2O	0.90	..	0.000	0.000	0.999	0.000	1.000
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	1.40	..	0.000	0.000	0.999	0.000	1.000
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	4.40	..	0.000	0.000	0.999	0.000	1.000
1.A.3.b. Road Transportation - natural gas	CH4	2.08	..	0.000	0.000	0.999	0.000	1.000
1.A.3.d Navigation - gasoline	N2O	0.64	..	0.000	0.000	0.999	0.000	1.000
1.A.5. Other - gaseous fuels	N2O	1.50	..	0.000	0.000	0.999	0.000	1.000
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	6.89	..	0.000	0.000	0.999	0.000	1.000
2.A.4 Soda Ash Use	CO2	9.87	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.21	..	0.000	0.000	0.999	0.000	1.000
1.A.5. Other - liquid fuels	CH4	1.20	..	0.000	0.000	1.000	0.000	1.000
5 (V) Biomass Burning	CH4	..	0.98	0.000	..	1.000	0.000	1.000
1.A.4. Other Sectors - other fuels	CH4	1.22	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	N2O	0.87	..	0.000	0.000	1.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	1.08	..	0.000	0.000	1.000	0.000	1.000
1.A.1 Energy Industries - liquid fuels	CH4	1.04	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	N2O	1.22	..	0.000	0.000	1.000	0.000	1.000
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	0.59	..	0.000	0.000	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	N2O	0.24	..	0.000	0.000	1.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	0.50	..	0.000	0.000	1.000	0.000	1.000
2.A.6 Road Paving with Asphalt	CO2	2.673	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.90	..	0.000	0.000	1.000	0.000	1.000
1.A.3.a Civil Aviation	CH4	0.23	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission	CH4	6.89	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	CH4	0.27	..	0.000	0.000	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	CH4	0.32	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - gaseous fuels	CH4	0.30	..	0.000	0.000	1.000	0.000	1.000
4.F Field Burning of Agricultural Residues	CH4	0.63	..	0.000	0.000	1.000	0.000	1.000
1.A.3.c. Railways	CH4	0.12	..	0.000	0.000	1.000	0.000	1.000

A	B			C	D'	E'	D	E
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	2007 estimate, non-LULUCF	2007 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)
5 (V) Biomass Burning	N2O	..	0.10	0.000	..	1.000	0.000	1.000
1.A.4. Other Sectors - solid fuels	N2O	0.12	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - solid fuels	CH4	0.06	..	0.000	0.000	1.000	0.000	1.000
4.F Field Burning of Agricultural Residues	N2O	0.19	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	CH4	0.06	..	0.000	0.000	1.000	0.000	1.000
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.21	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	CH4	0.03	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	N2O	0.02	..	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.A.5. Other - other fuels	CH4	0.00	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - solid fuels	CH4	0.00	..	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
2.B.1 Ammonia Production	CO2	0.00	..	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	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
Sum		53089.30	53079.71	0.041700	1.00000	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	-26348.41	-32665.77	0.015870	0.38057	0.38057
5.C1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	-2231.99	4016.30	0.008921	0.21392	0.59449
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	10027.37	6725.30	0.006130	0.14701	0.74150
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	6584.34	4617.71	0.002957	0.07092	0.81241
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	-2363.29	-3624.70	0.001482	0.03553	0.84794
1.A. Fuel Combustion - other fuels	CO2	5693.53	11015.16	0.001375	0.03296	0.88091
1.A. Fuel Combustion - solid fuels	CO2	14591.85	16768.36	0.001318	0.03160	0.91250
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	214.08	-1534.30	0.000947	0.02271	0.93521
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3377.61	2442.75	0.000568	0.01362	0.94883
1.A. Fuel Combustion - liquid fuels	CO2	27779.59	25769.93	0.000517	0.01241	0.96124
6.A. Solid Waste disposal on Land	CH4	3644.52	2060.68	0.000495	0.01187	0.97311
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	32.01	525.10	0.000354	0.00849	0.98160
5.A.1. Forest Land remaining Forest Land - net carbon stock change in dead organic matter	CO2	-4539.15	-3269.38	0.000148	0.00356	0.98516
1.A. Fuel Combustion - gaseous fuels	CO2	4970.23	8104.42	0.000128	0.00307	0.98823
4.D.Agricultural soils: indirect emissions	N2O	922.24	745.50	0.000110	0.00263	0.99086
2.B.2 Nitric Acid Production	N2O	1655.71	1482.05	0.000086	0.00207	0.99293
4.A.Enteric fermentation	CH4	1928.87	1559.95	0.000064	0.00153	0.99447
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	0.01	818.68	0.000063	0.00151	0.99598
2.C.1 Iron and Steel production	CO2	1861.21	2459.53	0.000053	0.00127	0.99725
	CO2, CH4,					
5.D2. Land Converted to Wetlands - peat production areas	N2O	1078.05	1379.51	0.000030	0.00071	0.99796
4.B.Manure management	N2O	664.76	497.01	0.000023	0.00055	0.99851
5.G Other (harvested wood products)	CO2	-945.64	-1219.67	0.000013	0.00030	0.99881
2.B.5 Other: Hydrogen Production	CO2	56.94	516.94	0.000011	0.00027	0.99908
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.42	271.56	0.000009	0.00023	0.99931
5 (IV) CO2 Emissions from Agricultural Lime Application	CO2	617.87	248.65	0.000009	0.00022	0.99952
1.A.4. Other Sectors - biomass	CH4	161.28	179.65	0.000003	0.00006	0.99959
1.A.1 Energy Industries - other fuels	N2O	34.64	123.25	0.000003	0.00006	0.99965
1.A.3.b. Road Transportation - diesel	N2O	68.12	96.43	0.000002	0.00005	0.99970
2.A.1 Cement Production	CO2	733.59	599.57	0.000001	0.00003	0.99973
4.B.Manure management	CH4	229.81	283.71	0.000001	0.00002	0.99976
1.A.1 Energy Industries - biomass	N2O	3.07	60.47	0.000001	0.00002	0.99978
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	74.79	52.93	0.000001	0.00002	0.99980
1.A.1 Energy Industries - solid fuels	N2O	43.40	82.99	0.000001	0.00002	0.99982
6.D Other: compost production	CH4	21.55	69.32	0.000001	0.00002	0.99984
6.D Other: compost production	N2O	20.43	68.01	0.000001	0.00002	0.99986
5.C1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	100.78	40.83	0.000001	0.00002	0.99988

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ⁽¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
2.A.2 Lime Production	CO2	382.60	480.03	0.000001	0.00002	0.99989
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.43	81.99	0.000001	0.00002	0.99991
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	59.42	21.87	0.000001	0.00001	0.99992
2.A.3 Limestone and Dolomite Use	CO2	88.02	152.27	0.000000	0.00001	0.99993
1.B.2. Oil and Natural Gas - flaring	CO2	122.80	91.23	0.000000	0.00001	0.99994
2.F.4 Aerosols	HFCs	0.00	75.32	0.000000	0.00001	0.99995
1.A.4. Other Sectors - biomass	N2O	27.77	30.17	0.000000	0.00000	0.99995
1.A.3.b. Road Transportation - gasoline	CH4	77.85	24.88	0.000000	0.00000	0.99996
1.A.1 Energy Industries - gaseous fuels	N2O	15.63	32.43	0.000000	0.00000	0.99996
2.F.8 Electrical Equipment	SF6	86.52	7.36	0.000000	0.00000	0.99996
6.B.1 Industrial Wastewater	CH4	22.23	26.92	0.000000	0.00000	0.99997
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.55	24.91	0.000000	0.00000	0.99997
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	114.23	94.00	0.000000	0.00000	0.99997
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.37	60.65	0.000000	0.00000	0.99998
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	7.94	25.41			
				0.000000	0.00000	0.99998
1.A.4. Other Sectors - liquid fuels	N2O	56.43	38.19	0.000000	0.00000	0.99998
3. Solvent and Other Product Use	N2O	62.00	36.42	0.000000	0.00000	0.99998
1.A.1 Energy Industries - liquid fuels	N2O	25.03	27.71	0.000000	0.00000	0.99998
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.45	37.09	0.000000	0.00000	0.99999
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	46.87	10.03	0.000000	0.00000	0.99999
1.B.2. Oil and Natural Gas - oil refining	CH4	7.56	10.71	0.000000	0.00000	0.99999
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.01	18.19	0.000000	0.00000	0.99999
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.26	16.58	0.000000	0.00000	0.99999
1.B.2. Oil and Natural Gas - gas distribution	CH4	0.00	33.60	0.000000	0.00000	0.99999
1.A.1 Energy Industries - biomass	CH4	1.51	7.19	0.000000	0.00000	0.99999
6.B.3. N input from Fish Farming	N2O	8.28	3.44	0.000000	0.00000	0.99999
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.80	8.66	0.000000	0.00000	0.99999
6.B.3. N input from industrial wastewater	N2O	30.17	19.78	0.000000	0.00000	0.99999
1.A.1 Energy Industries - other fuels	CH4	2.47	6.81	0.000000	0.00000	0.99999
1.A.3.e. Other Transportation - diesel	N2O	3.84	3.76	0.000000	0.00000	0.99999
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.56	3.40	0.000000	0.00000	0.99999
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	17.07	11.62	0.000000	0.00000	0.99999
1.A.3.a Civil Aviation	N2O	4.86	3.88	0.000000	0.00000	0.99999
1.A.3.d Navigation - gasoline	CH4	4.13	4.51	0.000000	0.00000	1.00000
1.A.3.e. Other Transportation - gasoline & diesel	CH4	4.61	6.45	0.000000	0.00000	1.00000
5 (V) Biomass Burning	CO2	3.26	4.91	0.000000	0.00000	1.00000
2.F.2 Foam Blowing	HFCs	0.00	8.14	0.000000	0.00000	1.00000
5 (I) Direct N2O Emissions from N Fertilization	N2O	26.82	16.69	0.000000	0.00000	1.00000
1.A.1 Energy Industries - gaseous fuels	CH4	1.03	4.36	0.000000	0.00000	1.00000
1.A.4. Other Sectors - liquid fuels	CH4	18.18	12.19	0.000000	0.00000	1.00000

