Statistics Finland

GREENHOUSE GAS EMISSIONS IN FINLAND 1990-2005

National Inventory Report to the UNFCCC

April 15th 2007

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) under the UNFCCC prepared using the reporting guidelines (UNFCCC 2006). 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 1990–2005 are included.

Part 2 CRF (Common Reporting Format) data tables of Finland's greenhouse gas emissions for the years 1990–2005. The CFR tables are compiled with the latest UNFCCC CRF Reporter software (version 3.1).

Since the submission of Finland's initial report under the Kyoto Protocol to the UNFCCC secretariat on 22 December 2006, no changes in the national system or registries have occurred. 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.

Main methodological improvements and changes since the inventory submission in 2006 are listed in Chapter 10.

Statistics Finland (Pia Forsell, Kari Grönfors, Aila Heinilä, Tuija Lapveteläinen, Teemu Oinonen, Riitta Pipatti, Leena Raittinen, Kai Skoglund, Jani Torniainen), MTT Agrifood Research Finland (Paula Perälä, Kristiina Regina), Finnish Forest Research Institute (Erkki Tomppo, Tarja Tuomainen, Timo Kareinen), Finnish Environment Institute (Päivi Lindh, Johanna Mikkola-Pusa, Jouko Petäjä, Kristina Saarinen, Tuulia Toikka), VTT Technical Research Centre of Finland (Kari Mäkelä) and Finavia (Niina Rusko) have made the inventory calculations, as well as the description of the methodologies and other information included in the national inventory report.

Statistics Finland is the National Authority in Finland's Greenhouse Gas Inventory System and responsible for the compilation and finalisation of inventory reports and their submission to the UNFCCC Secretariat and the European Commission. Statistics Finland approves the inventory submissions to the EC and UNFCCC independently.

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

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EXECUTIVE SUMMARY

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

Finland has prepared greenhouse gas inventories since the early 1990's to meet the obligations of the United Nations Framework Convention on Climate Change (UNFCCC). Inventory reports are submitted to the UNFCCC Secretariat and the European Commission annually.

In accordance with the Government resolution of 30 January 2003 on the organisation of climate policy activities of Government authorities in Finland, Statistics Finland has assumed the responsibilities of the National Authority for Finland's greenhouse gas inventory from the beginning of the year 2005. Statistics Finland as the general authority of the official statistics of Finland is independently responsible for greenhouse gas inventory submissions to the EC Commission and the United Nations Framework Convention on Climate Change (UNFCCC).

In Finland the national system, as intended in the Kyoto Protocol (Article 5.1), is based besides regulations concerning Statistics Finland on agreement between the inventory unit and expert organisations on the production of emission estimations and reports and on co-operation between the responsible ministries. According to the Government resolution, Finland's inventory system includes besides Statistics Finland the expert organisations that have taken part in the emission calculation also before the establishment of the National Greenhouse Gas Inventory System: the Finnish Environment Institute, MTT Agrifood Research Finland and the Finnish Forest Research Institute. Statistics Finland also acquires parts of the inventory as a purchased service. A short description on the National Greenhouse Gas Inventory System in Finland is provided in chapter 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: www.stat.fi/greenhousegases.

IPCC Good Practice Guidance and Revised 1996 IPCC Guidelines as well as national estimation methods are used in producing the greenhouse gas emission estimates. The Common Reporting Format (CRF) tables are used in reporting the emission figures. The CRF Tables are produced with the CRF Reporter software (version 3.1).

The national inventory and reporting system is being constantly developed and improved.

ES.2 Summary of trends in national emissions and removals

In 2005, Finland's greenhouse gas emissions totalled 69.3 Tg CO_2 eq. (million tonnes of CO_2 equivalent). The total emissions in 2005 was 2.7 per cent (~1.9 Tg) below the level of the year 1990 – the level to which Finland should limit its emissions during the Kyoto Protocol's first commitment period between 2008 and 2012.

Summary of the Finnish national emissions and removals for 1990-2005 is presented in Table ES.2_1.

Table ES.2_1. Finnish greenhouse gas emissions and removals in 1990-2005. Base year is 1990.

Tg CO_2 equivalent	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Energy	54.80	53.41	52.71	54.66	59.98	56.56	62.35	60.72	57.60	57.06	55.10	60.35	63.00	70.67	66.60	54.96
Industrial Processes (excluding F-gases)	4.98	4.60	4.32	4.33	4.55	4.50	4.64	4.91	4.82	4.87	4.98	4.86	4.83	5.25	5.44	5.27
F-gases	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
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
Agriculture	7.11	6.68	6.20	6.22	6.22	6.32	6.21	6.20	6.05	5.92	5.96	5.85	5.82	5.74	5.61	5.58
Waste	3.99	4.03	4.05	4.05	3.98	3.92	3.83	3.74	3.58	3.49	3.29	3.18	2.96	2.79	2.65	2.45
TOTAL	**71.15**	**68.95**	**67.48**	**69.44**	**74.91**	**71.55**	**77.32**	**75.95**	**72.49**	**71.88**	**70.03**	**75.09**	**77.25**	**85.25**	**81.14**	**69.26**
Land-Use Change and Forestry	-21.39	-36.13	-30.00	-27.60	-17.12	-15.38	-22.90	-16.85	-16.16	-16.98	-16.29	-19.06	-18.87	-17.85	-18.49	-30.93

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

The substantial decrease in the emissions in 2005 is largely due to decreased emissions in the Energy sector. Energy related CO_2 emissions vary mainly according to the economic trend, the energy supply structure, and climate conditions. In 2005 there was good availability of hydro power in the Nordic Countries and condensing power production fell to one third from the previous year's high level. Net imports of electricity rose to record levels. The total primary energy supply decreased in 2005 by 7% compared to previous year. This was mainly due to the changes in hydro and condensing power production mentioned above, but also to reduced final energy consumption in industry, which was affected for example by the industrial action in the forest industry (Energy Statistics Yearbook 2006).

Emissions in the Industrial Processes sector show a growing trend. Emissions in Agriculture and Waste sectors have decreased since 1990.

The LULUCF sector is a net sink as the removals in the sector exceed the emissions. The net removals in the sector have fluctuated much during 1990 to 2005. Annual variations in the drain (forest harvesting) have been the main cause of the fluctuations.

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 1A), 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).

In Figure ES.3_1 the composition of Finnish greenhouse gas emissions in 2005 is presented.

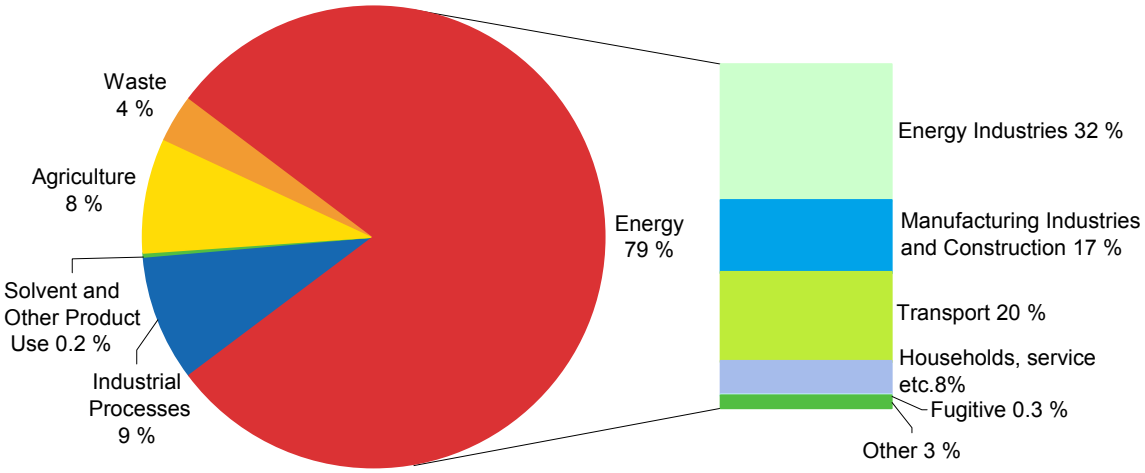


Figure ES.3_1. Composition of Finnish greenhouse gas emissions in 2005 (LULUCF sector excluded)**.**

The energy sector is the most significant source of greenhouse gas emissions in Finland with around 79% share of the total emissions. This reflects the high energy intensity of Finnish industry, extensive consumption for a long heating period, as well as energy consumption for transport in wide and sparsely inhabited country. Energy related CO_2 emissions vary mainly according to the economic trend, the energy supply structure, and climate conditions. In 2005 there was a clear decrease in emissions compared to 2004 and in particular to 2003 emission level. In 2005 the energy sector emissions were at the base year level. This was mainly due to the decreased condensing power production in Finland resulting from good availability of hydro power in Nordic electricity markets. The total primary energy supply decreased in 2005 by 7% compared to previous year, this was mainly due to the reduced condensing power and also reduced energy need of industry (Energy Statistics,Yearbook 2006).

The emissions from industrial processes (refer to non-energy related ones) including CO_2, CH_4, N_2O and F-gases were 8.9% of total greenhouse gas emissions in Finland in 2005 being the second largest source of greenhouse gas emissions. Emissions from process industry have increased about 21% (~1.1 Tg CO_2 eq.) since 1990, but their share from the total greenhouse gas emissions have remained relatively constant.

Agriculture is the third most significant source of greenhouse gas emissions in Finland. In 2005 agricultural emissions accounted for approximately 8.1% (5.6 Tg CO_2 eq.) of total emissions. Emissions from agriculture include CH_4 and N_2O emissions. The total emissions from agriculture have a clearly decreasing trend. The annual emissions have reduced 22% since 1990 due to decreases in the cultivation of organic soils, in the number of livestock, and in nitrogen fertilisation.

The waste sector accounted for 3.5% (2.4 Tg CO_2 eq.) of total Finnish greenhouse gas emissions in 2005. Emissions from waste sector consist of CH_4 and N_2O emissions, and have had a decreasing trend since 1990. Overall, the annual emissions in waste sector have decreased by over 38% since the 1990 level. The decrease has been mainly due to the implementation of the waste law 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 0.2% of the total greenhouse gas emissions in Finland. Indirect N_2O emissions caused from N deposition of NOx emissions are reported in the category Energy in the Finnish inventory. These contribute less than 0.5% to the total emissions.

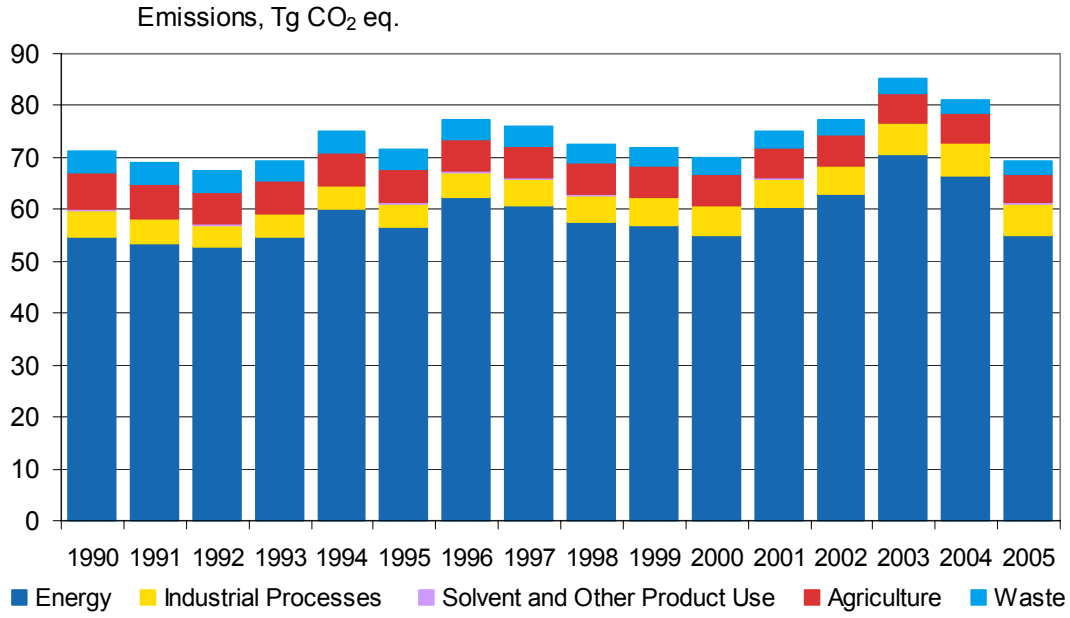


Figure ES.3_2. Greenhouse gas emissions in Finland in 1990–2005 by reporting sectors (Tg CO_2 eq).

The LULUCF sector is a net sink 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 forests and agricultural soils. The net sink in the LULUCF sector has varied from approximately 20 to 50 % of the annual emissions from other sectors during the 1990-2005 (Figure ES.3_3). During 1991 to 1993 the share was high, as the commercial fellings were very low at that time due to the economic recession in Finland and the poor global market situation.

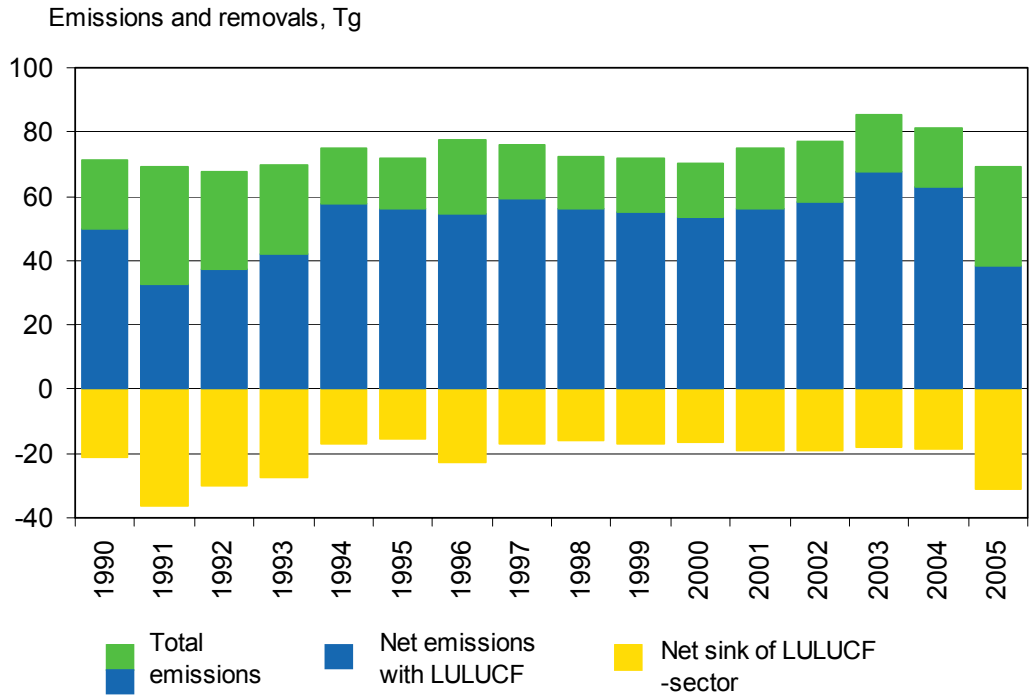


Figure ES.3_3. Net CO_2 equivalent emissions of greenhouse gases in 1990–2005 (emissions plus removals). Emissions are positive and removals negative quantities.

1. INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

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 established in the beginning of 2005.

The national system produces data on emissions and background information on them for the UNFCCC 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.

A Decision by the European Parliament, and by the Council for a Monitoring Mechanism of Community GHG Emissions and the Implementation of 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 year 2007 submission to the EU and UNFCCC includes data of the anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHGs) not controlled by the Montreal Protocol, i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). The emission estimates and removals are presented by gas and by source category and refer to the year 2005. Full times series of the emissions and removals from 1990 to 2005 are included in the submission.

The structure of this NIR follows the updated 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 an overall emission trend in Finland from the base year 1990 to year 2005. In Chapters 3–9 more detailed information of GHG emissions 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 are summarised. Annex 1 includes additional information on uncertainty reporting. In Annex 2 the VAHTI - emission database of Finland's environmental administration is described in more detail. Annex 3 discusses the applicability of the IPCC default CO_2 emission factor for coal to Finnish circumstances. National reference calculation for CO_2 emissions from energy combustion can be found in Annex 4 (Comparison of CO_2 emissions calculated from the Energy balance to Fuel combustion emissions as reported in the CRF tables).

Climate change

Over the past century, atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and halogenated hydrocarbons, i.e. greenhouse gases, have been increasing primarily as a consequence of human activity. As their name implies, greenhouse gases prevent the radiation of heat back to space and cause a warming of the climate. According to the Third Assessment Report of the International Panel of Climate Change (IPCC), the atmospheric concentrations of CO_2, CH_4 and N_2O have increased by 31(±4)%, 151(±25)% and 17(±5)% respectively compared to 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 endurance 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 the Finland's National Strategy for adaptation to climate change from the year 2005 (Ilmastonmuutoksen kansallinen sopeutumisstrategia 2005) the average temperature in Finland could rise by about 4–6°C and the average precipitation would grow by 15–25 % by the year 2080. Extreme weather events, such as storms, droughts and heavy rains, are likely to increase. The impacts of climate change on wide range of sectors including agriculture and food production, forestry, fisheries, reindeer husbandry, game husbandry, water resources, biological -diversity, industry, energy, traffic, land use and communities, building, health, tourism and recreation, and insurance are listed to the strategy. Strategy outlines possible actions and measures to improve the capacity of different sectors to adapt to future climate change.

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. Kyoto protocol entered into force on 16 February 2005 and became legally binding. *Under the Kyoto Protocol Finland's commitment is, as part of the EC's common emission reduction target and burden sharing agreement, to limit its emissions of greenhouse gases in the first commitment period, i.e. from 2008 to 2012, to the same average level as the emissions in 1990.*

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 and for reporting and archiving the results. In the Decision of the European Parliament and of the Council concerning a mechanism for monitoring community greenhouse gas emissions (280/2004/EC) it is required that Member Countries establish a national greenhouse gas inventory system as fast as possible and by the end of 2005 at the latest and that the Commission adopts the EC's inventory system by 30 June 2006. Finland's inventory system was established 1st of January in 2005.

The EU's greenhouse gas monitoring mechanism (280/2004/EC) combines annual emission inventories, the climate strategy and the evaluation of the effect 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) specifies in detail the content of the reports to be submitted to the Commission. By means of the monitoring mechanism, EU reports containing data from all Member States can be prepared for the UNFCCC.

Under the UNFCCC all Parties are required to provide annual national GHG inventories covering emissions and removals of direct GHGs 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 UNFCCC guidelines and are based on following IPCC methodologies to ensure the comparability, accuracy and completeness of the inventories;

- *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (GL 1996)*
- *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)*

1.2 A description of the institutional arrangement for inventory preparation

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 in place of the previous, workgroup-based emission calculation 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 agreement between the inventory unit and expert organisations on the production of emission estimates and reports as well as on co-operation between the responsible ministries. The National System is designed and operated to ensure the transparency, consistency, comparability, completeness, accuracy and timeliness of greenhouse gas emission inventories. The quality requirements are fulfilled by implementing consistently the inventory quality management procedures. The National System for the Greenhouse Gas Inventory in Finland is presented in Figure 1.2_1 below.

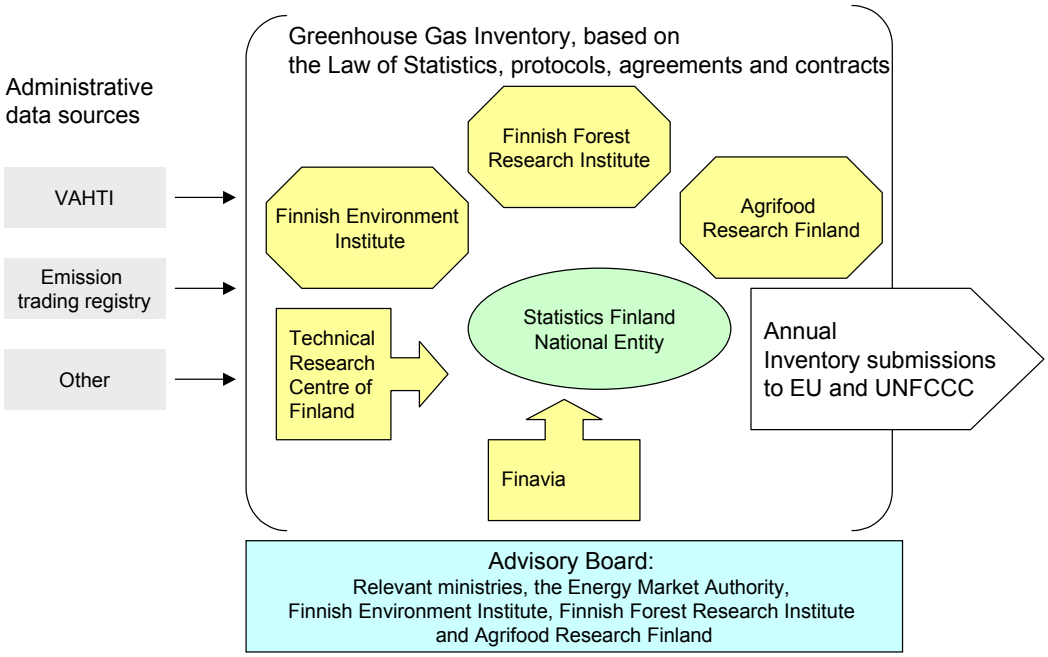


Figure 1.2_1. The National System for the Greenhouse Gas Inventory in Finland.

Statistics Finland as the National Authority for the inventory

Statistics Finland is the general authority of the official statistics of Finland and is independently responsible for greenhouse gas emission inventory preparation, reporting and submission to the United Nations Framework Convention on Climate Change (UNFCCC). 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. An advisory board of the greenhouse gas inventory set up by the Statistics Finland 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 supervises 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, 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 reviews, 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 a purchased service.

The agreements confirm the division of responsibilities recorded in so-called reporting protocols and they specify the procedures for the annual emission calculation and quality management 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 GHG emission inventory. The reporting sectors for which Statistics Finland is responsible are also defined in the protocols.

The role of responsible ministries 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 preparation of the climate policy advance in their administrative branch that the data collected in 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 compiled technically the fourth National Communication for the UNFCCC. Separate agreements have been made on division of responsibilities and co-operation between Statistics Finland and the ministries.

1.3 Brief description of the process of inventory preparation

The UNFCCC 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, e.g. the 2007 submission contains estimates for calendar year 2005.

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 and according to the UNFCCC guidelines in force (Table 1.3_1). 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 joint EU inventory is compiled from the Member States' submissions and it is 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. The greenhouse gas inventory is submitted to the UNFCCC Secretariat by 15 April.

Table 1.3_1. Reporting protocols and their responsible organisations.

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

1.4 Brief general description of methodologies and data sources used

The greenhouse gas inventory system in Finland is a combination of different methodologies and data sources. A specific feature of the Finnish system is its extensive use of bottom-up data. This is especially true in 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 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.

The methodologies used for the Finnish greenhouse gas inventory are consistent with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories 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 chapters 3–9.

Table 1.4_1 . Main data sources used in Finnish greenhouse gas inventory.

Sector	**Main data sources**
1.A Energy: Fuel combustion	VAHTI emission database Energy Statistics, Yearbook 2006 (Statistics Finland) surveys: electricity production, district heating plants, energy consumption of manufacturing industry LIPASTO and TYKO models of the VTT Technical Research Centre of Finland, 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 emission database individual production plants Energy Market Authority (ETS emission data)
2. (II)Industrial processes (F-gases)	surveys of Finnish Environment Institute
3. Solvents and other product use	VAHTI emission database ULTIKA, import statistics of Finland Association of Finnish Paint Industry individual companies published literature
4. Agriculture	Matilda-database of 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) Yearbook of Farm Statistics Association of Finnish Peat Industry VAHTI database published literature
6. Waste	VAHTI emission database Water and Sewage Works Register Register for industrial Water Pollution Control

The VAHTI emission database of Finland's environmental administration is one of the main data sources used in the inventory (especially in the Energy and Waste sectors). VAHTI database functions as a tool for the 13 regional environment centres in their work on processing and monitoring environmental permits. The data system contains information required by the environmental permits of the clients (more than 31 000), for example:

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

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

1.5 Brief description of key categories

Key categories are the most significant categories in an inventory. There are two criteria that define what significance means in this context:

- the level criterium: it is applied to base year estimates and to the current inventory year
- the trend criterium, which applies to the change of emissions between the base and the current inventory year.

The meaning of significance is dependent also on what methodology was used in the analysis. There are two choices; Tier 1 and Tier 2. Tier 1 key categories are those that contribute 95 per cent of total emissions. Tier 2 methodology incorporates uncertainty estimates, and yield categories that contribute 90 per cent of inventory uncertainty.

Table 1.5_1 presents the results of Tier 2 analysis on 1990 and 2005 inventory estimates, as well as the trend. A more detailed summary of the analysis is given in Annex 1. Uncertainty analysis is described in chapter 1.7.

Note that the level of disaggregation of categories is different from that used by the UNFCCC Secretariat. The categorization used here is more detailed and the same that is used in the uncertainty analysis. This is useful because in many cases it is possible to pinpoint the largest sources of uncertainty at the level where actual calculations are done.

Table 1.5_1 lists first those categories that where identified when LULUCF sector was excluded from the analysis. Then, LULUCF categories identified as key are listed. Finally, a summary of the number of categories identified is given. Other numbers in the table give ranks for the different categories using different criteria.

The identified categories are subject to stricter requirements regarding methodologies used and the level of documentation.

Table 1.5_1. Summary of Tier 2 key category analysis. Numbers attached to categories give ranks using three different criteria: 1990, 2005 levels of emissions, and the percentage change between the two (trend). Different criteria produce different rankings (a more detailed summary is in Annex 1). The body of the table is in three parts: first 17 rows list categories when LULUCF is excluded from the analysis, the following eight rows list additional categories when LULUCF is included, and finally, the three last rows give the totals.

Category	**Gas**	**1990**	**2005**	**Trend**
LULUCF excluded				
Agricultural soils, direct emissions (4.D)	N_2O	1	1	2
Agricultural soils, indirect emissions (4.D)	N_2O	2	2	4
Road transportation, cars with catalytic converters (1.A.3)	N_2O	–	3	1
Fuel combustion, solid fuels (1.A)	CO_2	5	4	5
Solid waste disposal on land (6.A)	CH_4	4	5	3
Fuel combustion, liquid fuels (1.A)	CO_2	6	6	–
Fuel combustion, other fuels (1.A)	CO_2	9	7	7
Manure management (4.B)	N_2O	8	8	8
Nitric acid production (2.B.2)	N_2O	3	9	–
Fuel combustion, other sectors, biomass (1.A.4)	CH_4	11	10	–
Iron and steel production (2.C)	CO_2	–	11	13
Enteric fermentation (4.A)	CH_4	7	12	–
Domestic and commercial wastewater, densely populated areas (6.B.2)	N_2O	10	13	11
Refrigeration and air conditioning (2.F.1)	HFCs, PFCs	–	14	6
Road transportation, cars without catalytic converters (1.A.3)	N_2O	–	–	9
Electrical equipment (2.F.8)	SF_6	–	–	10
Oil and natural gas, flaring (1.B.2)	CO_2	–	–	12
Fuel combustion, gaseous fuels (1.A)	CO_2	–	–	14
Additional categories when LULUCF included				
Carbon stock change in living biomass (5.A.1)	CO_2	1	1	1
Carbon stock change in organic soils (5.A.1)	CO_2	2	2	7
Carbon stock change in mineral soils (5.A.1)	CO_2	3	3	4
Carbon stock change in organic soils (5.B.1)	CO_2	4	4	–
Carbon stock change in mineral soils (5.C.1)	CO_2	5	5	2
Carbon stock change in mineral soils (5.B.1)	CO_2	–	6	3
Peat production areas (5.D.2)	CO_2	–	7	6
Carbon stock change in organic soils (5.C.1)	CO_2	6	–	5
Totals				
Number of key categories when LULUCF is excluded		11	14	14
Number of additional key categories when LULUFC is included		6	7	7
Total number of key categories		17	21	21

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

This section presents the general QA/QC programme including 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.

Quality management process

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. The principles and elements of the quality management system are congruent both with international agreements and guidelines concerning greenhouse gas inventories and with the ISO 9001:2000 standard. ISO 9001-certification is under consideration.

As the national entity, Statistics Finland bears the responsibility and has the resources for the co-ordination of the quality management measures for the partners of the national system and for the quality management of the greenhouse gas inventory at the national level. The expert organisations contributing to the production of emission or removal estimates are responsible for the quality of their own inventory calculations.

The quality of the inventory is ensured in the course of the compilation and reporting, that consists of four main stages: planning, preparation, evaluation and improvement. The quality management of inventory is a continuous process (Fig. 1.6_1) that starts from the consideration of the inventory principles. The setting of concrete annual quality objectives is based on this consideration. The next step is elaboration of the QA/QC plan and implementing the appropriate quality control measures (e.g. routine checks, documentation) focused on meeting the quality objectives set and fulfilling the requirements. In addition, the quality assurance procedures are planned and implemented. In the improvement phase of the inventory, conclusions are made on the basis of the realised QA/QC process and its results.

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.

A quality manual of the national greenhouse gas inventory system including guidelines, annual plans, templates, documentation of methodologies and work processes and checklists of QA/QC procedures is in preparation and will be in place in 2007.

Statistics Finland bears the responsibility of archiving the quality manual and the 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.

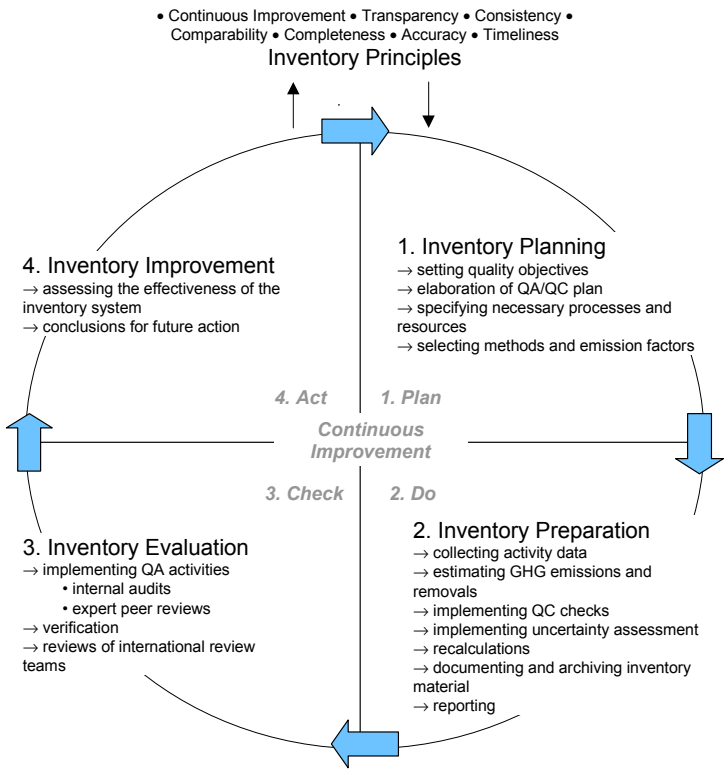


Figure 1.6_1. Quality management process of the Finnish greenhouse gas inventory.

Quality objectives

Statistics Finland, in collaboration with the expert organisations responsible for the inventory calculation sectors, sets yearly quality objectives for the whole inventory at the inventory planning stage and designs the QC procedures needed for achieving these objectives. In addition, the expert organisations set their own, sector and/or category specified quality objectives and prepare their QC plans. The quality objective and QC plans are set for following categories:
- Inventory compilation and reporting
- NMVOC (Protocol[1] G. Emissions of non-energy NMVOCs)
- CRF 1. Energy (Protocols A. Point sources, Stationary combustion, B. Mobile sources, C. Other fuel combustion)
- CRF 1. / 1.A.3.b Road transportation, 1.A.3.c Railways, 1.A.3.d Navigation (Protocol B. Mobile sources)
- CRF 1. / 1.A.3.a Civil aviation (Protocol B. Mobile sources)
- CRF 2. / Industrial processes (Protocol E. Emissions from industrial processes)
- CRF 2. / F-gases (Protocol F. Emissions of F-gases)
- CRF 4. Agriculture (Protocol H. Emissions from Agriculture, non-combustion emissions)
- CRF 5. LULUCF / Finnish Forest Research Institute (Protocol Ia. Emissions from LULUCF, Responsibilities of Finnish Forest Research Institute)
- CRF 5. LULUCF / MTT Agrifood Research Finland (Protocol Ib. Emissions from LULUCF, Responsibilities of MTT Agrifood Research Finland)
- CRF 6.A Waste, Solid waste disposal on land (Protocol J. Emissions from waste treatment)
- CRF 6.B Waste, Waste water handling (Protocol J. Emissions from waste treatment).

The quality objectives and QC plans are archived in the GHG extranet available to all parties of Finland's greenhouse gas inventory system.

The setting of quality objectives is based on the inventory principles presented in the UNFCCC Guidelines (FCCC/SBSTA/2006/9) and in the EU's decision on a mechanism for monitoring community greenhouse gas

[1] The protocols refer to the division of responsibilities in the Finnish national system. They are based on the responsibility areas of different expert organisations and Finland's established practice for the compilation of the emission inventory.

emissions, that is, transparency, consistency, comparability, completeness, accuracy and timeliness. In addition, the principle of continuous improvement is included.

Quality objectives are concrete expressions about the standard that is aimed for in the inventory preparation with regard to the inventory principles. The objectives aim to be appropriate and realistic taking account the available resources and other conditions in the operating environment. Where possible, quality objectives should be measurable.

So far, there is no definition for quality objectives in the IPCC or UNFCCC guidelines. The definition above used in the Finland's greenhouse gas inventory system is also applied in the EU's system for monitoring greenhouse gas emissions.

The quality objectives regarding all calculation sectors for the 2005 inventory are the following:

1. Continuous improvement
   - 1.1. A systematic procedure for treatment of review feedback has been established and documented.
   - 1.2. Review feedback is considered in a systematic way. The required corrections are made. Issues that are left unchanged are rationalised in the NIR.
   - 1.3. The improvements promised in the NIR are carried out. If planned improvement measures are not taken the reason is given in the NIR.
   - 1.4. A systematic procedure for improvement of the inventory has been established and documented.
   - 1.5. The inventory improvement needs and development projects are identified and prioritised making use of key category analysis, and recorded in the NIR and in the inventory improvement plan.
   - 1.6. Quality objectives are set for the inventory and recorded.
   - 1.7. General quality control (QC) procedures described in the IPCC GPG Table 8.1 are in use in all calculation areas and in compiling and reporting of the inventory. Results of the checks are recorded appropriately.
   - 1.8. In addition to general quality control (QC) procedures, category-specific QC checks (Tier2 QC) are applied for the key categories. Results of the checks are recorded appropriately.
   - 1.9. Appropriate and sufficient quality assurance procedures of the inventory are in place.
2. Transparency
   - 2.1. A systematic procedure for archiving the inventory has been established and documented.
   - 2.2. The annual inventory (NIR, CRF tables and calculation programs if possible) is archived.
   - 2.3. Calculation models and primary material (basic data, country-specific emission factors) have been recorded and archived electronically, if possible.
   - 2.4. The NIR includes transparent and appropriate descriptions of the assumptions, methodologies, references, and changes related to the estimation of GHG emissions and sinks. In addition, it includes the tables with essential activity data and emission factors.
   - 2.5. Internal documentation (e.g. working instructions) for the calculation is adequate and appropriate.
   - 2.6. Changes in calculation and recalculations have been recorded. The documentation includes information on the reason for the change, date and responsible expert.
3. Consistency
   - 3.1. The time series are consistent.
   - 3.2. In the inventory the data have been used in a consistent manner.
4. Comparability
   - 4.1. The methodologies and formats agreed by the COP are used in the inventory calculation and reporting.
   - 4.2. Inventory reporting (NIR and CRF tables) follows the guidelines FCCC/SBSTA/2004/8.
   - 4.3. The emission source / sink classification is in line with the IPCC guidelines on the level of summary and sector-specific tables.
5. Completeness
   - 5.1. The inventory covers all the emission sources, sinks and gases mentioned in the IPCC guidelines and other significant emission source / sink categories.
   - 5.2. Examination of emission sources and sinks is regionally comprehensive.
6. Accuracy
   - 6.1. Calculation of the key categories complies with the GPG method.

6.2. The source data used in key categories are accurate enough (see the decision trees of the IPCC Good Practice Guidance).
6.3. National factors are used in the key categories in place of IPCC default factors, if possible and appropriate.
6.4. Inventory uncertainties are estimated and reported.

7. Timeliness
7.1. The schedules are followed to ensure that the inventory reporting is of high quality and reach their receiver (EU / UNFCCC) within the set time.
7.2. Responses are given to different review stages within the set time frames.