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ⁽¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
2.A.7 Other - Glass Production	CO2	20.80	21.92	0.000000	0.000000	1.00000
1.A.5. Other - liquid fuels	N2O	8.89	6.19	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	36.98	28.84	0.000000	0.000000	1.00000
2.C.1 Iron and Steel production	CH4	5.11	9.08	0.000000	0.000000	1.00000
1.A.1 Energy Industries - solid fuels	CH4	2.29	3.24	0.000000	0.000000	1.00000
1.A.4. Other Sectors - other fuels	N2O	1.47	1.40	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	0.00	4.40	0.000000	0.000000	1.00000
1.A.3.e. Other Transportation - gasoline	N2O	0.63	0.96	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	0.99	1.40	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.54	2.33	0.000000	0.000000	1.00000
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	-1.44	-2.81	0.000000	0.000000	1.00000
1.A.3.c. Railways	N2O	1.51	0.90	0.000000	0.000000	1.00000
1.A.3.b. Road Transportation - natural gas	CH4	0.00	2.08	0.000000	0.000000	1.00000
1.A.5. Other - gaseous fuels	N2O	0.31	1.50	0.000000	0.000000	1.00000
1.A.3.d Navigation - gasoline	N2O	0.33	0.64	0.000000	0.000000	1.00000
1.A.3.b. Road Transportation - diesel	CH4	11.75	5.43	0.000000	0.000000	1.00000
2.A.4 Soda Ash Use	CO2	8.32	9.87	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.08	1.21	0.000000	0.000000	1.00000
1.A.4. Other Sectors - other fuels	CH4	1.24	1.22	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - flaring	N2O	1.17	0.87	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	1.01	1.08	0.000000	0.000000	1.00000
1.A.4. Other Sectors - gaseous fuels	N2O	0.59	1.22	0.000000	0.000000	1.00000
1.A.5. Other - liquid fuels	CH4	2.36	1.20	0.000000	0.000000	1.00000
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	24.41	6.89	0.000000	0.000000	1.00000
1.A.1 Energy Industries - liquid fuels	CH4	0.97	1.04	0.000000	0.000000	1.00000
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	0.43	0.59	0.000000	0.000000	1.00000
5 (V) Biomass Burning	CH4	4.00	0.98	0.000000	0.000000	1.00000
1.A.3.e. Other Transportation - LPG	N2O	0.29	0.24	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.57	6.89	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	1.37	0.50	0.000000	0.000000	1.00000
2.A.6 Road Paving with Asphalt	CO2	21.00	2.67	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.47	0.90	0.000000	0.000000	1.00000
1.A.3.a Civil Aviation	CH4	0.27	0.23	0.000000	0.000000	1.00000
1.A.4. Other Sectors - gaseous fuels	CH4	0.22	0.27	0.000000	0.000000	1.00000
1.A.5. Other - gaseous fuels	CH4	0.06	0.30	0.000000	0.000000	1.00000
1.A.3.e. Other Transportation - LPG	CH4	0.39	0.32	0.000000	0.000000	1.00000
4.F Field Burning of Agricultural Residues	CH4	1.88	0.63	0.000000	0.000000	1.00000
1.A.3.c. Railways	CH4	0.23	0.12	0.000000	0.000000	1.00000
5 (V) Biomass Burning	N2O	0.41	0.10	0.000000	0.000000	1.00000
1.A.4. Other Sectors - solid fuels	N2O	0.59	0.12	0.000000	0.000000	1.00000
1.A.5. Other - biomass	CH4	0.20	0.06	0.000000	0.000000	1.00000

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
4.F Field Burning of Agricultural Residues	N2O	0.55	0.19	0.000000	0.00000	1.00000
1.A.4. Other Sectors - solid fuels	CH4	2.34	0.06	0.000000	0.00000	1.00000
1.B.2. Oil and Natural Gas - flaring	CH4	0.04	0.03	0.000000	0.00000	1.00000
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.44	0.21	0.000000	0.00000	1.00000
1.A.5. Other - biomass	N2O	0.22	0.02	0.000000	0.00000	1.00000
1.A.3.b. Road Transportation - natural gas	N2O	0.00	0.00	0.000000	0.00000	1.00000
1.A.5. Other - other fuels	CH4	0.24	0.00	0.000000	0.00000	1.00000
1.A.5. Other - solid fuels	CH4	0.00	0.00	0.000000	0.00000	1.00000
1.A.5. Other - solid fuels	N2O	0.01	0.00	0.000000	0.00000	1.00000
2.B.1 Ammonia Production	CO2	44.00	0.00	0.000000	0.00000	1.00000

¹⁾ Gases have been combined to protect confidential information (category 2.G), and to remove correlations (category 5.D.2).

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	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
Sum		53 089.30	53 079.71	0.005193	1.00000	
5 (I) Direct N2O Emissions from N Fertilization	N2O	26.82	16.69	..	..	..
5 (IV) CO2 Emissions from Agricultural Lime Application	CO2	617.87	248.65	..	..	..
5 (V) Biomass Burning	CH4	4.00	0.98	..	..	..
5 (V) Biomass Burning	CO2	3.26	4.91	..	..	..
5 (V) Biomass Burning	N2O	0.41	0.10	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in dead organic matter	CO2	-4539.15	-3269.38	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	-26 348.41	-32 665.77	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	-2 363.29	-3 624.70	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	10 027.37	6 725.30	..	..	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	-1.44	-2.81	..	..	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	214.08	-1 534.30	..	..	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	6 584.34	4 617.71	..	..	..
5.C1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	-2 231.99	4 016.30	..	..	..
5.C1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	100.78	40.83	..	..	..
	CO2, CH4,					
5.D2. Land Converted to Wetlands - peat production areas	N2O	1078.05	1379.51	..	..	..
5.G Other (harvested wood products)	CO2	-945.64	-1219.67	..	..	..
1.A. Fuel Combustion - other fuels	CO2	5693.53	11015.16	0.001375	0.26467	0.26467
1.A. Fuel Combustion - solid fuels	CO2	14591.85	16768.36	0.001318	0.25371	0.51838
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3377.61	2442.75	0.000568	0.10935	0.62773
1.A. Fuel Combustion - liquid fuels	CO2	27779.59	25769.93	0.000517	0.09963	0.72736
6.A. Solid Waste disposal on Land	CH4	3644.52	2060.68	0.000495	0.09533	0.82269
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	32.01	525.10	0.000354	0.06819	0.89088
1.A. Fuel Combustion - gaseous fuels	CO2	4970.23	8104.42	0.000128	0.02462	0.91551
4.D.Agricultural soils: indirect emissions	N2O	922.24	745.50	0.000110	0.02114	0.93665
2.B.2 Nitric Acid Production	N2O	1655.71	1482.05	0.000086	0.01664	0.95329
4.A.Enteric fermentation	CH4	1928.87	1559.95	0.000064	0.01231	0.96560
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	0.01	818.68	0.000063	0.01213	0.97773
2.C.1 Iron and Steel production	CO2	1861.21	2459.53	0.000053	0.01022	0.98795
4.B.Manure management	N2O	664.76	497.01	0.000023	0.00441	0.99235
2.B.5 Other: Hydrogen Production	CO2	56.94	516.94	0.000011	0.00214	0.99450
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.42	271.56	0.000009	0.00182	0.99631
1.A.4. Other Sectors - biomass	CH4	161.28	179.65	0.000003	0.00052	0.99683
1.A.1 Energy Industries - other fuels	N2O	34.64	123.25	0.000003	0.00050	0.99733
1.A.3.b. Road Transportation - diesel	N2O	68.12	96.43	0.000002	0.00039	0.99772
2.A.1 Cement Production	CO2	733.59	599.57	0.000001	0.00027	0.99800
4.B.Manure management	CH4	229.81	283.71	0.000001	0.00020	0.99819

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ⁽¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
1.A.1 Energy Industries - biomass	N2O	3.07	60.47	0.000001	0.00018	0.99837
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	74.79	52.93	0.000001	0.00017	0.99854
1.A.1 Energy Industries - solid fuels	N2O	43.40	82.99	0.000001	0.00017	0.99870
6.D Other: compost production	CH4	21.55	69.32	0.000001	0.00016	0.99886
6.D Other: compost production	N2O	20.43	68.01	0.000001	0.00015	0.99902
2.A.2 Lime Production	CO2	382.60	480.03	0.000001	0.00013	0.99914
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.43	81.99	0.000001	0.00012	0.99927
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	59.42	21.87	0.000001	0.00011	0.99937
2.A.3 Limestone and Dolomite Use	CO2	88.02	152.27	0.000000	0.00009	0.99946
1.B.2. Oil and Natural Gas - flaring	CO2	122.80	91.23	0.000000	0.00007	0.99953
2.F.4 Aerosols	HFCs	0.00	75.32	0.000000	0.00004	0.99957
1.A.4. Other Sectors - biomass	N2O	27.77	30.17	0.000000	0.00004	0.99961
1.A.3.b. Road Transportation - gasoline	CH4	77.85	24.88	0.000000	0.00004	0.99965
1.A.1 Energy Industries - gaseous fuels	N2O	15.63	32.43	0.000000	0.00004	0.99968
2.F.8 Electrical Equipment	SF6	86.52	7.36	0.000000	0.00003	0.99971
6.B.1 Industrial Wastewater	CH4	22.23	26.92	0.000000	0.00003	0.99974
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.55	24.91	0.000000	0.00003	0.99977
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	114.23	94.00	0.000000	0.00002	0.99979
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.37	60.65	0.000000	0.00002	0.99981
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	7.94	25.41	0.000000	0.00002	0.99983
1.A.4. Other Sectors - liquid fuels	N2O	56.43	38.19	0.000000	0.00002	0.99985
3. Solvent and Other Product Use	N2O	62.00	36.42	0.000000	0.00001	0.99986
1.A.1 Energy Industries - liquid fuels	N2O	25.03	27.71	0.000000	0.00001	0.99987
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.45	37.09	0.000000	0.00001	0.99989
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	46.87	10.03	0.000000	0.00001	0.99990
1.B.2. Oil and Natural Gas - oil refining	CH4	7.56	10.71	0.000000	0.00001	0.99991
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.01	18.19	0.000000	0.00001	0.99992
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.26	16.58	0.000000	0.00001	0.99992
1.B.2. Oil and Natural Gas - gas distribution	CH4	0.00	33.60	0.000000	0.00000	0.99993
1.A.1 Energy Industries - biomass	CH4	1.51	7.19	0.000000	0.00000	0.99993
6.B.3. N input from Fish Farming	N2O	8.28	3.44	0.000000	0.00000	0.99994
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.80	8.66	0.000000	0.00000	0.99994
6.B.3. N input from industrial wastewater	N2O	30.17	19.78	0.000000	0.00000	0.99995
1.A.1 Energy Industries - other fuels	CH4	2.47	6.81	0.000000	0.00000	0.99995
1.A.3.e. Other Transportation - diesel	N2O	3.84	3.76	0.000000	0.00000	0.99995
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.56	3.40	0.000000	0.00000	0.99996
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	17.07	11.62	0.000000	0.00000	0.99996
1.A.3.a Civil Aviation	N2O	4.86	3.88	0.000000	0.00000	0.99996
1.A.3.d Navigation - gasoline	CH4	4.13	4.51	0.000000	0.00000	0.99997

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ⁽¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
1.A.3.e. Other Transportation - gasoline & diesel	CH4	4.61	6.45	0.000000	0.000000	0.99997
2.F.2 Foam Blowing	HFCs	0.00	8.14	0.000000	0.000000	0.99997
1.A.1 Energy Industries - gaseous fuels	CH4	1.03	4.36	0.000000	0.000000	0.99997
1.A.4. Other Sectors - liquid fuels	CH4	18.18	12.19	0.000000	0.000000	0.99998
2.A.7 Other - Glass Production	CO2	20.80	21.92	0.000000	0.000000	0.99998
1.A.5. Other - liquid fuels	N2O	8.89	6.19	0.000000	0.000000	0.99998
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	36.98	28.84	0.000000	0.000000	0.99998
2.C.1 Iron and Steel production	CH4	5.11	9.08	0.000000	0.000000	0.99998
1.A.1 Energy Industries - solid fuels	CH4	2.29	3.24	0.000000	0.000000	0.99998
1.A.4. Other Sectors - other fuels	N2O	1.47	1.40	0.000000	0.000000	0.99999
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	0.00	4.40	0.000000	0.000000	0.99999
1.A.3.e. Other Transportation - gasoline	N2O	0.63	0.96	0.000000	0.000000	0.99999
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	0.99	1.40	0.000000	0.000000	0.99999
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.54	2.33	0.000000	0.000000	0.99999
1.A.3.c. Railways	N2O	1.51	0.90	0.000000	0.000000	0.99999
1.A.3.b. Road Transportation - natural gas	CH4	0.00	2.08	0.000000	0.000000	0.99999
1.A.5. Other - gaseous fuels	N2O	0.31	1.50	0.000000	0.000000	0.99999
1.A.3.d Navigation - gasoline	N2O	0.33	0.64	0.000000	0.000000	0.99999
1.A.3.b. Road Transportation - diesel	CH4	11.75	5.43	0.000000	0.000000	0.99999
2.A.4 Soda Ash Use	CO2	8.32	9.87	0.000000	0.000000	0.99999
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.08	1.21	0.000000	0.000000	0.99999
1.A.4. Other Sectors - other fuels	CH4	1.24	1.22	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - flaring	N2O	1.17	0.87	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	1.01	1.08	0.000000	0.000000	1.00000
1.A.4. Other Sectors - gaseous fuels	N2O	0.59	1.22	0.000000	0.000000	1.00000
1.A.5. Other - liquid fuels	CH4	2.36	1.20	0.000000	0.000000	1.00000
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	24.41	6.89	0.000000	0.000000	1.00000
1.A.1 Energy Industries - liquid fuels	CH4	0.97	1.04	0.000000	0.000000	1.00000
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	0.43	0.59	0.000000	0.000000	1.00000
1.A.3.e. Other Transportation - LPG	N2O	0.29	0.24	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.57	6.89	0.000000	0.000000	1.00000
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	1.37	0.50	0.000000	0.000000	1.00000
2.A.6 Road Paving with Asphalt	CO2	21.00	2.67	0.000000	0.000000	1.00000
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.47	0.90	0.000000	0.000000	1.00000
1.A.3.a Civil Aviation	CH4	0.27	0.23	0.000000	0.000000	1.00000
1.A.4. Other Sectors - gaseous fuels	CH4	0.22	0.27	0.000000	0.000000	1.00000
1.A.5. Other - gaseous fuels	CH4	0.06	0.30	0.000000	0.000000	1.00000
1.A.3.e. Other Transportation - LPG	CH4	0.39	0.32	0.000000	0.000000	1.00000
4.F Field Burning of Agricultural Residues	CH4	1.88	0.63	0.000000	0.000000	1.00000
1.A.3.c. Railways	CH4	0.23	0.12	0.000000	0.000000	1.00000
1.A.4. Other Sectors - solid fuels	N2O	0.59	0.12	0.000000	0.000000	1.00000
1.A.5. Other - biomass	CH4	0.20	0.06	0.000000	0.000000	1.00000

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2007 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
4.F Field Burning of Agricultural Residues	N2O	0.55	0.19	0.000000	0.00000	1.00000
1.A.4. Other Sectors - solid fuels	CH4	2.34	0.06	0.000000	0.00000	1.00000
1.B.2. Oil and Natural Gas - flaring	CH4	0.04	0.03	0.000000	0.00000	1.00000
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.44	0.21	0.000000	0.00000	1.00000
1.A.5. Other - biomass	N2O	0.22	0.02	0.000000	0.00000	1.00000
1.A.3.b. Road Transportation - natural gas	N2O	0.00	0.00	0.000000	0.00000	1.00000
1.A.5. Other - other fuels	CH4	0.24	0.00	0.000000	0.00000	1.00000
1.A.5. Other - solid fuels	CH4	0.00	0.00	0.000000	0.00000	1.00000
1.A.5. Other - solid fuels	N2O	0.01	0.00	0.000000	0.00000	1.00000
2.B.1 Ammonia Production	CO2	44.00	0.00	0.000000	0.00000	1.00000

¹⁾ Gases have been combined to protect confidential information (category 2.G), and to remove correlations (category 5.D.2).