Quality control plan

The measures aiming at attainment of quality objectives are recorded as QC plans, which specify the actions, the schedules for the actions and the responsibilities. The expert institutions prepare of a QC plan in their respective calculation sectors. The inventory unit prepares the QC plan for the compilation and reporting of the national inventory. The QC plans are archived in the GHG extranet available to all parties of Finland's greenhouse gas evaluation system. The QC plans are written in Finnish.

Quality assurance plan

In the inventory quality management attention has been especially given to setting concrete quality objectives and preparing QC plans. In 2006 the focus of the development of quality management has shifted to QA procedures.

The inventory QA system comprises reviews and audits to assess the quality of the inventory, 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: basic reviews of the draft report, internal self-evaluations, peer reviews, international reviews of inventories, audits, system audits by an independent party and data verifications.

A basic review of the draft GHG estimates and the draft report takes place in November-December by the inventory working group, the advisory board and the inventory unit.

In internal self-evaluations experts in their specific calculation sectors examine the actual activity and results attained and compare them with the objectives set and the plans made. For the 2005 inventory, the findings of internal self-evaluations will be discussed in quality meetings that will be held between the inventory unit and the expert organisations in January-February 2007.

Peer reviews are performed by an external expert or expert group. Preferably the reviewers would be external experts who are independent from the inventory preparation. The reviewers may also be experts in other calculation sectors of the greenhouse gas 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.

The Finnish and Swedish greenhouse gas inventory teams have met twice annually to exchange knowledge, experiences and views relating to the preparation on the national GHG inventories. This collaboration provides opportunities for bilateral peer reviews also. 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 in September-October 2006. The objectives of the review was to check, whether the reporting and choice of emission factors is 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) are explainable and reasonable taking the national circumstances into account.

The procedures for audits are under development. In the audits made by the inventory unit, the representative of the unit evaluates how effectively the experts in their specific calculation sectors comply with the QC specifications outlined in the QC plans. Audits provide an in-depth analysis of the respective procedures taken to develop an inventory, and on the documentation available.

ISO 9001 -certification of the inventory quality management system 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 to the requirements of the ISO 9001 standard.

Emission and activity data are verified by comparing them with other available data compiled independently of the greenhouse gas 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 sector-specific chapters.

Documentation and archiving

Inventory documentation consists of inventory data and metadata (data explaining the calculated estimates). This information is summarised in this report.

Documentation has a key role in 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 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 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 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 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 archival 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 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. The expert organisation's archival procedures are described in greater detail in the sector-specific chapter of this report. Typically, these organisations keep records of their work on hard disks of individual expert's desktop workstations, with copies on backed up network servers. Also electronic copies on CD-ROMs are 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

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 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 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, 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 are included in the VTT´s official backup tapes and are stored for one year

The archiving of inventory records for 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. 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.

Agriculture

Back-up copies of the files used in the inventory calculations for agricultural emissions are stored in the specific folder in the server maintained by the information services of the 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 CR-ROM. In a database called Datainfo maintained by MTT, the location of the data and responsible persons are described. Datainfo is updated annually.

LULUCF

The Finnish Forest Research Institute (Metla) is an authority on reporting carbon stock changes and removals and emissions of greenhouse gases associated with LULUCF sector, excluding cropland and grassland, which are calculated by MTT. Metla will finish the documentation and archiving plan in the beginning of 2007. After that the documentation and archiving work will be started following the directions given by Metla.

The two main sources of information in LULUCF sector are the national forest inventory data (NFI) and the official statistics on forestry from 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 for Forestry. The quality documentation is available in Finnish in the web-site www.metla.fi/metinfo/tilasto. Other data sources were the Association of Finnish Peat Industry (areas for peat extraction) and the company Kemira GrowHow Oyj (volume of nitrogen fertilisers).

All activity data, calculation procedures, results and reports are storaged at Metla. The files are recorded in the network drives from which the backup copies are taken regularly. 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. Reported results are also stored in CRF Reporter database files and MS Excel files.

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 sock change in soils on forest land
- greenhouse gases from biomass burning
- direct N_2O emissions from forest fertilisation.

Waste

All electronic data (mainly excel, word or access files) on yearly waste inventory and documentation are collected in three different places: Folder of the hard disk of the computer used in inventory, Network disk (under backup copies) of Finnish Environment Institute and CD-ROM. Yearly information on paper are collected in one place.

1.7 Summary of the uncertainty analysis

Uncertainties of inventory estimates were quantified using KASPER model, developed by VTT Technical Research Centre of Finland. The model uses Monte Carlo simulation to estimate uncertainties, and is thus in accordance with the Tier 2 method presented by the IPCC Good Practice Guidance (IPCC, 2000). First version of the model was developed for the 2001 inventory. The uncertainties in input parameters were estimated using IPCC default uncertainties, expert elicitation, domestic and international literature and measurements, where available (Monni & Syri, 2003). Since then, KASPER model has been developed further, e.g. to correspond with requirements of the Good Practice Guidance for LULUCF (IPCC, 2003), and updated to reflect changes (such as addition of new categories) in the inventory (Statistics Finland, 2006).

Uncertainty analysis and Tier 2 key category analysis use the samel level of aggregation. Uncertainty analysis was, in most cases, done at the level in which methods or emission factors are given. All greenhouse gases were treated separately in uncertainty analysis, except F-gases, where several gases were grouped. In the energy sector, uncertainty in CO_2 emissions was estimated for activity data and emission factors on a much-aggregated level (CRF 1.A) by fuel type (solid, liquid, gaseous, other). This is because emissions of CO_2 depend on the carbon content of the fuel and almost all carbon in the fuel is oxidised. Therefore combustion technology does not affect uncertainty notably. In addition, fuel statistics are most accurate on the national level for imported fuels (coal, oil, natural gas). In the case of CH_4 and N_2O emissions from combustion, technology has a large effect on emissions. Therefore, a split into different subcategories was needed. In stationary combustion, emission factors are defined on a plant-specific level for CRF 1.A.1 and 1.A.2 which is a too detailed level for uncertainty assessment. Therefore, uncertainties were estimated at a level of CRF categories 1.A.1, 1.A.2, 1.A.4 and 1.A.5 by fuel type and separately for activity data and emission factors.

In transportation, uncertainties were mainly estimated for each sub-category (road transportation, civil aviation, etc.) by fuel type for activity data and emission factors, because this is the level at which accurate fuel statistics are usually available. In the case of N_2O from gasoline driven vehicles in road transportation, a split between cars with and without catalytic converters was done, because trends for these two sources are notably different.

In industrial processes, uncertainty analysis was done at the third CRF level (e.g. 2.A.1), which is also the level at which emission factors and methods are usually defined. Uncertainty estimates were given separately for activity data and emission factors. N_2O from nitric acid production was an exception. Uncertainty information obtained from the producer concerned the level of emissions only, and the estimate was based on a combination of measurements and expert judgment (Gåpå 2005). For F-gases, uncertainty analysis was done at a more detailed level.

In agriculture, an uncertainty estimate was given for each calculation parameter of the calculation model at a detailed level.

In the estimation of uncertainties in solid waste disposal on land (CRF 6.A), uncertainty estimates were given for each calculation parameter, and total uncertainty was estimated by simulating the FOD model (see chapter 8.2.2) with Monte Carlo simulation. In the case of wastewater treatment, uncertainty estimates were given at the third CRF level (e.g. 6.B.1). In addition, emissions from domestic wastewater were separated into densely and sparsely populated areas, because calculation methods and their uncertainties differ notably between the two sources.

Uncertainty analysis does not cover the minor sources that result in indirect CO_2 emissions due to oxidation of CH_4 and NMVOC in the atmosphere. Nor are indirect N_2O emissions from NO_x included.

Table 1.7_1 presents a summary statistics for 1990 and 2005 emission levels and the trend of emissions. The arithmetic mean and selected percentiles of the simulated sets of numbers are shown.Tables 1.7_2 and 1.7_3 present uncertainty of emissions by gases and by categories, respectively.

Table 1.7_1. Uncertainty estimates for the total level and trend (percentage change) of emissions.

Results when	Emissions 1990 (Tg)			Emissions 2005 (Tg)			Change 2005/1990 (%)		
		percentiles			percentiles			percentiles	
LULUCF is …	mean	2.5	97.5	mean	2.5	97.5	mean	2.5	97.5
excluded	71	66	80	69	66	74	–2	–14	6
included	50	25	75	38	17	58	–20	–65	45

Table 1.7_2. Uncertainty of emission estimates by gases.

Gases	Emissions 1990 (Tg)			Emissions 2005 (Tg)		
		percentiles			percentiles	
	mean	2.5	97.5	mean	2.5	97.5
CO_2	57	55	58	57	55	58
CO_2 (excl. LULUCF)	36	12	59	26	5	46
N_2O	7.5	4.0	16	6.5	4.5	11
CH_4	6.3	4.7	7.9	4.5	3.6	5.5
F-gases	0.09	0.05	0.14	0.91	0.81	1.1

Table 1.7_3. Uncertainty of emission estimates by category.

Categories	Emissions 1990 (Tg)			Emissions 2005 (Tg)		
		percentiles			percentiles	
	mean	2.5	97.5	mean	2.5	97.5
Energy	54	53	56	55	53	57
LULUFC	–21	–45	2.7	–31	–52	–11
Agriculture	7.1	4.1	15	5.6	13.9	9.5
Industrial processes	5.1	4.2	6.7	6.1	5.7	6.4
Waste	4.0	2.4	5.5	2.4	1.5	3.3
Solvents	0.06	0.04	0.09	0.05	0.03	0.06

The detailed results of Tier 2 uncertainty analysis are presented in Annex 1 of this report. For the sake of completeness, we also provide results of Tier 1 analysis in Annex 1.

More information on the methodology used in the Finnish greenhouse gas inventory is available in separate reports (Monni & Syri, 2003; Monni, 2004; Oinonen, 2003), and in peer-reviewed scientific journals (Monni et al., 2004; Monni et al. (in press)). At present, the uncertainty estimates for the whole inventory and the development of the Kasper model are done at Statistics Finland, in close co-operation with the sectoral experts. This submission does not contain the Tier 1 uncertainty analysis of Finland's GHG inventory.

1.8 General assessment of completeness

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 following gases: CO_2, N_2O CH_4, F-gases (HFC, PFC and SF_6), NMVOC, NO_x, CO and SO_2.

In accordance with the IPCC Guidelines, international aviation and marine bunker fuel emissions are not included in national totals. However, CO_2, CH_4 and N_2O emissions from lubricants from International bunkers are included in emissions from feedstocks 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.

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. The Finnish Environment Institute will make this information available by end of 2007 at the website www.environment.fi > State of the environment > Air > Finland's greenhouse gas emissions.

Completeness by timely coverage

In general, complete 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 2005 Finland's greenhouse gas emissions totalled 69.3 Tg CO_2 (million tonnes of CO_2 equivalent). The emissions decreased by 2.7 per cent (1.9 Tg CO_2 eq.) compared to year 1990 – the level to which Finland should limit its emissions during the Kyoto Protocol's first commitment period between 2008 and 2012. Emissions in 2005 were 14.6% smaller in comparison of the emissions of previous year. Figure 2.1_1 shows a time series of CO_2-equivalent emissions in Finland during 1990-2005 and the emission target of the Kyoto Protocol. In Table 2.1_1 the total greenhouse gas emissions as CO_2 equivalence and indexed emissions in relation to 1990 level are presented.

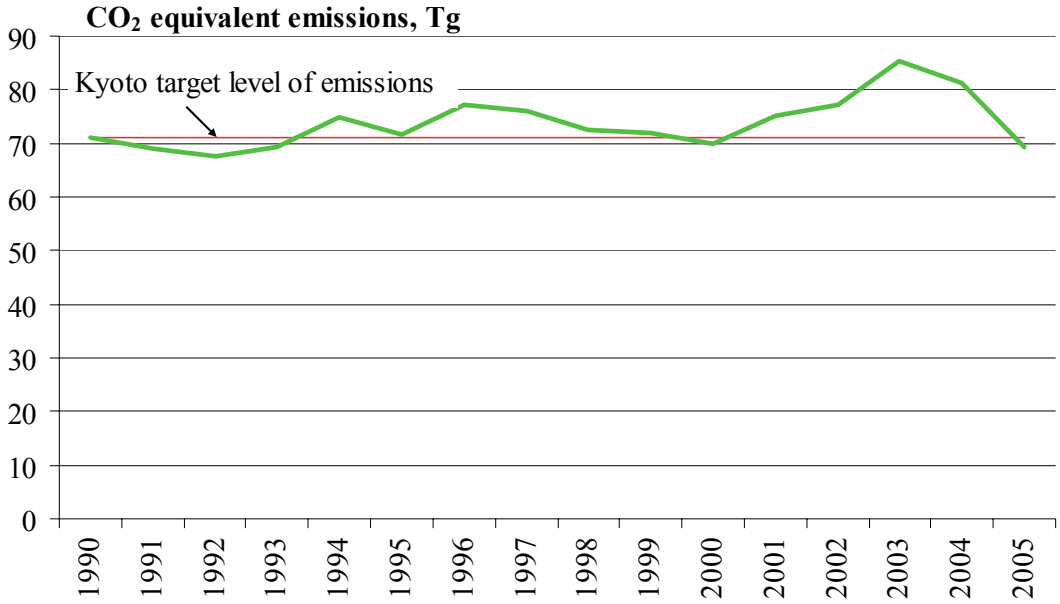


Figure 2.1_1. CO_2 equivalent emissions and the emission target of the Kyoto Protocol (Tg CO_2 eq.).

Table 2.1_1. Total greenhouse gas emissions in Tg CO_2 eq. and indexed 1990–2005 (index 1990=100).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2 without LULUCF	56.90	55.33	54.47	56.29	61.69	58.21	64.04	62.69	59.54	59.06	57.21	62.33	64.83	72.74	68.83	57.01
CO_2 with LULUCF	35.46	19.16	24.44	28.67	44.53	42.80	41.12	45.80	43.35	42.04	40.88	43.23	45.93	54.86	50.31	26.05
CH_4 without LULUCF	6.30	6.29	6.26	6.28	6.23	6.09	6.02	5.94	5.75	5.62	5.40	5.28	5.08	4.88	4.71	4.50
CH_4 with LULUCF	6.32	6.30	6.28	6.29	6.24	6.10	6.03	5.95	5.76	5.63	5.41	5.29	5.09	4.89	4.72	4.51
N_2O without LULUCF	7.85	7.27	6.72	6.84	6.95	7.15	7.11	7.08	6.91	6.80	6.85	6.76	6.81	6.92	6.86	6.85
N_2O with LULUCF	7.89	7.30	6.73	6.86	6.97	7.17	7.13	7.10	6.93	6.83	6.87	6.78	6.83	6.94	6.88	6.87
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
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
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
Total Emissions	**71.15**	**68.95**	**67.48**	**69.44**	**74.91**	**71.55**	**77.32**	**75.95**	**72.49**	**71.88**	**70.03**	**75.09**	**77.25**	**85.25**	**81.14**	**69.26**
Total Emissions With LULUCF	**49.76**	**32.82**	**37.48**	**41.85**	**57.79**	**56.17**	**54.43**	**59.10**	**56.33**	**54.89**	**53.74**	**56.03**	**58.39**	**67.40**	**62.65**	**38.32**
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Index (1990=100)																
CO_2 without LULUCF	100	97.2	95.7	98.9	108.4	102.3	112.5	110.2	104.6	103.8	100.5	109.5	113.9	127.8	121.0	100.2
CH_4 without LULUCF	100	99.8	99.4	99.7	98.9	96.6	95.5	94.3	91.2	89.2	85.7	83.7	80.6	77.5	74.8	71.4
N_2O without LULUCF	100	92.6	85.5	87.1	88.5	91.1	90.6	90.1	88.0	86.6	87.2	86.1	86.8	88.1	87.4	87.2
Total (group of three)	100	96.9	94.9	97.7	105.4	100.6	108.6	106.5	101.6	100.6	97.7	104.7	108.0	119.0	113.2	96.2
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
Total (group of six)	100	96.9	94.8	97.6	105.3	100.6	108.7	106.7	101.9	101.0	98.4	105.5	108.6	119.8	114.0	97.3

2.2 Description and interpretation of emission trends by gas

The most important greenhouse gas in Finland is carbon dioxide. The share of CO_2 emissions from the total greenhouse gas emissions have increased from 80% in 1990 to 82% in 2005. In absolute terms CO_2 emissions have increased 0.11 Tg (i.e. 0.2%) since 1990. Around 93% of the all CO_2 emissions originate from the Energy sector. Amount of energy related CO_2 emissions have fluctuated much according to the economic trend, the energy supply structure (including electricity import and export), and climate conditions.

Methane emissions (CH_4) have decreased by 29% from the 1990 level. This is mainly due to the improvements in waste treatment and a contraction in animal husbandry in Agriculture sector.

Correspondingly, emissions of nitrous oxide (N_2O) have also decreased by 13%, which has been occasioned mostly by the reduced nitrogen fertilisation of agricultural fields.

Development of emissions of three main greenhouse gases in 1990-2005 (CO_2, CH_4 and N_2O) relative to 1990 level is presented in Figure 2.2_1.

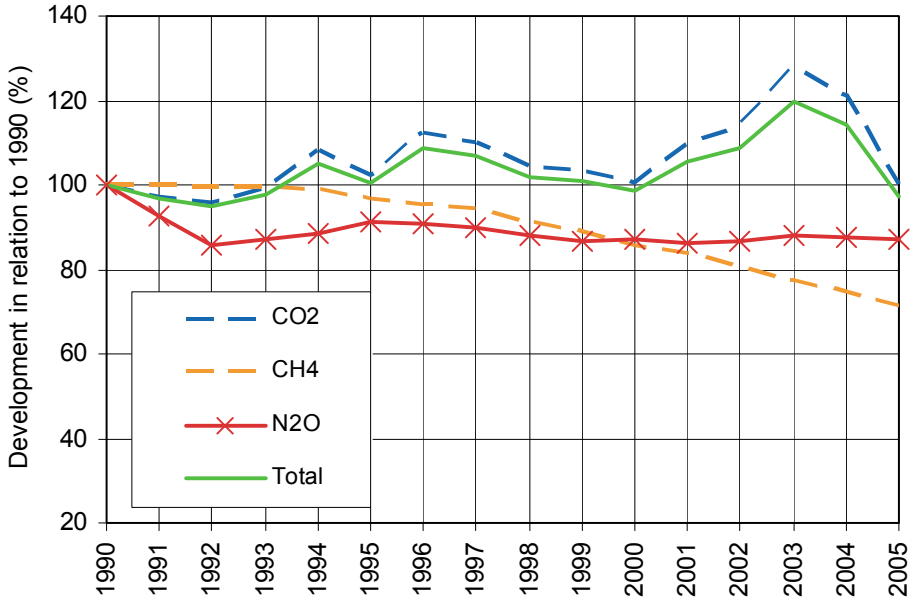


Figure 2.2_1. Relative development of CO_2, CH_4 and N_2O without LULUCF sector in 1990-2005 relative to 1990 level (%).

The emissions of F-gases have increased over eightfold during 1990-2005. 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 1990-2005 is presented by gas category.

Table 2.2_1. Actual emissions of HFCs, PFCs and SF_6 in1990–2005 (CO_2 equivalent Gg).

Year	HFCs	PFCs	SF_6	Total F-gases
1990	0.02	0.07	94.38	94.47
1991	0.05	0.08	67.32	67.45
1992	0.1	0.09	36.64	36.83
1993	0.1	0.1	33.61	33.81
1994	6.52	0.12	34.9	41.54
1995	29.33	0.14	68.53	98.00
1996	77.3	0.16	72.2	149.7
1997	167.8	0.18	75.98	243.9
1998	245.2	0.21	53.18	298.6
1999	318.6	27.97	51.98	398.6
2000	501.7	22.46	51.49	575.7
2001	656.9	20.06	55.03	732.0
2002	463.4	13.37	51.31	528.1
2003	652.1	14.85	41.71	708.6

2004	695.1	12.23	23.18	730.5
2005	863.8	9.88	19.56	893.2

2.3 Description and interpretation of emission trends by category

The energy sector is the most significant source of greenhouse gas emissions in Finland. This reflects the high energy intensity of 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 2005 energy sector's emissions were slightly (0.3%) over the 1990 level. The total energy consumption (or more specifically: total primary energy supply) decreased in 2005 by approximately 7% compared to previous year corresponding to 32.6 Mtoe. The decrease was mainly due to a substantial decrease in condensing power production and substantial increse in electricity import. The decrease in final consumption and electricity consumption was mainly due to the reduced energy need of industry, which was affected for example by the industrial action in the forest industry (Energy Statistics, Yearbook 2006).

Energy industries (mainly electricity and district heating production) caused approximately 40% of the total emissions in the energy sector in 2005. Emission from the energy industries were in 2005 14% higher than 1990, but 34% lower compared to the previous year.

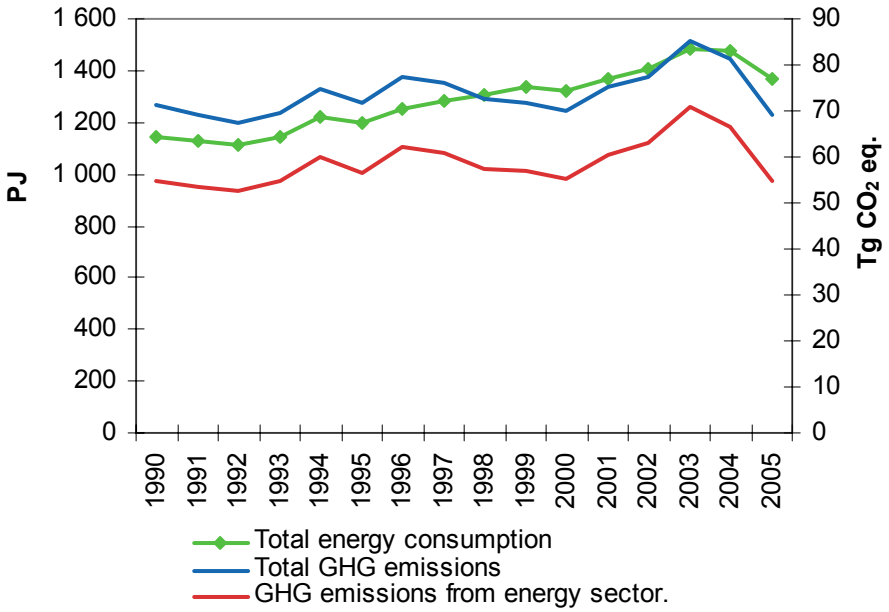


Figure 2.3_1. Development of total energy consumption (PJ), Total GHG emissions and energy sector's greenhouse gas emissions (Tg CO_2 eq) in Finland in 1990-2005.

Most important drivers in the trend of the energy sector's greenhouse emissions have been the changes in level of annually imported electricity and the volumes of hydro power and fossil fuel based condensing power in annual energy production (Figure 2.3_2). For example in 2003, growing use of fossil fuels and peat contributed much to the increase in the emissions as Finnish energy producers sold condensing power produced by hard coal and peat to domestic as well as Nordic electricity markets. In 2005 CO_2 emissions decreased substantially when there was good availability of hydro power in the Nordic Countries and condensing power production fell to one third from the previous year's high level. In 2005 net import of electricity rose to record levels, nearly 18TWh. In 2003 and 2004 Finland was a net exporter of electricity to Nordic countries (Energy Statistics, Yearbook 2006), which was reflected also to emission levels of those years.

Consumption of hard coal in energy production decreased by over 41% and oil by 3% and heavy fuel oil by 10% compared the previous year. Consumption of peat decreased by 23% (Energy Statistics, Yearbook 2006). The use of renewable energy fell also by 7% in 2005 compared to previous year. The industrial action of forest industry caused over 10 % decrease in the use of black liquor and other industrial wood residues, which are the most important source of renewable energy in Finland. The share of renewable energy from total energy remained in 2005 as 25 percent, the same as in 2004, due to the decrease in total energy consumption in 2005.

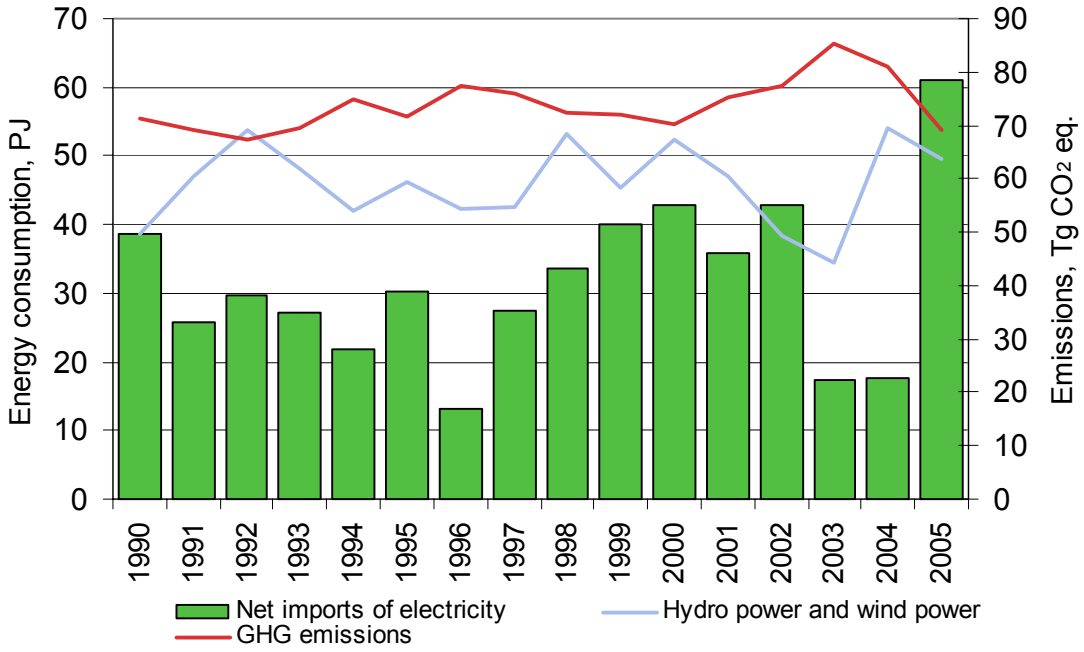


Figure 2.3_2. Greenhouse gas emissions (Tg CO_2 eq), net imports of electricity and hydro power and wind in energy consumption (PJ) in Finland in 1990-2005 (Energy Statistics, Yearbook 2006).

Manufacturing industries and construction produce much energy themselves. Their share of the energy-related emissions was around 21% in 2005. Emissions from manufacturing industries and construction have decreased 14 % since 1990. Main reason behind this trend has been increased use of biofuels in forest industry. Emissions in the transport sector have increased by around 8 % compared to 1990 level. The magnitude of this change is smaller in Finland than in many other Annex I countries, mainly due to the effect that economic recession in early 1990's had on transport (see chapter 3.2.2.3). The share of transportation of energy-related emissions was about one fourth in 2005. Emissions from the residential sector have decreased by 30 % and from commercial sectors by over 46% compared to 1990 levels. 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 the CO_2-equivalent emission in 1990-2005 per IPCC source sectors.

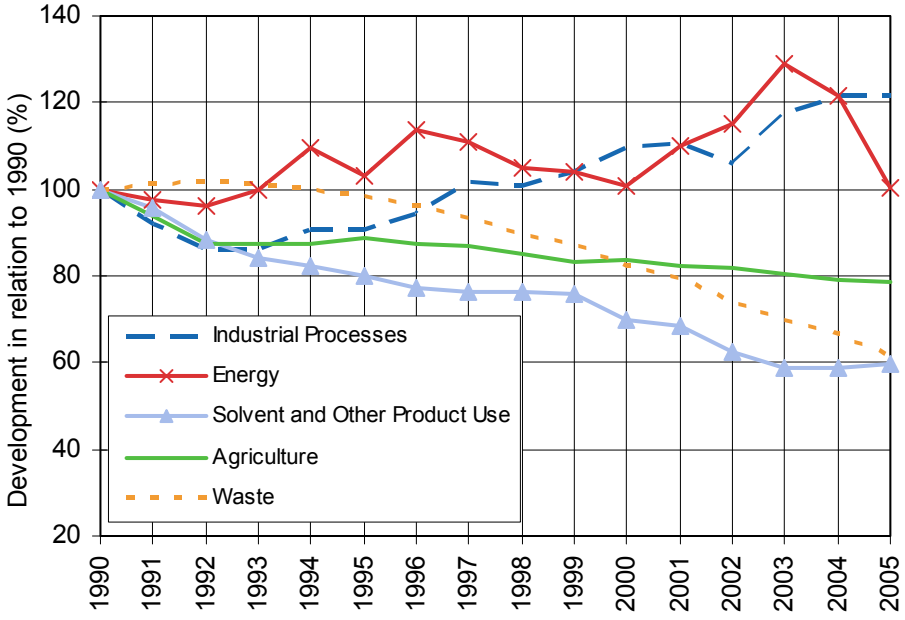


Figure 2.3_3. Relative development of greenhouse gas emissions by main source categories relative to 1990 level (1990=100%).

Emissions of industrial processes have increased 21% from 1990 to 2005. At the beginning of the timeseries some production plants were closed down and that caused fast decrease of emissions. After rise of production outputs also emissions increased and reached the level of year 1990 in 2000. During the period of 1990-2005 CO_2 emissions have increased 0.4 Tg and methane emissions 0.01 Tg CO_2 eq. Nitrous oxide emissions have decreased 0.1 Tg CO_2 eq. and emissions of all F-gases have increased 0.8 Tg CO_2 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 22% (1.5 Tg CO_2 eq.) over the period of 1990-2005. Main driver behind the decreasing trend has been the over all change in economy of agriculture, which has resulted in decrease in number of animals and average increase in farm size. Cattle produce the major part of the emissions from enteric fermentation in Finland, thus the 29% decrease in 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 contrary increased somewhat, despite of decrease in number of animals. This is mostly due to increase in the number of cattle and swine kept inslurry-based manure management systems, which have ten-fold methane emissions compared to 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 N_2O emissions.

The most important source of N_2O emissions in agricultural sector are agricultural soils. Nitrous oxide emissions from agricultural soils have decreased about 25% compared to 1990 level. The decrease has resulted mainly from decreased use of synthetic fertilisers and decrease in area under cultivation of organic soils. The drop in agricultural emissions in 1992 (Figure 2.3_3) is mostly due decreased use of synthetic fertilisers. In 1992 synthetic fertilisers were sold almost 30% less than in 1990.

Emissions from waste sector have declined quite constantly since 1990. The decrease of 1.5 Tg CO_2 eq. has been mainly due to the implementation of the new waste law in Finland in 1993. At the beginning of the 1990s, around 80% of the generated municipal waste were taken to solid waste disposal sites (landfills). After the implementation of the new waste law, 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. Also waste tax and adoption of the National Waste Plan have had an impact on the decreasing trend in emissions of the waste sector. In early 1990s the economic recession reduced the amount of waste.

Table 2.3_1. Summary of emission trend per source category and gas (unit Tg CO_2-eq.).

IPCC Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1. Energy	**54.80**	**53.41**	**52.71**	**54.66**	**59.98**	**56.56**	**62.35**	**60.72**	**57.60**	**57.06**	**55.10**	**60.35**	**63.00**	**70.67**	**66.60**	**54.96**
A Fuel combustion total	54.56	53.15	52.43	54.32	59.73	56.31	62.10	60.45	57.38	56.87	54.91	60.16	62.82	70.48	66.42	54.76
CO_2 1. Energy industries	19.06	18.82	18.58	21.29	26.20	23.92	29.59	27.19	23.94	23.43	21.89	27.23	29.94	36.83	32.57	21.67
CO_2 2. Manufacturing Industries and Construction	13.28	12.78	12.27	12.35	12.67	12.13	12.05	12.22	11.93	11.91	11.96	11.51	11.22	11.60	11.70	11.41
CO_2 3. Transport	12.55	12.21	12.13	11.67	12.02	11.82	11.80	12.40	12.53	12.73	12.63	12.75	12.95	13.15	13.51	13.49
CO_2 4. Other Sectors	7.04	6.89	6.99	6.51	6.16	5.70	5.81	5.82	5.92	5.83	5.46	5.68	5.63	5.48	5.28	5.02
CO_2 5. Other	1.32	1.16	1.17	1.15	1.28	1.36	1.40	1.33	1.56	1.44	1.46	1.40	1.42	1.69	1.62	1.55
CH_4	0.30	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
N_2O	1.00	1.00	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	1.34
B Fugitive fuel emissions	0.24	0.26	0.28	0.35	0.25	0.26	0.24	0.28	0.22	0.19	0.19	0.19	0.18	0.18	0.17	0.19
CO_2	0.23	0.21	0.22	0.27	0.17	0.18	0.16	0.20	0.15	0.13	0.13	0.12	0.13	0.12	0.12	0.13
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
N_2O	0.00	0.00	0.00	0.00	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	**5.07**	**4.66**	**4.36**	**4.36**	**4.59**	**4.60**	**4.79**	**5.15**	**5.12**	**5.27**	**5.55**	**5.60**	**5.36**	**5.96**	**6.17**	**6.16**
CO_2	3.31	3.15	3.01	2.95	3.10	3.03	3.16	3.45	3.43	3.51	3.60	3.56	3.48	3.81	3.96	3.68
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02
N_2O	1.66	1.44	1.30	1.36	1.43	1.46	1.46	1.44	1.38	1.35	1.36	1.28	1.34	1.42	1.46	1.57
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
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
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
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**
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
N_2O	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
4. Agriculture	**7.11**	**6.68**	**6.20**	**6.22**	**6.22**	**6.32**	**6.21**	**6.20**	**6.05**	**5.92**	**5.96**	**5.85**	**5.82**	**5.74**	**5.61**	**5.58**
CH_4 A. Enteric Fermentation	1.92	1.85	1.79	1.78	1.79	1.69	1.70	1.72	1.68	1.65	1.65	1.63	1.64	1.61	1.59	1.58
CH_4 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	0.27	0.27	0.27	0.28
N_2O 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	0.50
N_2O 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

IPCC Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
5. Land-Use Change and Forestry	**-21.39**	**-36.13**	**-30.00**	**-27.60**	**-17.12**	**-15.38**	**-22.90**	**-16.85**	**-16.16**	**-16.98**	**-16.29**	**-19.06**	**-18.87**	**-17.85**	**-18.49**	**-30.93**
CO_2	-21.44	-36.17	-30.03	-27.62	-17.16	-15.41	-22.93	-16.89	-16.19	-17.02	-16.32	-19.09	-18.90	-17.88	-18.51	-30.96
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.04	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
6. Waste	**3.99**	**4.03**	**4.05**	**4.05**	**3.98**	**3.92**	**3.83**	**3.74**	**3.58**	**3.49**	**3.29**	**3.18**	**2.96**	**2.79**	**2.65**	**2.45**
CH_4	3.83	3.87	3.89	3.89	3.82	3.76	3.67	3.57	3.42	3.34	3.13	3.02	2.81	2.63	2.49	2.29
N_2O	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
7. Other	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
National Total Emissions with LULUCF	**49.76**	**32.82**	**37.48**	**41.85**	**57.79**	**56.17**	**54.43**	**59.10**	**56.33**	**54.89**	**53.74**	**56.03**	**58.39**	**67.40**	**62.65**	**38.32**
NATIONAL TOTAL EMISSIONS	**71.15**	**68.95**	**67.48**	**69.44**	**74.91**	**71.55**	**77.32**	**75.95**	**72.49**	**71.88**	**70.03**	**75.09**	**77.25**	**85.25**	**81.14**	**69.26**

Figure 2.3_4 shows a plot of inventory estimates (in teragrams CO_2 eq.) versus calendar years. First of all, the graph shows year-to-year variability, perhaps increasing somewhat over the years. Secondly, the level of emissions seems to increase also: 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 CO_2 eq. to the level each year, starting from 1990.

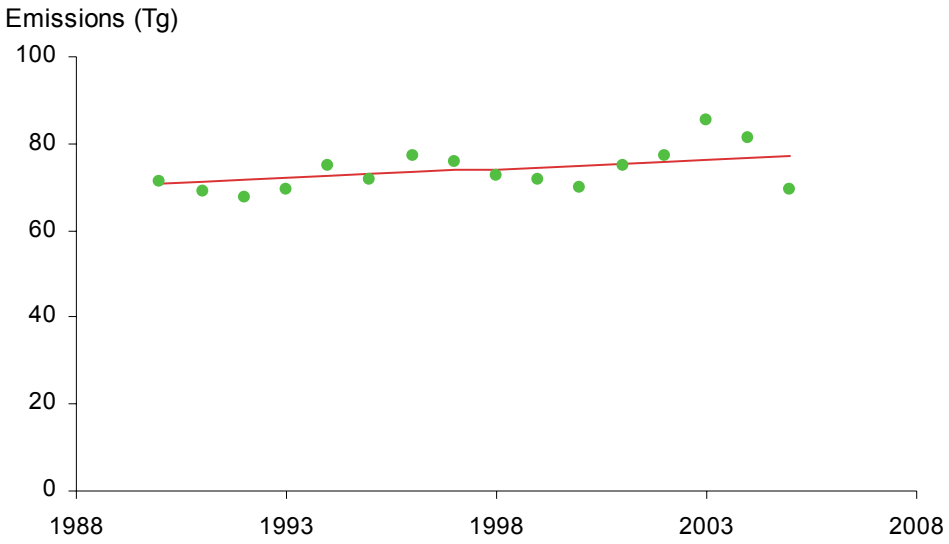


Figure 2.3_4. One possible description of a trend behind the data. The fitted line corresponds to an addition of 0.4 Tg CO_2 eq. to the level each year, starting from 1990.