ANNEX 2. Description of the Compliance Monitoring Data System VAHTI

The VAHTI compliance data system is an operational tool for the 13 Regional Environment Centres 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 Regional Environment Centres and by other interested parties. Additionally, case management has been incorporated into the system. VAHTI also contains information on how installations comply with environmental regulations.

VAHTI contains information on how installations comply with environmental regulations. In 2005 a new application was added which contains data on how the regional environment centres 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 petrol 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)⁵ and previously European Polluting Emissions Register (EPER). The PRTR and EPER reporting substance lists also include carbon dioxide, nitrous oxide and F-gases. However, the data to the integrated emission registers are reported as total emissions for the industrial site and cannot be split between the CRF reporting categories.

In addition to emission data the operators also report on the types, characteristics and consumption of fuels, though these data may not be as complete as emission data. In addition, waste amounts (with classification data) to solid waste disposal sites and wastewater handling data are reported to the VAHTI Data System.

Quality checking carried out by the supervising authority

When receiving the emission report from the operator the supervising authority checks whether the data are produced according to the methods agreed in the permit or in a separate monitoring programme for the plant. The methods usually include use of international standards or approved in-house methods. The principles of the EU IPPC Reference Document on Monitoring of Emissions (Monitoring BREF) are also followed.

Reporting options for the operators

The operators may submit the emission reports to the supervising authorities either as hard copies or electronically by email or through the Internet (Figure 2). Larger industrial installations have developed reporting systems which are based on direct information flow from the plant information systems to the supervising authority. The emission data are always checked by the supervising authority before recording into the VAHTI data system as described in Section 1.4. When the operator chooses to send the data over the Internet using a centralised data collection system⁶ the data will be automatically checked for completeness and only the completed data will be sent to the authorities for checking of the substance.

⁵ 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 Regional Environmental Centres 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.

⁶ The centralised data collection system TYVI is a consultant service used in various data collection procedures from the companies to the authorities, in addition to the environmental administration, such as the tax authority, customs and statistics.

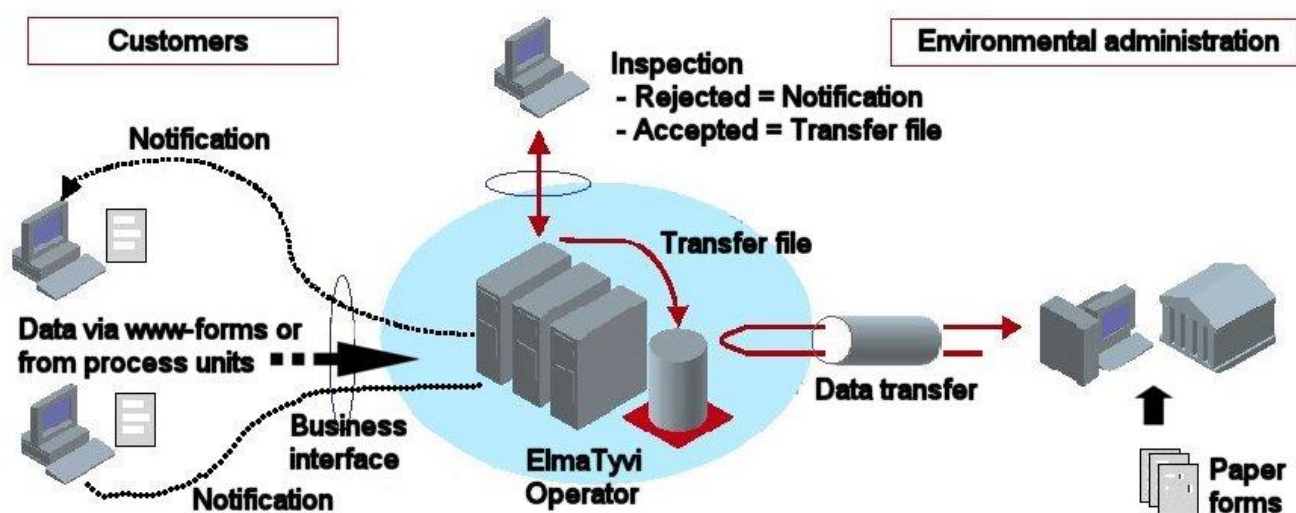


Figure 2. Reporting options for the operators

Further information on the VAHTI Data System is available from Mr Markku Hietamäki, Ministry of the Environment (email: firstname.surname@ymparisto.fi).

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

$$\bar{x}_t = s_{1,t}x_1 + s_{2,t}x_2 + \dots + s_{n,t}x_n,$$

where it is understood that constant properties of a given type of coal over time are assumed.

The data

We obtained data on coal imports by country of origin from Table 10.3 of energy statistics prepared by Statistics Finland. These data are available for 1990-2003, except for 1996 when the table was not prepared.

Data on properties of fuel combusted in Finland were obtained from Taipale (1996). This study reports results from measurements carried out mainly during the 1990's. It gives water contents, carbon contents and net calorific values for coal of different origins. The statistics reported are the number of measurements, minimum,

maximum and the mean. In case of the most important countries of coal origin, such as Poland and Russia, hundreds of measurements were available. This was the case for the net calorific value and water content. Measurements of carbon content were scarcer ranging from a few to tens of measurements, depending on the country of origin. For 13 countries or regions, the net calorific value and water content were not available. The carbon content was not available for 16 countries or regions. In all, the data consist of 23 countries or regions.

There is clearly a problem with the missing data. A first attempt was made by selecting values from literature to replace the missing data. Although the proportion of imports with the missing fuel property data was not greater than 1%-17%, depending on the year under consideration, this solution resulted in a correlation between the calculated emission factor and the proportion of missing data. The higher the proportion of missing data, the higher the calculated average emission factors.

The second attempt produced better results. An algorithm was constructed to select values at random from the available data to replace the missing values. The selection process was designed to give an equal probability of selection for any one value of fuel property. The sampling was done separately for each of the properties. Fuel properties for which data were available were modelled using triangular distributions, with min and max corresponding to the measured min and max, and the most likely value corresponding to the mean of all measurements. Import statistics were assumed relatively accurate. Imports were assumed to be normally distributed, means corresponding to the imported quantity and standard deviations equal to half of the unit used to report the data ($1000 \text{ t}/2 = 500 \text{ t}$).

Results and discussion

The simulation was designed to separate year-to-year variability from other uncertainties. Figure 1 shows a wide range of uncertainty in an individual year's emission factors and also that the years are clearly different from each other.