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

The emissions trends of the indirect greenhouse gases, sulphur dioxides, nitrogen oxides, carbon monoxide and non-methane volatile organic compounds, are presented in Figure 2.4_1 and Table 2.4_1.

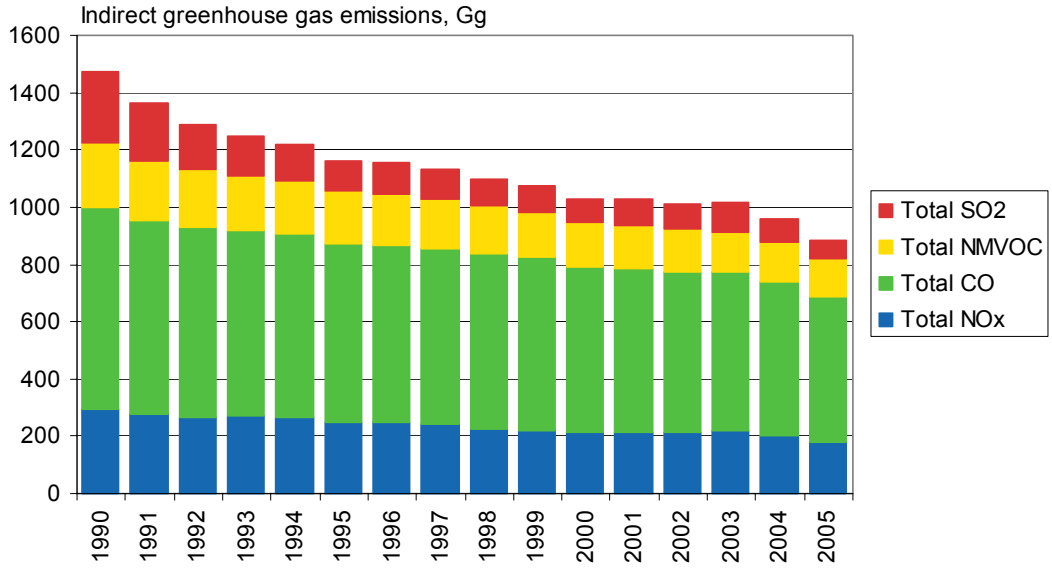


Figure 2.4_1. Indirect greenhouse gas emissions in 1990–2005, Gg.

Nitrogen oxides (NO_x) were generated almost[2] exclusively in the energy sector. The total emissions were 175.8 Gg. The transport category was responsible for 43% of the emissions. Energy industries as well as manufacturing industries and construction generated 20% and 23% of the emissions, respectively.

Carbon monoxide (CO) emissions, total 511.1 Gg, originated almost[3] exclusively in the energy sector, where transport generated 66% and other sectors (including small scale combustion in the residential energy sector as well as off-road machinery in forestry, agriculture and fishery) 21% of the total emissions.

The **non-methane volatile organic compounds (NMVOC)** totalled 136.2 Gg in 2005. 73% of the total emissions were generated in the energy sector, where transport generated 38%, other sectors 22% (including small scale combustion in the residential energy sector as well as off road machinery in forestry, agriculture and fishery) and fugitive emissions from fuels 10% of the total emissions. 20% of the NMVOC emissions originated from solvent and other product use and 7% from industrial processes.

The **sulphur dioxide (SO_2)** emissions totalled 68.4 Gg out of which 81% originated in the energy sector, where energy industries generated 46% of the total emissions and manufacturing industries and construction 23%.

[2] Very small amounts of NO_x and CO arise from forest fires

Table 2.4_1. Trends in total emissions of NO_x, CO, NMVOC and SO_2, 1990–2005.

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total NO_x	294.5	277.1	265.6	267.3	266.5	244.5	247.7	238.9	224.3	219.9	209.6	210.3	209.1	217.1	203.1	175.8
Total CO	710.8	681.0	670.7	655.2	644.5	635.3	624.2	623.2	616.9	609.6	588.3	581.3	572.1	559.7	540.7	511.1
Total NMVOC	229.4	217.0	209.6	201.9	196.7	192.0	185.2	180.3	175.5	171.0	164.5	161.9	156.1	151.4	147.4	136.2
Total SO_2	249.0	202.1	158.1	137.9	123.2	104.8	110.1	101.1	93.4	91.3	80.8	89.7	90.5	101.4	83.5	68.4

3. ENERGY (CRF 1)

3.1 Overview of sector (CRF 1)

Energy sector is the main source of greenhouse gas emissions in Finland. In 2005, the sector contributed a good 79% of total emissions, totalling 55.0 Tg CO_2 eq. (Figure 3.1_1). Compared to the base year 1990, the emissions were 0.3% over that level. Most of the emissions originate from fuel combustion. The substantial amount of energy related emissions reflect the high energy intensity of the Finnish industry, extensive consumption of fuels during the long heating period, as well as energy consumed for transport in a wide and sparsely inhabited country. The energy sector releases three greenhouse gases, CO_2 and small amounts of CH_4 and N_2O. Energy related CO_2 emissions vary from year to year, mainly following the economic trend, the structure of the energy supply, and climatic conditions. 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).

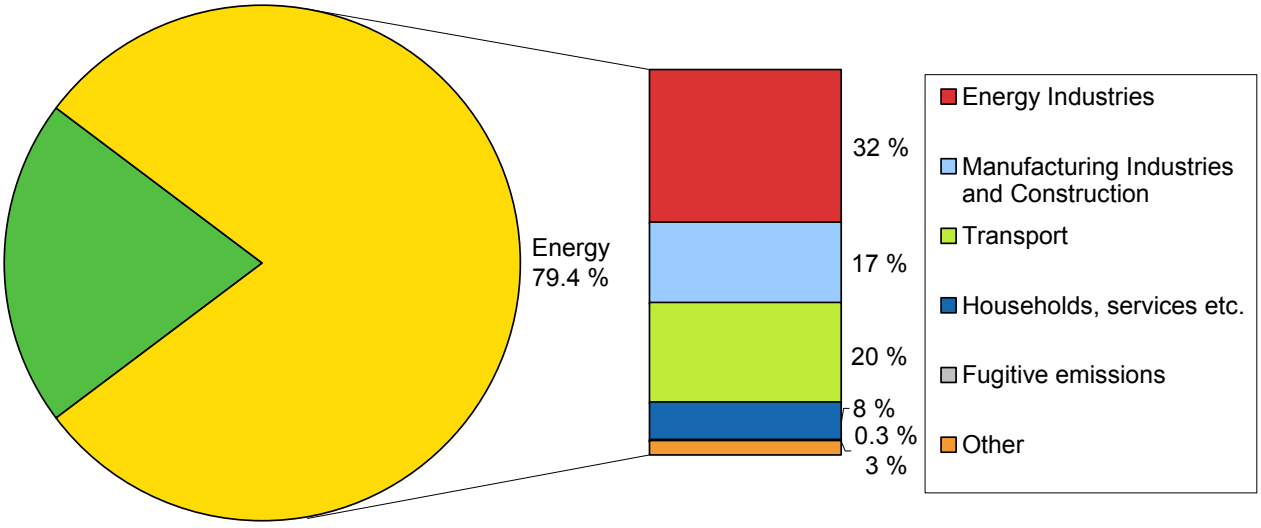


Figure 3.1_1. Emissions from the energy sector compared to the total emissions in 2005.

Emissions from the energy sector come from a variety of sources. In the Finnish inventory, emissions from fuel combustion include direct (CO_2, CH_4, N_2O) and indirect (NO_x, CO, NMVOCs) greenhouse gas emissions, as well as emissions of SO_2 from fuel combustion. Point sources, transport and other fuel combustion are included. Fugitive emissions from fuels in Finland consist of CH_4 and NMVOCs emissions arising from oil refining and storage. CO_2, CH_4 and N_2O emissions from venting and flaring at oil refineries and petrochemical industry are included as well, and so are CH_4 emissions from natural gas transmission and distribution (Table 3.1_1). In addition, indirect CO_2 emissions due to oxidation of fugitive CH_4 and NMVOCs have been taken into account as well as indirect N_2O emissions from NOx, which are reported in category 1.A 5 a Stationary.

Table 3.1_1. Emissions from energy sector in 1990–2005 by subcategories and gases (Tg CO_2 eq).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1. Energy	**54.80**	**53.41**	**52.71**	**54.66**	**59.98**	**56.56**	**62.35**	**60.72**	**57.60**	**57.06**	**55.10**	**60.35**	**63.00**	**70.67**	**66.60**	**54.96**
A. Fuel combustion	54.56	53.15	52.43	54.32	59.73	56.31	62.10	60.45	57.38	56.87	54.91	60.16	62.82	70.48	66.42	54.76
CO_2	53.25	51.85	51.14	52.97	58.33	54.93	60.64	58.96	55.88	55.34	53.41	58.57	61.16	68.74	64.69	53.17
CH_4	0.30	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
N_2O	1.00	1.00	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	1.34
B. Fugitive fuel emissions	0.24	0.26	0.28	0.35	0.25	0.26	0.24	0.28	0.22	0.19	0.19	0.19	0.18	0.18	0.17	0.19
CO_2	0.23	0.21	0.22	0.27	0.17	0.18	0.16	0.20	0.15	0.13	0.13	0.12	0.13	0.12	0.12	0.13
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
N_2O	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

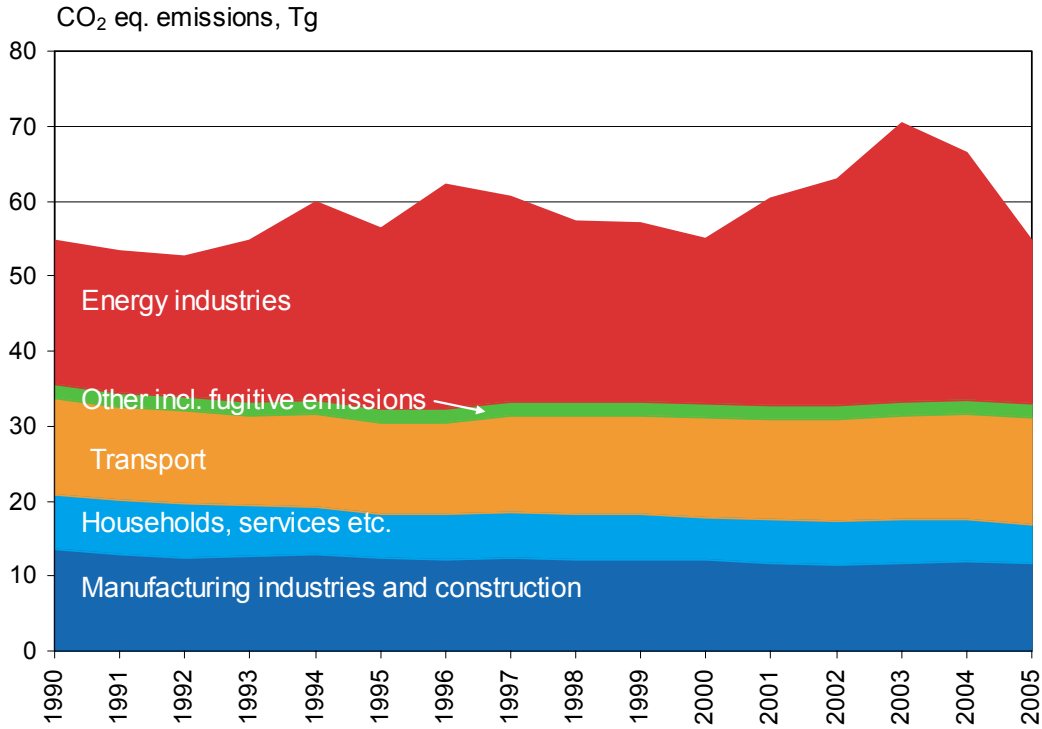


Figure 3.1_2. Emissions from the energy sector by subcategories in 1990–2005 (Tg CO_2 eq.).

3.2 Emissions from fuel combustion (CRF 1.A)

Description

Emissions from fuel combustion comprise all fuel combustion, including point sources, transport and other fuel combustion. Direct and indirect greenhouse gases (CO_2, CH_4, N_2O, CO, NMVOC, NO_x) as well as SO_2 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

Quantitative overview

CO_2 emissions from fossil fuel combustion (53.1 Tg) accounted for 97% of the energy sector's total emissions and 79% of total greenhouse gas emissions in 2005.

The portion of N_2O emissions from fuel combustion in 2005 was about 2%. N_2O emissions come mainly from fluidised bed combustion and transportation. CH_4 emissions from fuel combustion are relatively small and are mainly due to the incomplete combustion of wood fuels (small-scale combustion).

The availability of hydropower in the Nordic electricity market influences the electricity supply structure and hence the emissions significantly. Especially in 2001–2003 shortage of hydropower in the Nordic market increased coal and peat-fuelled condensing power generation in Finland. Due to this, there was a ~15.9 Tg CO_2 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 hydropower in Nordic electricity markets and domestic condensing power production in Finland was replaced by imports of electricity. Total emission from fuel combustion decreased 22% from the year 2003 record level compared to 2005 level and were 0.4 percent above the 1990 level.

Table 3.2_1. Emissions from fuel combustion in Finland in 1990–2005 (Tg CO_2 eq.).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1. Energy	**54.80**	**53.41**	**52.71**	**54.66**	**59.98**	**56.56**	**62.35**	**60.72**	**57.60**	**57.06**	**55.10**	**60.35**	**63.00**	**70.67**	**66.60**	**54.96**
A Fuel combustion total	54.56	53.15	52.43	54.32	59.73	56.31	62.10	60.45	57.38	56.87	54.91	60.16	62.82	70.48	66.42	54.76
CO_2 1. Energy industries	19.06	18.82	18.58	21.29	26.20	23.92	29.59	27.19	23.94	23.43	21.89	27.23	29.94	36.83	32.57	21.67
CO_2 2. Manufacturing Industries and Construction	13.28	12.78	12.27	12.35	12.67	12.13	12.05	12.22	11.93	11.91	11.96	11.51	11.22	11.60	11.70	11.41
CO_2 3. Transport	12.55	12.21	12.13	11.67	12.02	11.82	11.80	12.40	12.53	12.73	12.63	12.75	12.95	13.15	13.51	13.49
CO_2 4. Other Sectors	7.04	6.89	6.99	6.51	6.16	5.70	5.81	5.82	5.92	5.83	5.46	5.68	5.63	5.48	5.28	5.02
CO_2 5. Other	1.32	1.16	1.17	1.15	1.28	1.36	1.40	1.33	1.56	1.44	1.46	1.40	1.42	1.69	1.62	1.55
CH_4	0.30	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
N_2O	1.00	1.00	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	1.34

Fuel combustion by fuels (PJ) and related CO_2 emissions for 1990-2005 are given in Appendix 3_b in the end of the Energy chapter.

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 technology-specific emission factor. When calculating CO_2 emissions, adjustment with the fraction of carbon (un)oxidised is included.

Calculations of all emissions from fuel combustion are done with the ILMARI calculation system developed in Statistics Finland. The ILMARI system has been specifically designed for the calculation of energy-based emissions. ILMARI uses mostly bottom-up methodology consistent with the IPCC Tier 2 approach.

ILMARI combines three main types of activity source data:

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

The ILMARI calculation system has been used for national emission estimations of CO_2, SO_2, NO_2, CO, CH_4, N_2O, NMVOC and PM emissions of fuel combustion from the year 1992. In addition, the year 1990 emissions have been calculated with ILMARI. 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 the technical data of combustion processes, such as type of power plant, capacity, combustion technique, emission reduction equipment, etc.

The input data for ILMARI comes from various models, databases and other information sources. The data sources of the ILMARI calculation system are presented in Figure 3.2_1.

The production process of ILMARI and CRF 1.A data tables are described in Figure 3.2_2.

A new version of the ILMARI calculation system has been developed, starting from 2002. Emissions from 2001 on have been calculated using this new system. The calculation methods and formulas are the same as in the previous ILMARI, but a new database system has been constructed. The activity data and time series consistency have been checked during 2005-2006 and this has resulted in some revisions in the emissions estimates. The overall impact of the changes is small. 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 categories is produced using SAS Database queries and taken to CRF Reporter via MS Excel sheets using 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 CRF reporter).

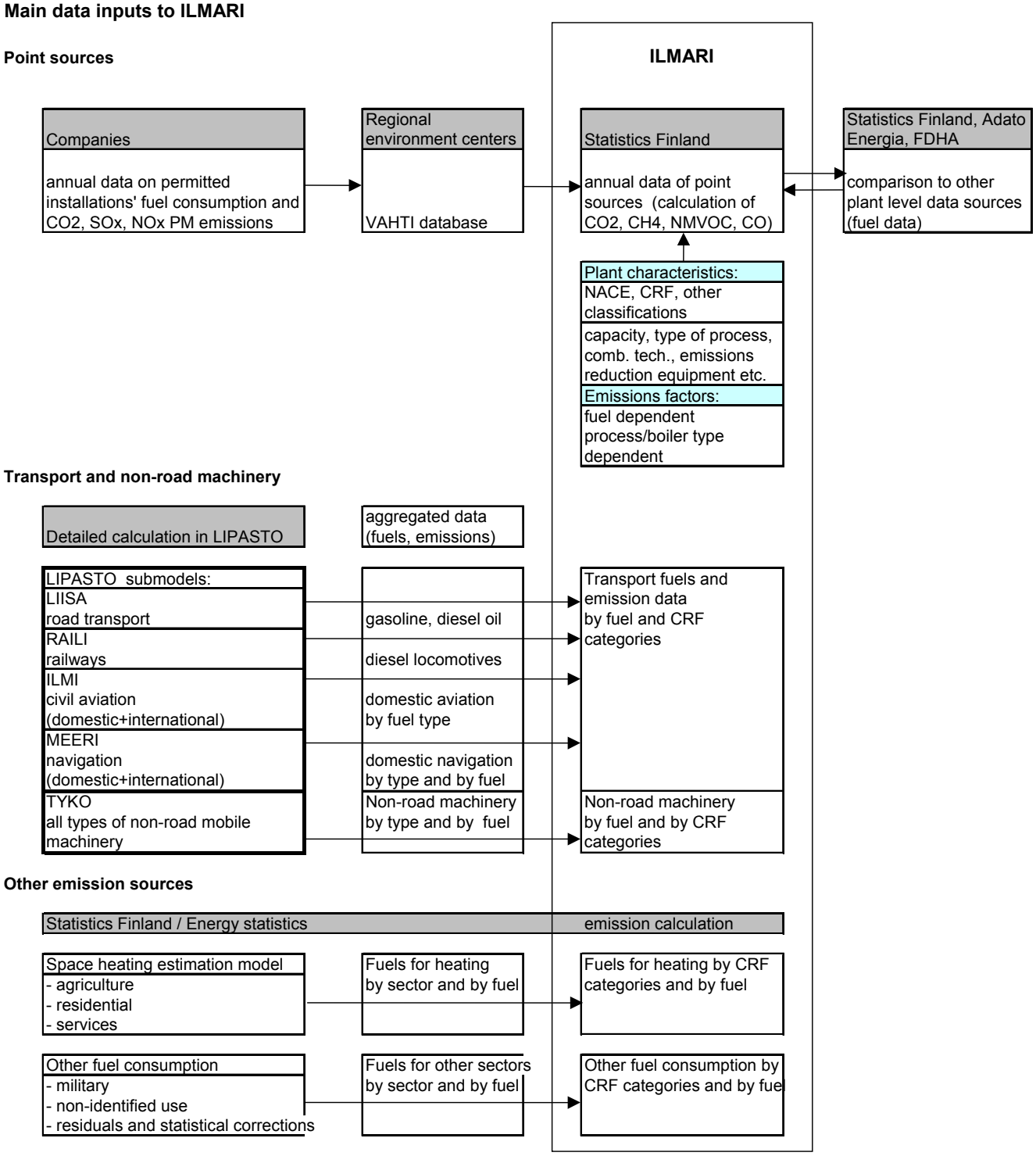


Figure 3.2_1 . Data sources in the ILMARI calculation system.

Production of CRF data tables for sector 1A Fuel combustion

1. **VAHTI data input to ILMARI** — point source data input from database

Checks, corrections	missing data (plants, fuels, emissions) erraneous data order of magnitude errors quantity units fuel codes
New plants data	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 of ILMARI, stored in SAS time series database) — 2000 plants + 50 sectoral sources
identification data, classifications
technical data, fuels, emissions
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

Figure 3.2_2. Production process of ILMARI and CRF 1.A data tables.

Key Categories

Several emission sources in the energy combustion sector are key categories. The key categories in 2005 by level and trend, without LULUCF are listed in the Table 3.2_2.

Table 3.2_2. Key categories in Energy combustion (CRF 1.A) in 2005 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
CRF 1.A Fuel combustion, Solid fuels	CO_2	L, T
CRF 1.A Fuel combustion, Liquid fuels	CO_2	L, T
CRF 1.A Fuel combustion, Other fuels	CO_2	L, T
CRF 1.A 3 b Road transportation, Cars with catalytic converters	N_2O	L, T
CRF 1.A 3 b Road transportation, Cars without catalytic converters	N_2O	T
CRF 1.A 4 Other sectors, Biomass	CH_4	L

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

3.2.1.1 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_{fuel}>5MW and industrial plants with boilers and/or other combustion). The emissions from energy industries by relevant subcategories and gases in 1990–2005 are presented in Table 3.2_3.

The emissions from Manufacturing industries and construction by relevant subcategories and gases in 1990–2005 are presented in Table 3.2_4.

Table 3.2_3. The emissions from Energy industries by relevant subcategories and gases in 1990–2005 (Tg CO_2).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2																
1. Energy industries	**19.06**	**18.82**	**18.58**	**21.29**	**26.20**	**23.92**	**29.59**	**27.19**	**23.94**	**23.43**	**21.89**	**27.23**	**29.94**	**36.83**	**32.57**	**21.67**
a. Public Electricity and Heat Production	16.45	16.21	15.98	18.73	23.28	21.05	26.50	24.34	20.91	20.33	18.99	24.38	26.86	33.63	29.35	18.65
b. Petroleum Refining	2.26	2.25	2.25	2.20	2.59	2.56	2.78	2.52	2.65	2.68	2.55	2.53	2.73	2.80	2.79	2.63
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
CH_4																
Total	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	**0.02**
N_2O																
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**	**0.30**	**0.23**

Table 3.2_4. The emissions from Manufacturing industries and construction by relevant subcategories and gases in 1990–2005 (CO_2 eq, Tg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2																
2. Manufacturing Industries and Construction	**13.28**	**12.78**	**12.27**	**12.35**	**12.67**	**12.13**	**12.05**	**12.22**	**11.93**	**11.91**	**11.96**	**11.51**	**11.22**	**11.60**	**11.70**	**11.41**
a. Iron and Steel	2.56	2.62	2.68	2.90	2.96	2.74	2.88	3.16	3.31	3.38	3.64	3.27	3.32	3.55	3.52	3.63
b. Non-Ferrous Metals	0.34	0.23	0.14	0.17	0.14	0.11	0.11	0.13	0.13	0.14	0.14	0.15	0.13	0.12	0.11	0.10
c. Chemicals	1.34	1.32	1.30	1.32	1.38	1.42	1.38	1.32	1.21	1.21	1.24	1.30	1.22	1.36	1.35	1.46
d. Pulp, Paper and Print	5.33	5.15	4.97	4.93	5.16	4.82	4.63	4.57	4.25	4.18	4.04	3.91	3.68	3.81	3.94	3.51
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	0.33	0.26	0.24	0.22
f. Other	2.90	2.67	2.43	2.30	2.31	2.36	2.38	2.43	2.46	2.51	2.57	2.56	2.55	2.49	2.54	2.50
CH_4																
Total	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
N_2O																
Total	**0.17**	**0.16**	**0.15**	**0.16**	**0.17**	**0.17**	**0.17**	**0.19**	**0.18**	**0.19**	**0.19**	**0.18**	**0.17**	**0.17**	**0.18**	**0.17**

3.2.1.2.Methodological issues

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) are based on bottom-up data. In the ILMARI system emissions are calculated using the annual fuel consumption. Fuel combustion data is available by installations and by fuel type. For each point source, SO_2, PM, NO_x and CO_2 emissions are reported plant by plant. In the ILMARI system, SO_2, PM and NO_x emissions are split into each fuel. CO_2, N_2O, CH_4 and NMVOC are calculated based on fuel combustion data. The calculated CO_2 emissions from each fuel in a certain plant are summarised and compared to total CO_2 emissions reported by the same plant.

The ILMARI system was designed specially for the calculation of emissions from fuel combustion. 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) provides the possibility of taking into account the changes in technology in combustion processes.

Basic calculation formulas used in 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, SOx and NOx).

Calculation of the CO_2 emissions is based on a country-specific (Tier 2, Revised (1996) Guidelines) method using detailed activity (fuel consumption) data and fuel-specific emission factors.

The SO_2 and NO_x emissions are based on the emission data reported by the plants and recorded in the VAHTI database. The emissions are allocated to fuel based emissions (CRF 1) by each fuel and non-fuel-based, i.e. process emissions (CRF 2).

The emissions of CH_4, N_2O and CO are based on a country-specific method (Tier 2, 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).

Emission factors and other parameters

Mainly country specific or plant specific emission factors are used in calculations, although for some minor fuels IPCC default emission factors are used. CO_2 emission factors, oxidation factors and net caloric values for different fuels are presented in Table 3.2_5 below.

Table 3.2_5. CO_2 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 (32-85)	GJ/t	65-71.4	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 (28-36)	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 (23-32)	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 3.6	GJ/1000 m^3	155 263-265	0.99	Plant specific
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	GJ/t	109.6	0.99	EE (=wood)
Biogas (landfill gas, biogas from wastewater treatment, industrial biogas and other	15–20.5	GJ/1000 m^3	56.1	0.99	EE

Fuels	NCV	Unit	Emission factor g CO_2/MJ	Oxidation factor	Source of emission factor
biogas)					
Hydrogen	10.8	GJ/1000 m^3	0		
Other fuels					
Peat (milled)	10.1	GJ/t	105.9	0.99	VTT 2003
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
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; CO_2 emission factor refers only to fossil fraction of total energy content.

Sources:
EE: expert estimation
Neste 1993: Composition and properties of natural gas and liquefied petroleum gas (in Finnish)
Neste: product data sheets, personal communications
ET2004: Energy Statistics 2004 (Statistics Finland 2005)

VTT/Liisa Model: Calculation system of road traffic emissions
StatFi 2004: Mixed fuels in the 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)
Ekokem 2004: Environmental report 2004
Gasum 2005: personal communication
VTT2045: Properties of fuels used in Finland, VTT 2000
Fortum 2002: Composition of kerosenes
VTT 2003: Vesterinen 2003

The CH_4, N_2O, CO and NMVOC emission factors used in the Finnish inventory are largely based on the compilation of research data by Prosessikemia Oy (Boström et al. 1992; Boström 1994) in the inventory calculations for the year 1990 for Finland's first national communication to the UNFCCC. The emission factor database from Prosessikemia Oy 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 has been available from other sources).

A research study at VTT Technical Research Centre of Finland has evaluated the non-CO_2 (CH_4 and N_2O) emission factors used in the Finnish inventory. In 2005 VTT measured the non-CO_2 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 also start-ups, partial loads and other exceptional conditions. The results of the study were published in late 2005, and 2006 (Tsupari et al. 2005; Tsupari et al. 2006). The results of this study have been used in the recalculation of time series. All emission factors used in the ILMARI system were checked and revised according to the VTT study. The final results of this study caused some changes compared with the preliminary results, which were used in the previous submission. The CRF tables and NIR have been updated accordingly.

Emission factors for small combustion are partly IPCC default and partly taken from the reference Boström et al. (1992). Emission factors for CH_4 and N_2O for small combustion of wood were revised taking into account the VTT study.

Updated CH_4 and N_2O emission factors by main category/fuel are presented in Tables 3.2_6 and 3.2_7.

Table 3.2_6. CH_4 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
Oil fired boiler	30 (> 80% oil) and 83 (50 - 80% oil)	All / > 1	1
		All / <1	5
Gas fired boiler	60 (> 80% gas) and 86 (50 - 80% gas)	All / >1	1
		All / <1	5
Soda recovery boiler	70 (> 80% black liquor)	All	1
Gas turbine	121 (gas turbine plant, oil) and 123 (gas turbine plant, other)	All / < 50	3
		All / > 50	1
Gas turbine	122 (gas turbine plant, gas) and 130 (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 Fluidized Bed,
BFB = Bubbling Fluidized Bed
PFB = Pressurized Fluidized Bed

Table 3.2_7. N_2O 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
	10 (>80% coal) and 81 (50 - 80% coal)	Pulverised comb.	1
Peat fired boiler	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

Activity data

Activity data for the ILMARI calculations are collected from several data sources. The detailed bottom-up data for point sources is collected mainly from the VAHTI system - the Compliance Monitoring Data system of Finland's environmental administration. Supplementary data is obtained from other plant level data sources. The VAHTI system functions as a tool for the 13 Finnish 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. More detailed description of VAHTI database is included in Annex 2.

The VAHTI data contains, for example:

- basic data like identification of plants, location etc.
- technical data like boiler or process type, emission reduction equipment, 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 database includes the detailed (boiler/process level) data, which allows emissions calculation using technology-specific emission factors for non-CO_2 emissions. There are numerous emission components reported directly in the VAHTI system; CO_2, SO_2, NO_x, PM emission data are used as input for the ILMARI system. This input data from the VAHTI database is 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 Finnish District Heating Association)
- structural business statistics (survey by Statistics Finland)
- business register (by Statistics Finland).

Individual plants and boilers from the VAHTI data are linked to statistical data collection units (local kind-of-activity unit) to allow comparisons to e.g. fuel consumption census and business surveys made by Statistics Finland. This linking enables the use of standard classifications for example NACE code, which is a pan-European classification system of economic activities. Fuel codes used in the VAHTI database are also linked to national fuel classification.

The total number of plants (sites) included in the ILMARI system is ~1000, including ~2000 individual combustion units or process installations.

The fuel consumption in Energy industries and Manufacturing industries and construction is presented in Table 3.2_8. Peat, an important domestic fuel in Finland, is included in “Other fuels”. In Energy industries in 1990 the share of peat was almost 100% of “Other fuels” and in Manufacturing industries it was 94.4%. In 2005 corresponding figures were 92.6% and 86.8%, respectively. Use of industrial wastes and waste-derived fuels for energy production has increased compared to 1990 decreasing the relative share of peat fuel in "Other fuels" category.

Table 3.2_8. Fuel consumption in Energy industries (CRF 1.A 1) and Manufacturing industries and construction (CRF 1.A 2) in 1990–2005 (PJ).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1.A 1																
Liquid Fuels	38.5	38.9	39.3	39.7	45.9	43.2	48.9	41.9	42.8	43.7	37.1	40.7	44.8	43.7	37.8	36.8
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
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	113.5	104.4
Other Fuels	3.1	4.0	4.8	9.8	14.0	16.2	18.5	24.3	28.4	35.2	34.7	38.9	51.0	59.3	59.9	60.3
1.A 2																
Liquid Fuels	60.0	57.0	53.8	51.1	53.2	53.8	52.3	53.1	55.3	56.7	55.4	54.5	54.0	54.4	56.4	54.4
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
Gaseous Fuels	40.1	40.9	41.8	42.8	44.2	43.1	40.8	39.5	38.4	38.2	39.9	41.7	40.1	39.3	40.7	37.0
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

3.2.1.3. Uncertainties and timeseries consistency

Uncertainty in CO_2 emissions from fuel combustion was estimated at an aggregated level (CRF 1.A). Uncertainty in CH_4 and N_2O 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 ±4% in Finland in 2005. 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 (±1-2%) 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 a 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 ±5%. The uncertainties in biomass use are estimated larger (±15-20%). This is because the energy content of different biomass types varies quite a lot, and because industrial plants, e.g. pulp and paper mills, burn product residues – the amount of which is not as exactly known as the amount for commercially traded fuels.

In fuel combustion, the CO_2 emission factor mainly depends on the carbon content of the fuel instead of on combustion technology. Therefore, uncertainty in CO_2 emissions was calculated at a rather aggregated level, i.e. by fuel type rather than by sector. Uncertainties in CO_2 emission factors of oil, gas and coal are rather small (±1-3%), because the carbon content of these fuels is rather constant, and carbon is nearly completely oxidised in combustion.

Uncertainty in the CO_2 emission factor for peat may 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 CO_2 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 use represents rather 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 ±5%.

Emission factors for CH_4 and especially N_2O from combustion are highly uncertain. The nitrous oxide emission factor depends strongly on combustion technology. For example, fluidised bed combustion has higher N_2O 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-control techniques).

The research and measurement project at VTT on non-CO_2 (CH_4 and N_2O) emission factors from stationary sources in Finland has given new information on the emission factors and uncertainties of these emissions. Based on this study, ±60% uncertainty was chosen for CH_4 and N_2O emission factors in all stationary combustion categories.

The 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 Chapter 1.7). A detailed description of the methodology of the uncertainty analysis has been presented in Monni & Syri (2003) and Monni (2004).

During 2005 and 2006 the whole time series was checked to remove possible inconsistencies in the earlier inventories caused by missing data of some plants, chancing classifications etc. Most of theses corrections were already included in the previous inventory, but as the work has been going on, some more 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 year 1991; the point source data of 1991 is

not included in the ILMARI system. Instead of actual point source data, the inventory for 1991 is partly based on interpolation between years 1990 and 1992 at CRF source category and fuel catogory level

3.2.1.4. Source-specific QA/QC and verification

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 is 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 1000 m^3) as well as in energy quantities (TJ). If both quantity values are reported, NCV is calculated and compared to default NCV of this fuel. If calculated value is out of range, data will be marked for checking. If either physical quantity or energy is missing, the missing value will be calculated using default NCV. If neither of quantity nor energy has been reported, then missing data will be taken from other available data sources. For certain non-standard fuel types both fuel code and the data itself will be checked. After data input process there will be numerous manual checks, like comparison to previous years' data (totals and single values), comparison to other fuel data sets, "top 20" lists, etc.

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

Both the original data from VAHTI database and possibly corrected data are stored in ILMARI system, thus corrections can be checked afterwares, if needed..

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

Both Energy statistics compilation and 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 complete each other to find out the final total consumption.

CO_2 emissions are checked also in the plant level data. ILMARI system includes calculated CO_2 emission from each fuel batch. It also includes plant level CO_2 emissions reported to VAHTI system, but this data is not split between different fuels and non-fuel based emissions (although CO_2 from biomass is separated from fossil CO_2). Reported data is compared to calculated data and out-of-range differences are checked.

Each year the latest inventory calculations (activity data and CO_2 emissions) are cross-checked against national energy balance (Annex 4). This reference calculation is based on energy balance and shows activity data (PJ) and CO_2 emissions. The idea of Annex 4 is to compare the results of bottom-up calculation (reported as Sectoral approach in the CRF data) to top-down calculation (from energy balance sheet). Figures based on energy balance are aggregated to best matching CRF source categories and best matching CRF fuel categories.

This top-down calculation differs clearly from the IPCC reference approach.

The main differences are:

- different method: unlike in the RA, emissions in Annex 4 are calculated using consumption of (secondary) fuels
- different mapping/allocation/aggregation of fuels
- different units (kt or 1000 m^3 in RA, ktoe and PJ in Annex 4)
- different aggregation to source categories in some cases
- emission factors in Annex 4 are in more general level (for example combined CO_2 EF for all secondary oil products)

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 in 2006.

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

CO_2 emission data taken from the EU emission trading system was compared to calculated emission data in the ILMARI system. Both systems include point source (bottom-up) data. There is a mark in the ILMARI showing, whether each point source is included in the ETS or not. Thus summaries of total ETS- and non-ETS plants can be made fairly easily.

Total CO_2 emissions taken from the ETS data were 33075 Gg. The corresponding amount taken from GHG inventory data was 33487 Gg. However, in the ETS data 233 Gg of CO_2 was transferred out of the ETS plants. This is not done in the GHG inventory. If we add transferred CO_2 to ETS data, the emissions are 33308 Gg, and the difference between ETS and GHG data is 178 Gg, 0.5 % of total ETS. There are more differences in the allocation of emissions to CRF categories, which can be seen in Figure 3.2_3.

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 mass balance approach in the ETS. In the GHG inventory emissions are split between to Energy and Industrial processes. Another difference is the emissions of combustion of catalytic cracking coke in oil refineries, which is included in Energy sector in the inventory and in Industrial processes in the ETS.