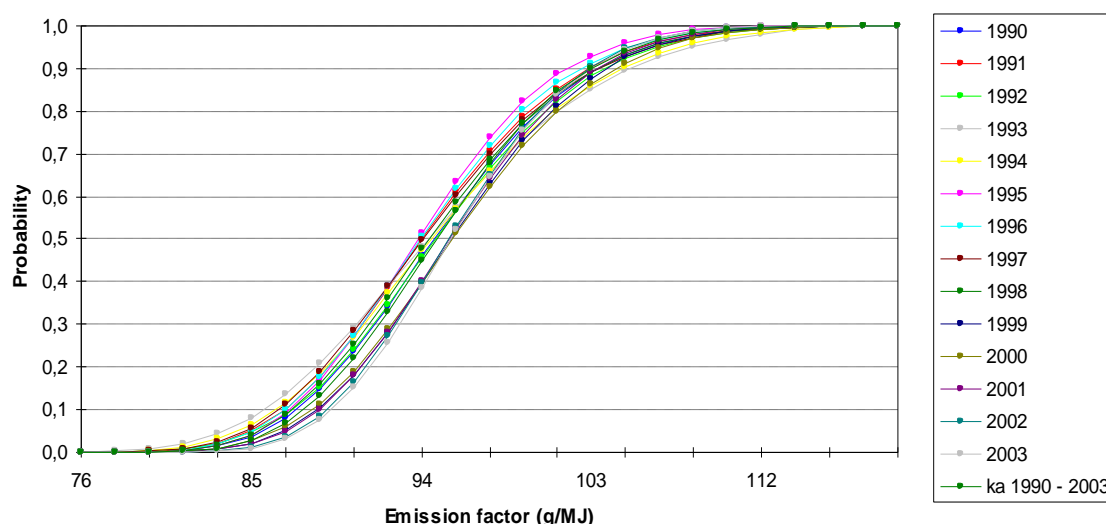


Figure 1. Uncertainty and year-to-year variability in the average coal emission factor.

Figure 2 shows a combined view of uncertainty as a trend over time. The central value of the simulated average emission factor (the light blue area in Fig. 2) does not display a clear trend over time. The 1996 emission factor, the year for which import data were not available, was calculated simply as the average of the 1995 and 1997 emission factors.

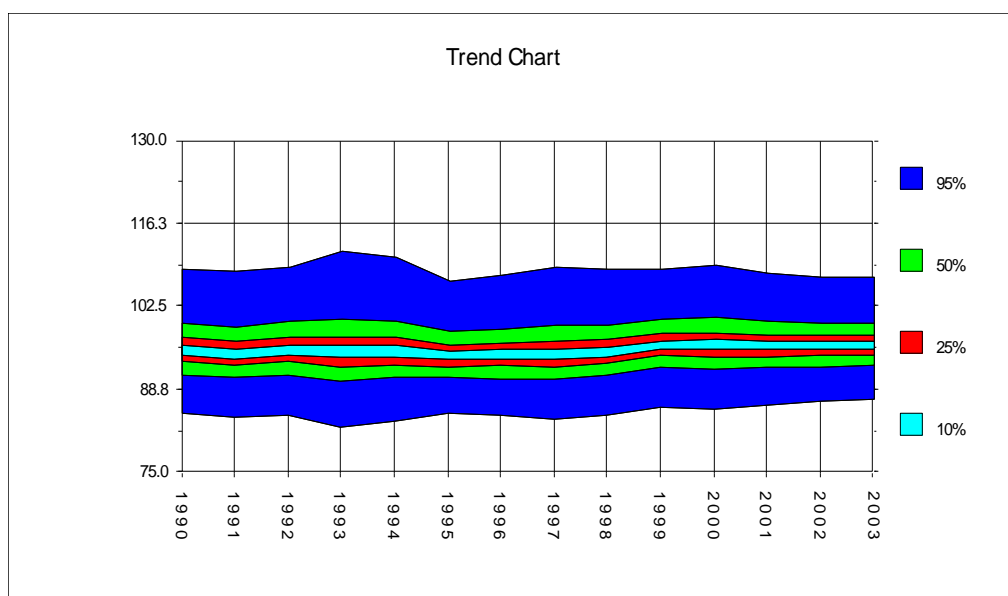


Figure 2. Uncertainty in the coal emission factor over time.

Figure 3 displays a time average of the simulation results. Two observations are immediate: (i) the distribution is centred around a value which is not far from the default emission factor 94.6 g/MJ; (ii) the width of the distribution suggests a much larger uncertainty than the $\pm 3\%$ given in the OECD/IEA (1991) for regional emission factors. Note, however, that this is in agreement with an example shown in that text for Greece, for which the national level of variation was found to be much wider (OECD/IEA, p. 155). The distribution in Figure 3 suggests an uncertainty around 12%-13%. It is much larger than the current uncertainty used for solid fuels in the inventory, which is 3%-5%.

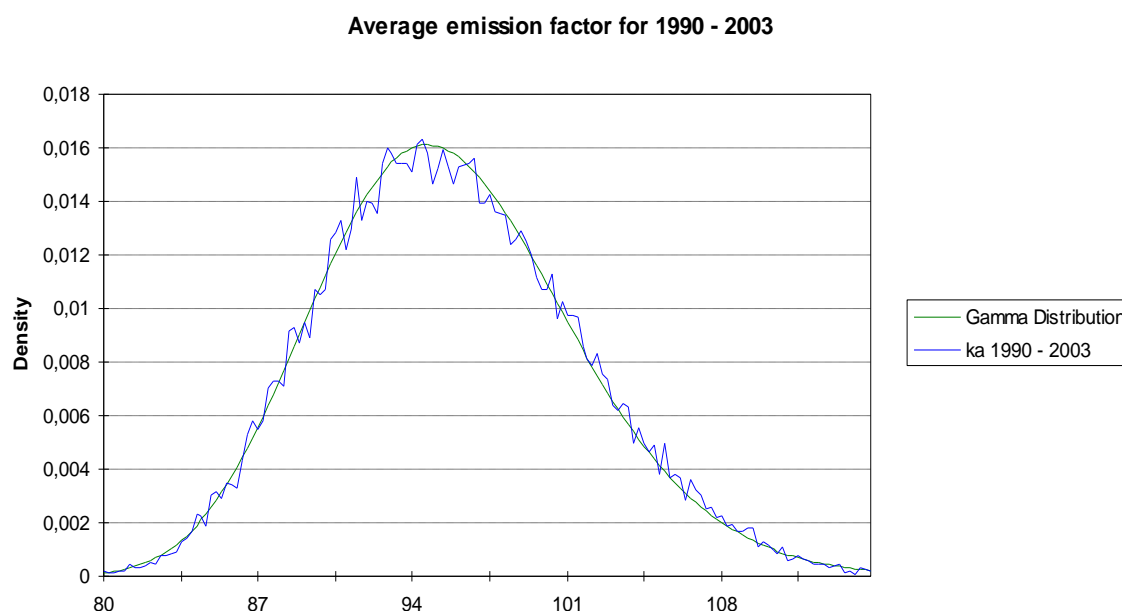


Figure 3. An average coal emission factor for 1990-2003.

Variance decomposition suggests that most of the uncertainty in the emission factor for 1990-2003 is due to a variable net calorific value of the Polish coal combusted in Finland (Fig. 4). The carbon content of Polish coal and the net calorific value of Russian coal are also important factors affecting uncertainty of the average emission factor. Other factors play a minor role in the overall uncertainty.

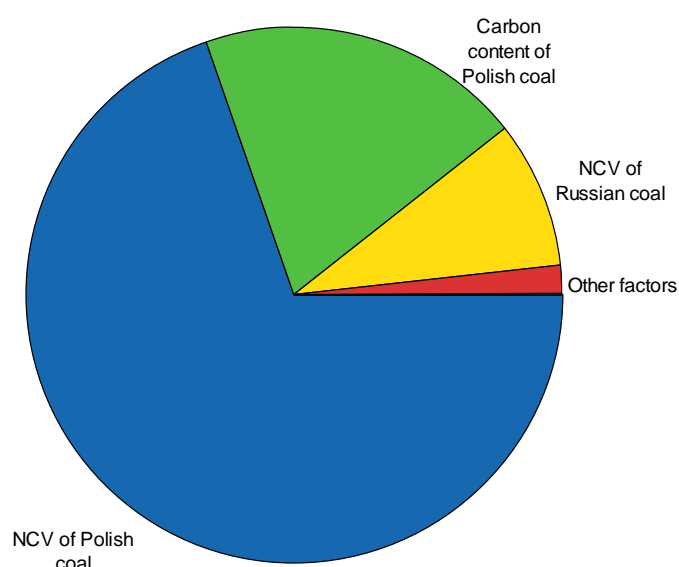


Figure 4. Variance decomposition of the average emission factor for 1990-2003.

Summary statistics for the simulation are given in Table 10. Estimates of the means are 0.3%-2.2% larger than the current default emission factor used.

Table 1. Summary statistics for simulation (n = 30 000) of coal emission factors. All numbers have the unit of measurement g/MJ.

	Year	Mean	Sd	MCSE*	Quantiles		
					2.5%	50.0%	97.5%
	1990	95.87	6.18	0.036	85.0	95.5	109.0
	1991	95.27	6.27	0.036	84.3	94.8	108.7
	1992	95.93	6.44	0.037	84.5	95.5	109.5
	1993	95.75	7.55	0.044	82.6	95.2	112.0
	1994	95.87	7.09	0.041	83.5	95.3	111.1
	1995	94.92	5.68	0.033	84.9	94.6	106.9
	1996	95.12	6.04	0.035	84.5	94.7	108.0
	1997	95.32	6.51	0.038	84.0	94.8	109.3
	1998	95.66	6.26	0.036	84.7	95.2	109.0
	1999	96.69	5.92	0.034	86.1	96.4	109.0
	2000	96.77	6.20	0.036	85.6	96.4	109.8
	2001	96.54	5.71	0.033	86.3	96.2	108.5
	2002	96.50	5.37	0.031	86.9	96.2	107.7
	2003	96.66	5.29	0.031	87.3	96.3	107.8

*Monte Carlo standard error of the mean, Sd/\sqrt{n} .

ANNEX 4. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

Completeness of the Finnish inventory submission 2008 is evaluated by sectors in the tables below. The completeness is estimated by the gases (CO₂, N₂O, CH₄, F-gases) 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 1B)

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.	
3. Aluminium Production	NO	NO			

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
4. SF ₆ Used in Aluminium and Magnesium Foundries	NO	NO			
5. Other Non-ferrous metals	X	NO	NO		
D. Other Production					
1. Pulp and Paper	NO				
2. Food and Drink	NO				
G. Other	NO				

F-gases (CRF 2F)

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 SF₆					
1. By-product Emissions	NO	NO	NO		
Production of HCFC-22	NO	NO	NO		
Other	NO	NO	NO		
F. Consumption of Halocarbons and SF₆					
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	HFCs	PFCs	SF6	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		X			
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			Reindeer
B. Manure Management					
1.Cattle		X	X		
Dairy Cattle		X	X		
Non-Dairy Cattle		X	X		
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		
8.Swine		X	X		

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
9.Poultry		X	X		
10. Fur animal		X	X		
11. Reindeer		X	X		
12.Anaerobic Lagoons		NO	NO		
13.Liquid Systems		X	X		
14.Solid Storage and Dry Lot		X	X		
15.Other		NA	NA		
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	IE	IE	IE	Emissions from CRF 5.B 2 are included into cropland remaining cropland (CRF 5.B 1)	For N ₂ O emissions from conversions to cropland, see 5(III) below.
C. Grassland					
1. Grassland remaining grassland	X	NA	NA		Non-CO ₂ emissions included under agriculture CRF 4.D
2. Land converted to grassland	IE	IE	IE	Emissions from CRF 5.C 2 are included into grassland remaining grassland (CRF 5.C 1)	
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).	

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
F. Other land					
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	NE	NE	NE	No data available to separate emissions GL remaining GL and land categories converted to GL	
5 (I) Direct N₂O emissions from N fertilization			X		
5(II) N₂O 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) N₂O emissions from disturbance associated with land-use conversion to cropland			NE	Data on area of land converted to cropland are not available.	
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		

ANNEX 5. Uncertainty and sensitivity analyses

Annex 5 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, 2007	Activity data uncertainty ²⁾	Emission factor uncertainty ²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2007	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	8104.42	1 %	1 %	1 %	0.22 %	0.0590	0.1527	0.06 %	0.22 %	0.22 %	R	R	E1	
1.A. Fuel Combustion - liquid fuels	CO2	27779.59	25769.93	2 %	2 %	3 %	1.37 %	-0.0376	0.4854	-0.08 %	1.37 %	1.37 %	R	R	E1	
1.A. Fuel Combustion - other fuels	CO2	5693.53	11015.16	4 %	5 %	7 %	1.37 %	0.1002	0.2075	0.50 %	1.26 %	1.36 %	R	R	E1	
1.A. Fuel Combustion - solid fuels	CO2	14591.85	16768.36	2 %	10 %	10 %	3.20 %	0.0409	0.3159	0.41 %	0.71 %	0.82 %	M	R	E1	M4
1.A.1 Energy Industries - biomass	CH4	1.51	7.19	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	60.47	20 %	60 %	63 %	0.07 %	0.0011	0.0011	0.06 %	0.03 %	0.07 %	R/M	R	E1	M2
1.A.1 Energy Industries - gaseous fuels	CH4	1.03	4.36	1 %	60 %	60 %	0.00 %	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	32.43	1 %	60 %	60 %	0.04 %	0.0003	0.0006	0.02 %	0.00 %	0.02 %	R	R	E1	
1.A.1 Energy Industries - liquid fuels	CH4	0.97	1.04	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	27.71	2 %	60 %	60 %	0.03 %	0.0001	0.0005	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.1 Energy Industries - other fuels	CH4	2.47	6.81	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	123.25	5 %	60 %	60 %	0.14 %	0.0017	0.0023	0.10 %	0.02 %	0.10 %	R	R	E1	
1.A.1 Energy Industries - solid fuels	CH4	2.29	3.24	2 %	60 %	60 %	0.00 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.1 Energy Industries - solid fuels	N2O	43.40	82.99	2 %	60 %	60 %	0.09 %	0.0007	0.0016	0.04 %	0.00 %	0.04 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.80	8.66	15 %	60 %	62 %	0.01 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.43	81.99	15 %	60 %	62 %	0.10 %	0.0005	0.0015	0.03 %	0.03 %	0.04 %	R/M	R	E1	M2
1.A.2. Manufacturing Industries and Construction -	CH4	1.01	1.08	1 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2

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, 2007	Activity data uncertainty ⁽²⁾	Emission factor uncertainty ⁽²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2007	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
gaseous fuels																
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.26	16.58	1 %	60 %	60 %	0.02 %	0.0000	0.0003	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.54	2.33	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	36.98	28.84	2 %	60 %	60 %	0.03 %	-0.0002	0.0005	-0.01 %	0.00 %	0.01 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.08	1.21	5 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.01	18.19	5 %	60 %	60 %	0.02 %	0.0000	0.0003	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	1.37	0.50	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	46.87	10.03	2 %	60 %	60 %	0.01 %	-0.0007	0.0002	-0.04 %	0.00 %	0.04 %	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	3.88	5 %	150 %	150 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.b. Road Transportation - diesel	CH4	11.75	5.43	1 %	50 %	50 %	0.01 %	-0.0001	0.0001	-0.01 %	0.00 %	0.01 %	M	R		L5 L6,L7,L8 ,L9,L10, L19,L20, L21,L22, L23
1.A.3.b. Road Transportation - diesel	N2O	68.12	96.43	1 %	158 %	158 %	0.29 %	0.0005	0.0018	0.08 %	0.00 %	0.08 %	M	R		L6, L9, L10, L19, L21
1.A.3.b. Road Transportation - gasoline	CH4	77.85	24.88	1 %	50 %	50 %	0.02 %	-0.0010	0.0005	-0.05 %	0.00 %	0.05 %	M	R		
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	32.01	525.10	1 %	378 %	378 %	3.74 %	0.0093	0.0099	3.51 %	0.01 %	3.51 %	M	R		L5
1.A.3.b. Road Transportation - gasoline - cars without	N2O	59.42	21.87	1 %	259 %	259 %	0.11 %	-0.0007	0.0004	-0.18 %	0.00 %	0.18 %	M	R		L6, L8, L11, L21