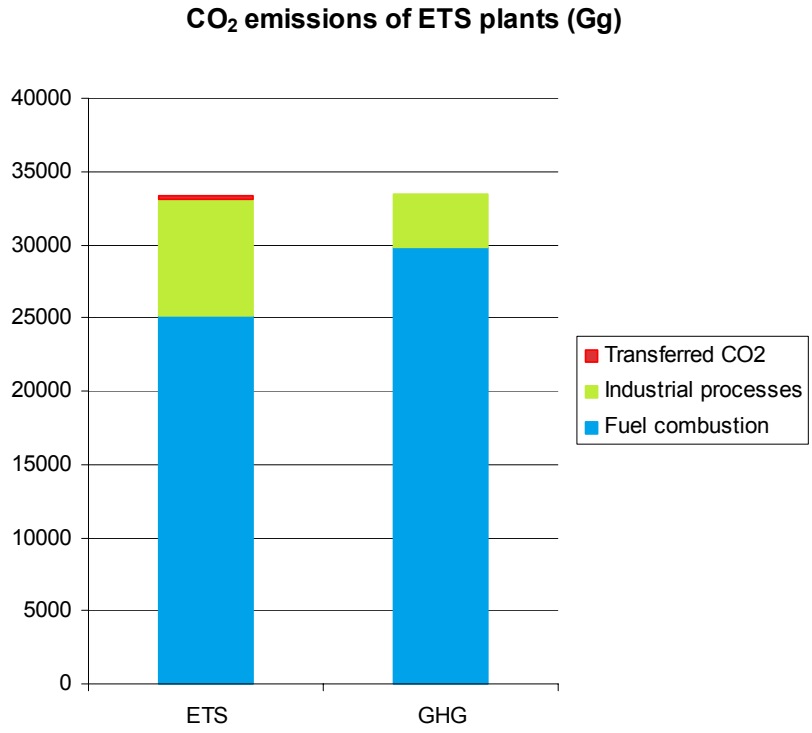


Figure 3.2_3. CO_2 emission of ETS plants compared to corresponding emissions reported in greenhouse gas inventory.

3.2.1.5. Source-specific recalculations

The time series recalculation for the point sources has been going during 2005 and 2006. Most of the on results were already reported in the previous inventory (2006 submission). There are some further corrections in this submission. The time series data for the point sources have been checked and updated where gaps or errors in activity data or inconsistencies in the use of emission factors were identified. The

updated values have been included in the database of the ILMARI calculation system. The data checks have included examination of the data in the VAHTI database, the annual survey of the industrial energy use in Finland by Statistics Finland and other relevant sources. The update has also included an update of the classifications (NACE, CRF, fuels). The improvement of the time series was initiated to correct for inconsistencies identified during the reviews of the sectors and has been very resource consuming. The improvement involved checking the data in the VAHTI database and the supplementary surveys of Statistics Finland. The industries were contacted when inconsistencies could not be corrected using these sources. The revision has resulted in very many smaller corrections for the point sources, however the total impact of the recalculations has been small. Because classifications, activity data, emission and oxidation factors were changed simultaneously, it is not possible to document all changes and their effects.

Updating of CO_2 emission factors and oxidation factors

In the previous inventories calculations IPCC default emission factors had been used for the most important fuels. In the recalculation emission factors were checked and replaced with country specific emission factors where possible. Also IPCC default oxidation factors were replaced with regional (EU) default oxidation factors (COM 2004). Note that this change was not applied to transport, where the models use an oxidation factor equal to unity.

The most important changes in emission factors were already included in the 2006 submission.

3.2.1.6 Source-specific planned improvements

Emissions from fuel combustion are by far the largest source of greenhouse gas emissions in Finland, and most of the point source in the category is part of the EU Emission Trading Scheme. Monitored data for CO_2 emissions from these sources has become available from the emission trading system for the inventory year 2005 in spring 2006. In the Energy sector ETS data was mainly used to identify missing point sources, but in the future ETS data will be used more in checking and verifying the inventory data.

3.2.2. Transport (CRF 1.A 3)

3.2.2.1. Source category description

Emissions from Transport (CRF 1.A 3) include all domestic transport sectors: road transport, civil aviation, domestic navigation, railways and mobile sources (which are not included in other sectors) (Table 3.2_9). Road transport includes all transportation on roads in Finland. Types of vehicles with combustion engines are: cars, vans, buses and coaches, lorries and articulated vehicles, motorcycles and mopeds. The source category does not cover farm and forest tractors driving occasionally on the roads because they are included under other categories (agriculture CRF 1.A 4c, industry CRF 1.A 2f.) or military vehicles. Railway transport in Finland includes railway transport operated by diesel locomotives. 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 1A 4c). Emissions from civil aviation include all domestic civil aviation transport: jet and turboprop powered aircraft (turbine engined fleet) and piston engined aircraft. Helicopters are not included in the calculations due to the small number of flights and the lack of emission factors.

The share of the transport sector from total greenhouse gas emissions has remained rather constant since 1990. In 1990, emissions from the transport sector were 18.0% of the total greenhouse gas emissions in Finland. In 2005, the corresponding figure was 20.4%.

Table 3.2_9. Emissions from the Transport sector in 1990–2005 by subcategories (Tg CO_2-eq).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2																
3. Transport	**12.55**	**12.21**	**12.13**	**11.67**	**12.02**	**11.82**	**11.80**	**12.40**	**12.53**	**12.73**	**12.63**	**12.75**	**12.95**	**13.15**	**13.51**	**13.49**
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
b. Road transport.	10.87	10.56	10.53	10.06	10.39	10.25	10.18	10.68	10.78	10.94	10.85	11.04	11.26	11.45	11.81	11.80
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
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
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
CH_4																
3. Transport	**0.10**	**0.09**	**0.09**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**	**0.07**	**0.07**	**0.07**	**0.06**	**0.06**	**0.06**	**0.05**	**0.05**
N_2O																
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**
a. Civil Aviation	0.005	0.004	0.004	0.004	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004
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
c. Railways	0.002	0.001	0.001	0.002	0.002	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
d. Navigation	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.004	0.004	0.003	0.004	0.004	0.003	0.004
e. Other transport	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

3.2.2.2. Methodological issues

In the Finnish calculation system, the separate models are developed for different sectors of transport, allowing the use of traffic data and transport equipment fleet. Aggregate transport is originally calculated by the detailed transport calculation models LIPASTO of VTT Technical Research Centre of Finland. The calculation system LIPASTO covers emissions and energy consumption of all traffic modes in Finland.

The LIPASTO system is comprised of four sectoral sub-models:
- road transport emissions model LIISA
- civil aviation emissions model ILMI (by Finavia)
- domestic navigation emissions model MEERI and
- railways emissions model RAILI
- non-road machinery emissions model TYKO

VTT and Finavia are responsible for running the calculation models of mobile sources' emissions. Statistics Finland is responsible for combining the results of these models to CRF sector 1.A Fuel combustion and to national energy balances. All emissions components are calculated with the same level of detail (subsector, fuel type).

The fuel consumption in transport sector in 1990–2005 can be seen in Table 3.2_10.

Table 3.2_10. Fuel consumption by fuel type in transport in 1990–2005 (PJ)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1.A 3 a 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
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
1.A 3 b Road Transport																
Gasoline	81.20	81.27	81.45	76.49	78.36	77.45	74.75	76.68	75.32	74.54	71.68	72.57	73.98	74.36	75.84	74.78
Diesel oil	67.39	63.12	62.46	60.97	63.65	62.58	64.34	69.29	71.95	74.92	76.51	78.10	79.75	81.86	85.36	86.17
Natural gas	-	-	-	-	-	-	-	0.01	0.01	0.04	0.05	0.06	0.11	0.13	0.12	0.11
1.A 3 c 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.A 3 d 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
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	2.99
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
1.A 3 e 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
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
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

Road transportation

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. The calculations comprise the emissions of CO_2, CH_4 and N_2O. The methods are, in general, consistent with the IPCC Guidelines. The same model is also used for calculation of SO_2, CO, NMVOC, NO_2 and PM emissions.

The methods for calculating emissions from road transportation correspond to the IPCC Tier 3 level method. Calculation of CO_2 emissions is based on fuel consumption of road vehicles and the fixed emission factors. The calculation model is described in the Appendix 3a in the end of the 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. 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, but is calculated separately in the ILMARI model.

There has been a small amount of bioethanol blended in motor gasoline as an experiment in Finland in few years. (Energy Statistics, yearbook 2006):

2002:	1143 t	(33 TJ)
2003:	6255 t	(176 TJ)
2004:	6752 t	(186 TJ).
2005:	0 t	(0 TJ).

In the previous inventories these figures are included in total use of gasoline (as fossil origin). Due to expiration of periodic deduction of fuel tax there was no consumption of bioethanol in 2005 (Ministry of Trade and Industry, 2006).

The share of non-fossil carbon however seems to be so small that it has no effect on total GHGs. This subject will be studied further in the future, whenever there will be more significant amounts.

N_2O and CH_4 emissions are calculated for gasoline and diesel vehicles separately. The mileage (km/a) of each automobile type and model year on different road types and in different speed classes are multiplied with corresponding CH_4 and N_2O emission factors (g/km). Emissions factors are a sum of hot driving, idle and cold start-ups. Finally all emissions are summed up. The calculation model is described in the Appendix 3a in the end of the Chapter 3.

Motorcycle and moped emissions are calculated using a separate model. The kilometrage of the two two-wheel types by different road types is multiplied with corresponding emission factors. The kilometrage [km/a] data for automobiles consists of two main categories: kilometrage on public roads (roads governed by the Finnish Road Administration (Finnra)) and kilometrage on streets (governed by municipalities). The accuracy of this kilometrage data is high.

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 area, classified roads in built-up area, main roads in rural area and classified roads in rural area) in six speed limit classes (50, 60, 70, 80, 100 and 120 km/h). This data allows detailed calculations to be performed on a smaller area than a country because the detailed data in the model is on the municipality level. For the nation wide calculations kilometrage is summed up.

Street kilometrage is based on a total kilometrage estimation made in the Finnish Road Administration (Finnra) and crosschecked by the studies made at inspection stations. The estimated street kilometrage data is further divided into sub types by vehicles based on 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). Further more 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 1000 vehicle kilometres is determined based on a separate research project. (Technical Research Centre of Finland, Projects 1993 - 1994 including mail inquiry and interview studies).

Emission factors are determined for all the activity categories mentioned above.

Activity data

The activity data in CO_2 calculation is 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.

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. Gasoline used in leisure boats is calculated with MEERI model. Diesel oil sold in Finland is used almost exclusively in road traffic.

For modelling purposes, the data is broken down into different vehicle types and road types. However, this does not affect the country level CO_2 emission calculation because at the end these sub results are summed up and the total fuel consumption remains unchanged.

For activity data for N_2O and CH_4 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 is obtained from the Finnish Road Administration. Further division is done at VTT.

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). Before completion of the VTT model (2001), the moped and motorcycle kilometrages have only been rough estimations.

Road traffic kilometrage in Finland in 1990–2005 is presented in Table 3.2_11.

Table 3.2_11. Road traffic kilometrage in Finland [Million km/a]

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

Year	Cars	Vans	Buses	Lorries	MC+Mopeds	Total
2004	42 945	4 280	590	3 077	898	51 790
2005	43 617	4 335	591	3 134	989	52 665

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 (Technical Research Centre of Finland, Projects 1993 - 1994 including mail inquiry and interview studies).

Emission factors and other parameters

CO_2 emission factors are based on national figures (Table 3.2_12). They differ slightly from those expressed in IPCC guidelines. The difference is small. The emission factors are based on production 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 CO_2 emission factors. The same emission factor is used for both gasoline types E95 and E9.

Table 3.2_12. CO_2 emission factors, net caloric value and density used in calculation of emissions from road transportation.

Fuel type	Emission factor g/kg fuel	Net caloric value TJ/kilotonne fuel	Density kg/m^3 fuel
Gasoline E95 and E98	3133	43.0	750
Diesel oil	3148	43.0	845

Emissions factors for CH_4 and N_2O are a sum of hot driving, idle and cold start-ups. The emission factors are based on literature review by VTT (Juhani Laurikko) and last updated in 2001.

Railway transportation

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. Calculation comprises the emissions of CO_2, CH_4 and N_2O. 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 in the end of the Chapter 3). The calculation method is in general consistent with the IPCC Guidelines (corresponds to Tier 3 level method.). The method is widely used.

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 where the total energy use of these activities was calculated and then divided with the total amount of tonne kilometres resulting in a factor for the extra fuel consumption per tonne kilometre.

Activity data

Activity data consists of gross tonne kilometres for 10 train weight classes on all rail sections (229 sections). Shunting locomotive use is expressed as time (h/a) in all rail yards. There are 4 separate diesel locomotive types in the model and 10 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 every compound. 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 3.2_13.

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 announcement of VR Ltd of 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 3.2_13. Fuel oil consumption in railway transportation in Finland [tonnes/a]

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

Emission factors and other parameters

The emission factors used in the calculation of emissions from Railway transportation are presented in Table 3.2_14. The emission factors of CH_4 and N_2O are based on international measurements and IPCC guidelines. The N_2O emission factor for wagon heating (0.0071 g/kg fuel) is derived from U.S. EPA (2002) (residential furnace). CO_2 factor is based on national figure. The factor slightly differs from that expressed in IPCC guidelines (3140 g/kg fuel). The factor has been obtained from the production analysis by Neste Oil laboratories.

Table 3.2_14. Emission factors used in the calculation of emissions from Railway transportation

Fuel type	CO_2 emission factor g/kg fuel	N_2O emission factor g/kg fuel	CH_4 emission factor g/kg fuel	Net caloric value TJ/kilotonne fuel	Density kg/m^3 fuel
Gasoil	3164	0.0854	0.1708	42.7	845

Emissions of CH_4 and N_2O have been calculated in the RAILI model from the 2005 submission onwards. Formerly they were calculated in the ILMARI model in the Statistics Finland. ILMARI results have been updated to be consistent with RAILI data.

As the N_2O emission factor for all non-road diesel engines in previous inventories, the IPCC's emissions factor for European mobile sources and machinery (1.3 g/kg$_{fuel}$) has been used (Table 1-49, IPCC 1997). Compared to the same factor for US Non-Road Mobile Sources (0.08 g/kg$_{fuel}$) (Table 1-47, IPCC 1997), the factor for Europe proved to be 16 times higher. According to the international measurement data obtained so far, the US value seems to be more accurate and are in line with automobile engines.

Domestic navigation

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 CO_2, CH_4 and N_2O.

In the MEERI model, emissions are calculated by multiplying the amount of energy used (kWh) by 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 IPCC Tier 3 level method.

The activity data of ships driving in shipping channels outside ports (km/a) is 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, time (h) of manoeuvring and berthing are 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- and 4-stroke and auxiliary engines) (g/kWh). Emission factors are at the year 1996 level but correction factors are used to update factors to date.

Icebreaker and ferryboat emissions are calculated by using total fuel consumption (from statistics) 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 in the end of Chapter 3.

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 the year 1999 all ferries have been put in at 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 Helsinki 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 is obtained from the Finnish Maritime Administration.

Data on total fuel consumption of ferryboats is obtained 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.) is obtained from the Finnish Maritime Administration.

The number of bigger leisure boats is obtained from the Finnish Boat Register, the number of smaller boats is an estimation based on the thorough study made by VTT in 2004. Boat Register data includes 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.

Emission factors and other parameters

The CH_4 and N_2O emission factors for ships are the IPCC values for Ocean-going ships (IPCC 1997, Table 1-48). CO_2 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 production analysis in Neste Oil laboratories. Neste Oil Corporation is the leading company of oil product manufacturing in Finland (market share over 90%).

The CH_4 and N_2O 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 3.2_15. below.

Table 3.2_15. Emission factors, net caloric values and densities used in the calculation of emissions from domestic navigation.

Fuel type	**CO_2 emission factor g/kg fuel**	**N_2O emission factor g/kg fuel**	**CH_4 emission factor g/kg fuel**	**Net caloric value TJ/kilotonne fuel**	**Density kg/m^3 fuel**
Gasoline	3133	0.039	3.76	43.0	750
Gasoil	3195	0.0854	0.1708	42.7	845
Heavy fuel oil HFO	3238	0.082	0.287	41.0	970

Civil aviation

Methods

Gaseous emissions and energy consumption of civil aviation within Finnish Flight Information Region (FIR) have been calculated using ILMI calculation model (Figure 3.2_3). The model is meant for emission studies on jet and turboprop powered aircraft (turbine engined fleet). Furthermore, it includes a simplified routine for estimating emissions from piston engined aircraft. ILMI model is a sub model of the LIPASTO calculation system. The sub model has been prepared by the Finavia and the data is fed to the LIPASTO system.

Main part of the model has been produced in the years 1994 and 1995 and the project has been part of research programme MOBILE of the Ministry of Trade and Industry. This project has been published as a report (Savola M. & Viinikainen M 1995), (in Finnish only) where calculation method has been described more closely. The model is updated by the Finavia annually with data of the previous year. The calculation application itself is not meant for public use.

The methane, nitrous oxide, carbon dioxide and sulphur dioxide emissions from jet and turboprop powered aircraft are calculated directly from the estimated fuel consumption. Emission factors for CH_4 and N_2O are taken from Revised 1996 IPCC Guidelines (IPCC 1997). The methods for calculating emissions from civil aviation are comparable with IPCC Tier 3 level method.

The calculated emissions of jet and turboprop powered aircraft include nitrogen oxides (NOx), carbon monoxide (CO) and unburned hydrocarbons (HC). The methodology is based on traffic statistics, aircraft performance data and engine emission factors from the ICAO (International Civil Aviation Organisation) database.

Finavia has verified ILMI model with Eurocontrol's emission data. Finavia's domestic data and overflight data were comparable and very close to each other. Only NOx in overflights was of different magnitude. International data were not comparable because ILMI doesn't calculate the full length of international flights, only the flight in Finnish FIR.