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IPCC Greenhouse Gas Source and Sink Categories	Direct Greenhouse Gas ⁽¹⁾	Base Year emissions, 1990	Current Year emissions, 2007	Activity data uncertainty ⁽²⁾	Emission factor uncertainty ⁽²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2007	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
catalytic converters																
1.A.3.b. Road Transportation - natural gas	CH4	0.00	2.08	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	0.00	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	0.12	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	0.90	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	4.51	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	0.64	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	0.59	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	3.40	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	3.76	30 %	150 %	153 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.e. Other Transportation - gasoline	N2O	0.63	0.96	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	6.45	30 %	50 %	58 %	0.01 %	0.0000	0.0001	0.00 %	0.01 %	0.01 %	R	R		
1.A.3.e. Other Transportation - LPG	CH4	0.39	0.32	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	0.24	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	179.65	15 %	150 %	151 %	0.51 %	0.0003	0.0034	0.05 %	0.07 %	0.09 %	R/M	R	E1	M2
1.A.4. Other Sectors - biomass	N2O	27.77	30.17	15 %	150 %	151 %	0.09 %	0.0000	0.0006	0.01 %	0.01 %	0.01 %	R/M	R	E1	M2
1.A.4. Other Sectors - gaseous fuels	CH4	0.22	0.27	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	1.22	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	12.19	3 %	75 %	75 %	0.02 %	-0.0001	0.0002	-0.01 %	0.00 %	0.01 %	R/M	R	E1	M2
1.A.4. Other Sectors - liquid fuels	N2O	56.43	38.19	3 %	75 %	75 %	0.05 %	-0.0003	0.0007	-0.03 %	0.00 %	0.03 %	R	R	E1	
1.A.4. Other Sectors - other fuels	CH4	1.24	1.22	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	1.40	25 %	150 %	152 %	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, 2007	Activity data uncertainty ⁽²⁾	Emission factor uncertainty ⁽²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2007	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.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	0.12	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	439.42	271.56	15 %	60 %	62 %	0.32 %	-0.0032	0.0051	-0.19 %	0.11 %	0.22 %	R/M	R	E1	M2
1.A.5. Other - biomass	CH4	0.20	0.06	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	0.02	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	0.30	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	1.50	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	2.36	1.20	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	6.19	7 %	60 %	60 %	0.01 %	-0.0001	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 - 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	
1.B.2. Oil and Natural Gas - flaring	CH4	0.04	0.03	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	122.80	91.23	50 %	0 %	50 %	0.09 %	-0.0006	0.0017	0.00 %	0.12 %	0.12 %			E14	
1.B.2. Oil and Natural Gas - flaring	N2O	1.17	0.87	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	33.60	5 %	0 %	5 %	0.00 %	0.0006	0.0006	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	4.40	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	6.89	3 %	0 %	3 %	0.00 %	0.0001	0.0001	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	0.90	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	10.71	2 %	90 %	90 %	0.02 %	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	0.99	1.40	90 %	25 %	93 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E12	

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1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.45	37.09	5 %	10 %	11 %	0.01 %	-0.0011	0.0007	-0.01 %	0.00 %	0.01 %			E11	
2.A.1 Cement Production	CO2	733.59	599.57	2 %	5 %	5 %	0.06 %	-0.0025	0.0113	-0.01 %	0.03 %	0.03 %	R	R	E9	
2.A.2 Lime Production	CO2	382.60	480.03	2 %	3 %	4 %	0.03 %	0.0018	0.0090	0.01 %	0.03 %	0.03 %	R	R	E9	
2.A.3 Limestone and Dolomite Use	CO2	88.02	152.27	7 %	9 %	11 %	0.03 %	0.0012	0.0029	0.01 %	0.03 %	0.03 %	R	R	E9	
2.A.4 Soda Ash Use	CO2	8.32	9.87	7 %	2 %	7 %	0.00 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %	R	R	E9	
2.A.6 Road Paving with Asphalt	CO2	21.00	2.673	5 %	10 %	11 %	0.00 %	-0.0003	0.0001	0.00 %	0.00 %	0.00 %			E11	
2.A.7 Other - Glass Production	CO2	20.80	21.92	7 %	9 %	11 %	0.00 %	0.0000	0.0004	0.00 %	0.00 %	0.00 %			E12	
2.B.1 Ammonia Production	CO2	44.00	0.00	5 %	19 %	20 %	0.00 %	-0.0008	0.0000	-0.02 %	0.00 %	0.02 %			E13	
2.B.2 Nitric Acid Production	N2O	1655.71	1482.05	5 %	100 %	100 %	2.80 %	-0.0033	0.0279	-0.33 %	0.20 %	0.38 %	R/M	R		M1
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	24.41	6.89	5 %	10 %	11 %	0.00 %	-0.0003	0.0001	0.00 %	0.00 %	0.00 %			E11	
2.B.5 Other: Hydrogen Production	CO2	56.94	516.94	12 %	5 %	13 %	0.13 %	0.0087	0.0097	0.04 %	0.16 %	0.17 %	R	R	E9	
2.C.1 Iron and Steel production	CH4	5.11	9.08	3 %	20 %	20 %	0.00 %	0.0001	0.0002	0.00 %	0.00 %	0.00 %	R	R	E1	
2.C.1 Iron and Steel production	CO2	1861.21	2459.53	0 %	10 %	10 %	0.46 %	0.0113	0.0463	0.11 %	0.00 %	0.11 %			E10	
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.44	0.21	5 %	10 %	11 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E11	
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	0.01	818.68	26 %	0 %	26 %	0.40 %	0.0154	0.0154	0.00 %	0.57 %	0.57 %	R	R	E8	
2.F.2 Foam Blowing	HFCs	0.00	8.14	24 %	0 %	24 %	0.00 %	0.0002	0.0002	0.00 %	0.01 %	0.01 %	R	R	E8	
2.F.4 Aerosols	HFCs	0.00	75.32	10 %	0 %	10 %	0.01 %	0.0014	0.0014	0.00 %	0.02 %	0.02 %	R	R	E8	
2.F.8 Electrical Equipment	SF6	86.52	7.36	88 %	0 %	88 %	0.01 %	-0.0015	0.0001	0.00 %	0.02 %	0.02 %	R	R	E8	
2.F.9 Other (grouped data)	HFCs	7.94	25.41	38 %	0 %	38 %	0.02 %	0.0003	0.0005	0.00 %	0.03 %	0.03 %				
	PFCs, SF6												R	R	E8	
3. Solvent and Other Product Use	N2O	62.00	36.42	30 %	20 %	36 %	0.02 %	-0.0005	0.0007	-0.01 %	0.03 %	0.03 %	R	R	E1	
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.37	60.65	5 %	10 %	11 %	0.01 %	-0.0010	0.0011	-0.01 %	0.01 %	0.01 %			E11	

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4.A.Enteric fermentation	CH4	1928.87	1559.95	0 %	32 %	32 %	0.94 %	-0.0069	0.0294	-0.22 %	0.00 %	0.22 %	D/R	R		L4, L13
4.B.Manure management	CH4	229.81	283.71	0 %	16 %	16 %	0.08 %	0.0010	0.0053	0.02 %	0.00 %	0.02 %	R	R		
4.B.Manure management	N2O	664.76	497.01	0 %	82 %	82 %	0.77 %	-0.0032	0.0094	-0.26 %	0.00 %	0.26 %	R	R		L12, L14, L15, L16, L17, L4
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3377.61	2442.75	0 %	71 %	71 %	3.26 %	-0.0176	0.0460	-1.25 %	0.00 %	1.25 %	R/M	R		L1
4.D.Agricultural soils: indirect emissions	N2O	922.24	745.50	0 %	248 %	248 %	3.49 %	-0.0033	0.0140	-0.83 %	0.00 %	0.83 %	R/M	R		L1
4.F Field Burning of Agricultural Residues	CH4	1.88	0.63	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	0.19	15 %	14 %	21 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E15	
5 (I) Direct N2O Emissions from N Fertilization	N2O	26.82	16.69	10 %	380 %	380 %	0.12 %	-0.0002	0.0003	-0.07 %	0.00 %	0.07 %				see table 7.2_12
5 (IV) CO2 Emissions from Agricultural Lime Application	CO2	617.87	248.65	20 %	20 %	28 %	0.13 %	-0.0070	0.0047	-0.14 %	0.13 %	0.19 %				see section 7.2.3.2
	CH4															see section 7.2.3.2
5 (V) Biomass Burning		4.00	0.98	10 %	70 %	71 %	0.00 %	-0.0001	0.0000	0.00 %	0.00 %	0.00 %				L25
5 (V) Biomass Burning	CO2	3.26	4.91	10 %	70 %	71 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %				
5 (V) Biomass Burning	N2O	0.41	0.10	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 dead organic matter	CO2	-4539.15	-3269.38	0 %	10 %	10 %	-0.62 %	0.0239	-0.0616	0.24 %	0.00 %	0.24 %	R		E7	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	-26348.41	-32665.77	0 %	22 %	22 %	-13.35 %	-0.1197	-0.6153	-2.60 %	0.00 %	2.60 %	D	R	E4	L24
5.A.1. Forest Land remaining Forest Land - net carbon	CO2	2363.29087	-3624.70	0 %	92 %	92 %	-6.28 %	-0.0238	-0.0683	-2.19 %	0.00 %	2.19 %	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, 2007	Activity data uncertainty ⁽²⁾	Emission factor uncertainty ⁽²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2007	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
stock change in mineral soils																
5.A.1. Forest Land remaining																
Forest Land - net carbon stock change in organic soils	CO2	10027.37	6725.30	0 %	78 %	78 %	9.88 %	-0.0620	0.1267	-4.84 %	0.00 %	4.84 %	D	R	E4	L24
5.B.1. Cropland Remaining																
Cropland - net carbon stock change in living biomass	CO2	-1.44	-2.81	0 %	56 %	56 %	0.00 %	0.0000	-0.0001	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	214.08	-1534.30	0 %	100 %	100 %	-2.89 %	-0.0329	-0.0289	-3.29 %	0.00 %	3.29 %				see appendix 7c
5.B.1. Cropland Remaining																
Cropland - net carbon stock change in organic soils	CO2	6584.34	4617.71	20 %	90 %	92 %	8.02 %	-0.0370	0.0870	-3.33 %	2.46 %	4.14 %	R/M	R		L1
5.C1. Grassland Remaining																
Grassland - net carbon stock change in mineral soils	CO2	-2231.99	4016.30	0 %	100 %	100 %	7.57 %	0.1177	0.0757	11.77 %	0.00 %	11.77 %	R	R	E5	
5.C1. Grassland Remaining																
Grassland - net carbon stock change in organic soils	CO2	100.78	40.83	30 %	90 %	95 %	0.07 %	-0.0011	0.0008	-0.10 %	0.03 %	0.11 %	D	R		L24
5.D2. Land Converted to																
Wetlands - peat production areas	CO2, CH4, N2O	1078.05	1379.51	15 %	13 %	20 %	0.51 %	0.0057	0.0260	0.07 %	0.55 %	0.56 %	D	R		L24
5.G Other (harvested wood products)																
	CO2	-945.64	-1219.67	0 %	11 %	11 %	-0.25 %	-0.0052	-0.0230	-0.06 %	0.00 %	0.06 %	D	R		L24
6.A. Solid Waste disposal on Land																
	CH4	3644.52	2060.68	0 %	43 %	43 %	1.67 %	-0.0298	0.0388	-1.28 %	0.00 %	1.28 %	R/D		E2	L4
6.B.1 Industrial Wastewater																
	CH4	22.23	26.92	10 %	104 %	105 %	0.05 %	0.0001	0.0005	0.01 %	0.01 %	0.01 %	R/D	R	E2	L4
6.B.2 Domestic and Commercial Wastewater - densely populated areas																
	CH4	17.07	11.62	5 %	104 %	105 %	0.02 %	-0.0001	0.0002	-0.01 %	0.00 %	0.01 %	R	R	E3	
6.B.2 Domestic and Commercial Wastewater - densely populated areas																
	N2O	74.79	52.93	5 %	380 %	380 %	0.38 %	-0.0004	0.0010	-0.16 %	0.01 %	0.16 %	R	R	E2	L4
6.B.2 Domestic and																
	CH4	114.23	94.00	15 %	32 %	35 %	0.06 %	-0.0004	0.0018	-0.01 %	0.04 %	0.04 %	R	R	E2	L2

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, 2007	Activity data uncertainty ²⁾	Emission factor uncertainty ²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2007	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
Commercial Wastewater - sparsely populated areas																
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.55	24.91	10 %	380 %	380 %	0.18 %	-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	3.44	10 %	380 %	380 %	0.02 %	-0.0001	0.0001	-0.03 %	0.00 %	0.03 %	R	R	E2	L2
6.B.3. N input from industrial wastewater	N2O	30.17	19.78	5 %	380 %	380 %	0.14 %	-0.0002	0.0004	-0.07 %	0.00 %	0.07 %	R	R	E2	L2
6.D Other: compost production	CH4	21.55	69.32	30 %	50 %	58 %	0.08 %	0.0009	0.0013	0.04 %	0.06 %	0.07 %				AD, section 8.5.3; EF, table 4.1 in IPCC (2006)
6.D Other: compost production	N2O	20.43	68.01	30 %	50 %	58 %	0.07 %	0.0009	0.0013	0.04 %	0.05 %	0.07 %				AD, section 8.5.3; EF, table 4.1 in IPCC (2006)
Total		53 089.30	53 079.71				22.6%					14.9%				

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 or EF.

Expert Elicitations

- E1 Kari Grönfors and Mikko Äikäs (Statistics Finland), 27 August 2002
- E2 Jouko Petäjä (Finnish Environment Institute), 21 November 2002
- E3 Jouko Petäjä (Finnish Environment Institute), 15 January 2004
- E4 Merja Myllys (Agrifood Research Finland), 3 March 2005
- E5 Suvi Monni (VTT Technical Research Centre of Finland), Riitta Pipatti (Statistics Finland), 7 March 2005
- E6 Suvi Monni (VTT Technical Research Centre of Finland), Tuija Lapveteläinen (Statistics Finland) and Association of Finnish Peat Industry, 7 March 2005
- E7 Kristiina Regina, Paula Perälä (Agrifood Research Finland), 7 March 2005
- E8 Teemu Oinonen (Finnish Environment Institute), 3 March 2005
- E9 Saku Slioor (Statistics Finland), 15 Aug 2004
- E10 Kari Grönfors (Statistics Finland) 2007
- E11 Johanna Mikkola-Pusa (Finnish Environment Institute) 18 November 2008
- E12 Pia Forsell (Statistics Finland) 27 January 2009
- E13 Teemu Oinonen (Statistics Finland) 30 January 2009
- E14 Pia Forsell (Statistics Finland) 2 February 2009
- E15 Sanna Pitkänen (Agrifood Research Finland), 4 February 2009
- E16 Kari Grönfors (Statistics Finland) 5 February 2009
- E17 Teemu Oinonen (Statistics Finland) 6 February 2009

Measurement data

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- M3 Korhonen, R. and Määttänen, M. 1999. To solve the specific emissions of locomotive diesel engines, Final Report. MOBILE 237T-1. Kymenlaakso Polytechnic, Kotka. 15 pp.
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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 6 Reporting under Article 7, paragraph 1

General

This Annex includes the supplementary information required under Article 7, paragraph 1. The information is presented in the same order as the reporting requirements are addressed in the Annex of Decision 15/CMP.1.

Greenhouse gas inventory information

The reporting on Article 3, paragraphs 3 and 4 will start in 2010.

Information on emission reduction units, certified emissions reductions, temporary certified emission reductions, long-term certified emissions reductions, assigned amount unit and removal units

Finland's assigned amount and commitment period reserve

Finland's assigned amount in accordance with decision Article 3, paragraphs 7 and 8 is 355,017,545 tonnes of CO₂ equivalent.

Finland's commitment period reserve is 319,515,790 tonnes of CO₂ equivalent. The commitment period reserve has not changed since the previous submission.

Standard electronic format (SEF)

The standard electronic format tables are included in the submission for the first time (SEF v.1.2_FI.xls). The tables include information on the AAU, ERU, CER, t-CER, l-CER and RMU in the registry 31.12.2008 as well as information on transfers of the units in 2008 to and from other Parties of the Kyoto Protocol. The implementation of the SEF reporting to the Greta software has started January 2009 but was not completed when this report was completed wherefore the SEF tables have been filled manually.

The total number of AAU units in the registry at the end of the year 2008 corresponded to 352,773,544 tonnes CO₂ eq, of which 318,858,851 units were in the Party holding account, 33,914,666 units in the entity holding accounts and 27 units in the "other cancellation accounts". The units of CERs in the registry corresponded to 1,841,101 tonnes CO₂ eq, the division between the Party holding account and the entity holding accounts was 51,768 units and 1,789,331 units, respectively. Two CER units were in the other cancellation account.

Changes in the national system

No changes in the national system under Article 5, paragraph 1, of the Kyoto Protocol have been implemented. The agreements between Statistics Finland and the Ministry of the Environment, the Finnish Forest Research Institute, the MTT Agrifood Research Institute, Finavia and VTT have been updated. These updates confirm current practices for inventory preparation and reporting under the Kyoto Protocol and changes in the institutional, legal or procedural arrangement in the national system have not been made (see also section 1.2 of this report).

Changes in the national registry

The changes in the national registry are:

The Greta registry software has been updated in 2008 (version 2.3 to version 2.4). The change enables certain new annual registry functions such as the removal of the emissions units of the previous period.

The successful testing of the registry with ITL and CITL was completed, and the ITL Administrator authorised (29 August 2008) the registry of Finland to commence live operation with production environment of the ITL. The connection to the ITL was completed successfully in October 2008, together with 24 other EU member states. The registry has been operational since the connection.

Finland is also planning to replace the Greta registry with the registry software developed by the Commission (CR). This is expected to take place during the year 2009. The tests and documentation required in the reporting under the Kyoto Protocol will be updated in accordance with the requirements.

Minimisation of adverse impacts

The reporting on this item will start in 2010.