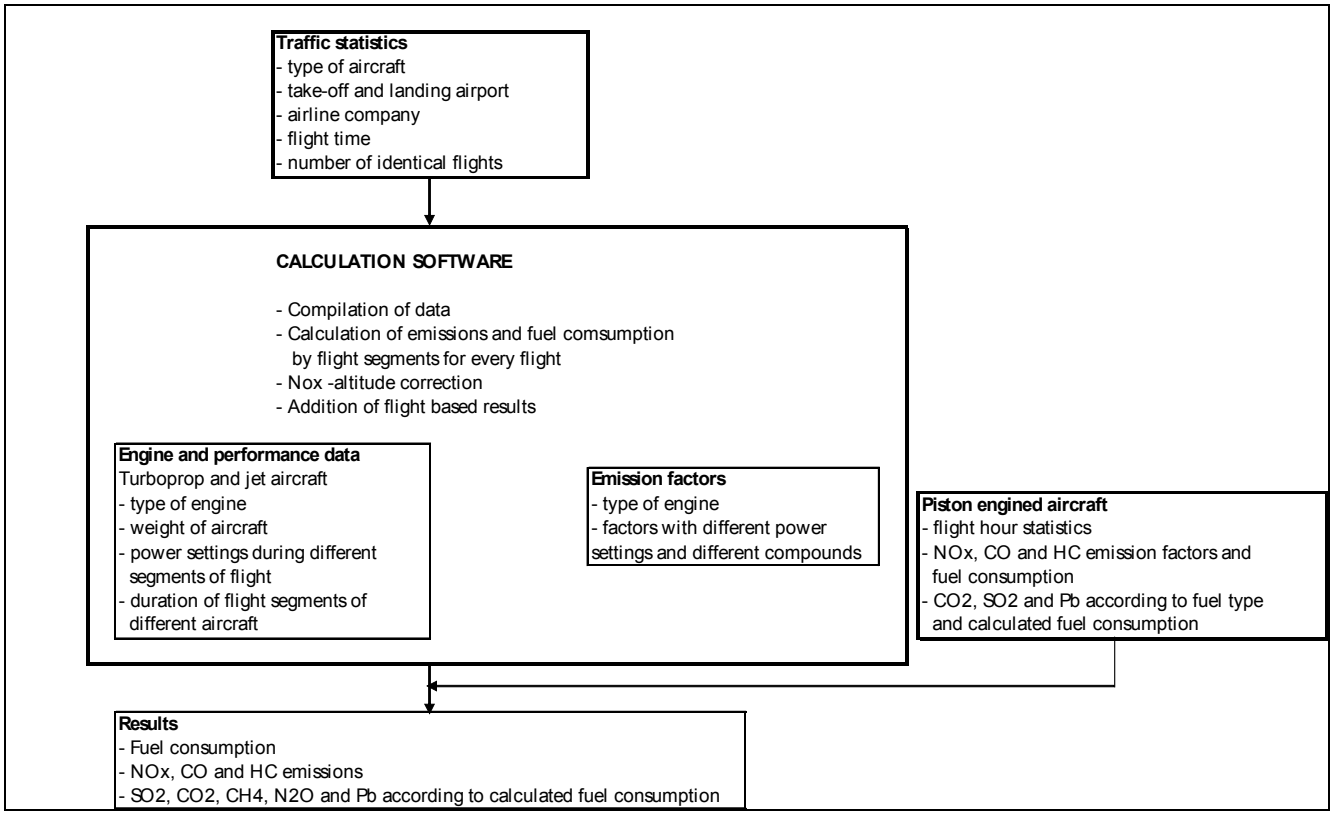


Figure 3.2_3. ILMI calculation model.

Activity data

The used traffic data is taken from Finavia's database for the calculation year. The data includes fields for:

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

In the calculation application each operation is divided into the following flight segments: taxi in, take-off, climb-out, cruise, descent, approach, taxi out.

The methodology for assessing emission from piston engined aircraft is different from the one used for turbine engined aircraft. It is based on the annually published statistics of total flight hours. The fuel burn and emission indexes used are generalised for two typical reference aircraft types only. Therefore, the results are not as reliable as for turbine engined aircraft.

Emission factors and other parameters

Emission factors for the CH_4 and N_2O are taken from Revised 1996 IPCC Guidelines (IPCC 1997).

Other transportation

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 in 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 chapter 3.2.3) 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 web link: http://lipasto.vtt.fi/tyko/tyko2005results.xls

Emissions are calculated separately for gasoline, diesel and LPG machinery. The main method is to sum up the product of machinery population, engine power, load factor, activity hours and emission factors. 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 the Appendix 3a in the end of the Chapter 3.

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

The TYKO model was updated in the year 2006. Description of the updating is presented in chapter 3.2.2.6.

Activity data

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

Emission factors and other parameters

Emissions 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 chapter 3.2.2.6) all emission factors were checked, especially the emission stages II – IV.

3.2.2.3 Uncertainties and time-series consistency

The 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).

Road transportation

The activity data for fuels used in road transportation are very accurate due to accurate statistics. For the purposes of uncertainty estimate, road transportation is divided into gasoline, diesel and natural gas driven vehicles. For the estimation of N_2O emissions, gasoline driven cars are divided into cars with and without catalytic converters. As CO_2 emissions mainly depend on carbon content of the fuel, uncertainty in these emissions was estimated at an upper level (CRF 1.A).

Emissions of CH_4 and N_2O depend on, e.g., driving conditions and hot and cold start-ups, and vary a lot during the driving cycle and between different vehicles. CH_4 emission factors are estimated to contain uncertainty of around ±50% based on measurements of hydrocarbon emissions (Tarantola & Kioutsioukis, 2001), and IPCC default uncertainties (IPCC, 2000).

N_2O emissions vary more than CH_4 emissions, and are highly dependent on the type and age of 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; Egebäck and Bertilsson, 1983; Odaka et al., 2000; Jimenez et al., 2000; Lipman and Delucchi, 2002; Oonk et al., 2003; Behrentz, 2003). For N_2O emission factors, uncertainties are estimated largest for cars with catalytic converters.

During the centralised review of 2005, the ERT noted that, in Annex I countries, emissions from road traffic have increased more rapidly than in Finland (FCCC/ARR/2005/FIN). The ERT compared 2003 emissions to 1990 emissions, and concluded that in Finland, emissions were 6 per cent above the 1990 level, whereas in Annex I countries, emissions were 25 per cent above the 1990 level.

This observation may perhaps be explained by the economic recession of the early 1990s in Finland. Figure 3.2_4 shows the consumption of diesel and gasoline in road transportation. Both fuels show an increase of about 1 PJ per year during 1970s and 1980s. 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 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 early 1990s, then the current level of consumption would give comparable percentage growth rates to those observed for other Annex I countries.

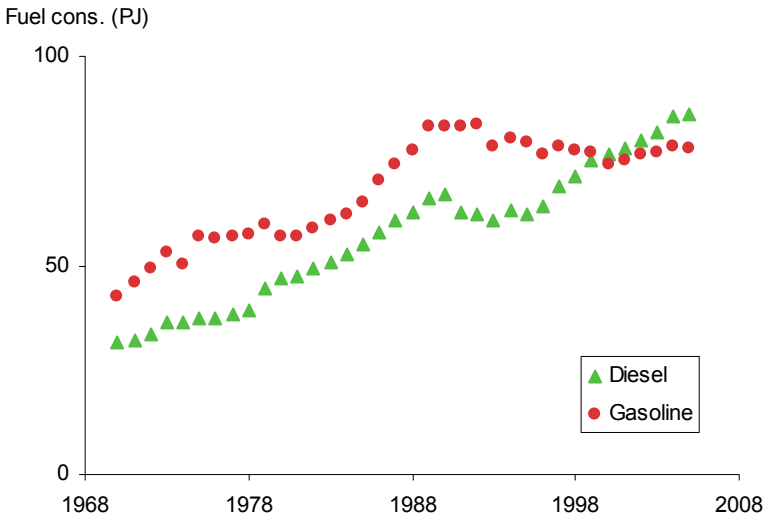


Figure 3.2_4 Consumption of diesel and gasoline in road transportation 1970–2005.

Railway transportation

All non-electric locomotives in Finland use gasoil as fuel. Uncertainty in fuel use is estimated at ±5% based on expert judgement. As the fuel quality is rather constant and carbon in the fuel is nearly completely oxidised, uncertainty in CO_2 emissions is estimated to be low. This was also shown in a measurement project of Kymenlaakso Polytechnic (Korhonen & Määttänen, 1999). In the current inventory, CO_2 uncertainties are estimated at CRF category level 1.A.

Uncertainties in CH_4 and N_2O emission factors are larger than those of CO_2. These emissions vary depending on engine design and maintenance, and the start-ups and shutdowns of the engines are likely to affect emissions. Uncertainty in the emission factor for CH_4 was estimated based on variation in hydrocarbon emissions in a measurement project (Korhonen & Määttänen, 1999). Uncertainty in the N_2O emission factor was based on expert judgement (see Monni et al., 2003) and on uncertainty in emission factors for diesel engines used for other purposes. Reduction of uncertainty in CH_4 and N_2O 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). But, the importance of these emissions in the Finnish greenhouse gas inventory is very small.

Domestic navigation

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 that is used in leisure boats is rather poorly known due to a lack of statistics. Uncertainty in this activity data is estimated at ±20% based on expert judgement. Uncertainty in the use of oil and gasoil is estimated smaller, ±10%.

As CO_2 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 CH_4 and N_2O emission factors are larger than those of CO_2. These emissions vary depending on engine design and maintenance, and the start-ups and shutdowns of the engines are likely to affect emissions. Measurements done for diesel engines in ships have shown that variation in N_2O emissions is larger than in CH_4 emissions. Reduction of uncertainty in CH_4 and N_2O emission estimates would require more measurement data and more information of the use of engines in ships (frequency of start-ups, shut-downs etc).

3.2.2.4 Source-specific QA/QC and verification

QA/QC plan for transport sector includes the QC measures based on guidelines of IPCC (Penman et al. 2000, Table 8.1, p. 8.8-8.9). 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 results attained and compared them with the objectives set and the plans made. For the 2005 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-February 2007.

Verification of sub-sector civil aviation has been done by Finavia with Eurocontrol's emission data as mentioned in the chapter 3.2.2.2 Methodological issues.

Results of the updated non-road TYKO model were compared with the similar Danish calculations described in the report: Winther M. & Nielsen O-K. (2006), Fuel use and emissions from non-road machinery in Denmark from 1985- 2004 – and projections from 2005-2030.

See: http://www.xn--miljstyrelsen-enb.dk/udgiv/publications/2006/87-7052-085-2/pdf/87-7052-086-0.pdf

3.2.2.5 Source-specific recalculations

The time series of transport sub-sectors reported in CRF tables has not been fully consistent in the previous inventories, because emissions in the early 1990s have been originally calculated with the ILMARI system before all parts of the LIPASTO transport models have been available. There have also been some updates in the LIPASTO submodels.

The recalculation of emissions for transport sub-sectors was started in the previous submission and continued in this submission. During 2006 TYKO model was updated for the whole time series 1990 - 2005. The results of the recalculation have impacted mainly on years after 2000.

When the non-road machinery model TYKO was developed in the year 2000 it was decided that the model will be updated at intervals of five years. Forecasts up to the year 2020 were included in the model. For the inventory years between updates (2000 – 2004) forecasted figures were used. The model was updated in the year 2006. Main amendments concerned population of machines. The numbers of machine groups already included in the model (43) were updated and 8 new machine groups were added. These new machines were: 5 types of ATV (2-stroke, 4-stroke etc.), 2 types of snow mobiles and one excavator (mini excavator). The growth of these machine types has been exceptionally and unexpected high during the years 2000 - 2005. The emission factors, especially for the emission stages II – IV, were adjusted.

After recalculation fuel consumption, emission factors and emission time series for each transport sector should be consistent. The recalculation also affected to fuel allocation between energy subsectors.

Emissions from the civil aviation in 1990-1997 were recalculated because more accurate data was available. Earlier they were calculated based on the total landings per year and now activity data is derived from the Finavia's air traffic statistics, which includes both aircraft type and operations per year per aircraft type. The aircraft is divided into five (5) or more aircraft classes. The emissions per operation per aircraft class are from the year 1998 emission data. The emissions in 1998-2005 are derived from the civil aviation emissions model ILMI. A table format has also been developed for data exchange between VTT, Finavia and Statistics Finland to reduce errors.

3.2.2.6 Source-specific planned improvements

During 2005 and 2006 there has been a fuel shift in non-road transport. Previously heating gasoil has been used, but from 2005 there is a new fuel, gasoil for non-road use. This has to be reflected in transport emission models (MEERI, RAILI and TYKO) and reporting of fuels.

In 2005 calculation this shift has been partly taken reflected in the emission factors, but non-road gasoil has not been reported as a separate fuel. From 2006 there will be a new fuel code for non-road gasoil.

A preliminary study will be prepared to find out data for inclusion of helicopters in the ILMI model. Both activity data and emission factors will be studied.

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

3.2.3.1. Source category description

Sub-category CRF 1.A 5 includes emissions from non-specified consumption of fuels, military use and statistical corrections of fuel consumption. In this inventory emissions from feedstock and non-energy use of fuels have been recalculated. Estimated emission from non-identified combustion of feedstocks was reallocated from CRF category 7 to category 1.A 5a.

The sector Other includes also indirect N_2O emissions caused from N deposition by total NOx emissions in Finland. The main source for the NOx emissions is fuel combustion in the Energy sector, with transportation being the most significant source category. These emissions were included in the submissions by Finland until the 2004 submission, when they were removed from the inventory based on two subsequent requests from the UNFCCC Expert Review Teams (ERTs). The ERTs used as the reasoning for their proposal increased comparability and transparency. However, the IPCC GPG 2000 (IPCC, 2000) clearly states that indirect N_2O 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. Also the 2006 IPCC Guidelines for National Greenhouse Gas Inventories include a methodology and guidance on estimating and reporting of indirect N_2O emissions from the atmospheric deposition of nitrogen in NO_x and NH_3.

The indirect N_2O emissions from agricultural sources (mainly from NH_3 emissions) are included in the Agriculture sectors as done in previous submissions and in accordance the guidance in the IPCC Guidelines. Possibilities to complement the estimates on indirect N_2O emissions with emissions from nitrogen deposition due to industrial NH_3 emissions and other possible sources will be explored in future inventories. These sources are estimated to be of small, if not negligible, significance.

Table 3.2_16. Emissions from other sectors in 1990–2005 by subcategories (Tg CO_2).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2002	2001	2002	2003	2004	2005
CO_2																
4. Other sectors	**7.04**	**6.89**	**6.99**	**6.51**	**6.16**	**5.70**	**5.81**	**5.82**	**5.92**	**5.83**	**5.46**	**5.68**	**5.63**	**5.48**	**5.28**	**5.02**
a. Commercial and Institutional	1.95	1.88	2.01	1.60	1.47	1.20	1.27	1.28	1.29	1.27	1.17	1.23	1.22	1.18	1.13	1.04
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	2.30	2.18	2.05
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	1.97	1.99	2.00	1.98	1.93
5. Other	**1.32**	**1.16**	**1.17**	**1.15**	**1.28**	**1.36**	**1.40**	**1.33**	**1.56**	**1.44**	**1.46**	**1.40**	**1.42**	**1.69**	**1.62**	**1.55**
Stationary, non-specified	0.92	0.75	0.75	0.73	0.79	0.89	0.96	0.88	1.14	0.98	0.99	0.96	0.94	1.19	1.20	1.07
Stationary, feedstocs and non-energy use	0.35	0.31	0.31	0.29	0.33	0.33	0.33	0.33	0.32	0.33	0.32	0.31	0.31	0.33	0.31	0.31
Mobile	0.06	0.11	0.11	0.13	0.16	0.13	0.11	0.11	0.10	0.13	0.16	0.14	0.16	0.17	0.12	0.17
CH_4																
4. Other sectors	**0.18**	**0.18**	**0.18**	**0.18**	**0.19**	**0.19**	**0.19**	**0.19**	**0.20**	**0.19**	**0.19**	**0.19**	**0.20**	**0.20**	**0.19**	**0.19**
5. Other	**0.003**	**0.003**	**0.002**	**0.002**	**0.002**	**0.003**	**0.003**	**0.002**	**0.003**	**0.003**	**0.003**	**0.002**	**0.003**	**0.003**	**0.003**	**0.003**
N_2O																
4. Other sectors	**0.09**	**0.08**	**0.09**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**	**0.07**	**0.08**	**0.08**	**0.08**	**0.07**	**0.07**
5. Other	**0.45**	**0.42**	**0.40**	**0.41**	**0.41**	**0.38**	**0.38**	**0.37**	**0.35**	**0.34**	**0.32**	**0.32**	**0.32**	**0.34**	**0.31**	**0.27**

3.2.3.2 Methodological issues

Methods

Emissions from sub-categories 1.A 4 and 1.A 5 are calculated with the ILMARI system (see chapter 3.2.1).

Methodology for estimating the CO_2 emissions from feedstock a non-energy use of fuels was revised, because there was obvious double counting. ILMARI system includes point source (bottom-up) data on feedstock combustion in petrochemical industry as well as recycled waste oil combustion in different sectors in industry, and they are reported in corresponding CRF categories 1.A 2. These known uses of feedstocks and lubricants are subtracted from corresponding total amounts. For the rest of the feedstocks 10% of carbon is estimated to be released as CO_2, and 90% is estimated to be stored in products (mainly plastics). For the rest of lubricants, 33% of carbon is estimated to be stored in products (recycled lubricants) and 67% of carbon released as CO_2 either in burning of lubricants in motors or illegal combustion of waste oil in small boilers. Emission from natural gas used as feedstock are calculated and reported in sector 1.B 2.

These non-specified emissions from feedstocks (which are not reported in 1.A 2 or 1.B 2) are now included in this category instead of CRF 7.

Nitrous oxide (N_2O) is produced in soils and surface waters through nitrification and denitrification. Increased nitrogen input to these systems enhance the production of N_2O, and all anthropogenic sources of NH_3 and NO_x emissions are potential indirect sources of N_2O. The emissions are estimated based on the amount of nitrogen emitted in the country times an emissions factor assuming 1% of the nitrogen in the emissions to be converted to N_2O. The calculation method is the IPCC default method. The emissions are estimated at Statistics Finland based on total NOx emissions in Finland. The methodology is the same independent of the source of the nitrogen, but agricultural indirect N_2O emissions are reported in the Agriculture sector, indirect N_2O emission from other sources are included in this sector.

Activity data

The activity data for sub-category CRF 1.A 4 is taken from annual energy statistics. The fuel consumption data for CRF 1.A 4 is presented in Table 3.2_17. 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/m^3, a) and annual heating degree days.

Activity data for forest machinery and agricultural machinery is taken from the TYKO model of VTT.

Activity data for fishing is taken from MEERI model of VTT. (See descriptions in chapter 3.2.2.2).

The indirect N_2O emissions are estimated at Statistics Finland based on total NOx emissions in Finland.

Table 3. 2_17. 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
1.A 4																
Liquid Fuels	90.72	89.09	90.12	83.57	78.36	72.76	74.07	74.18	75.44	74.18	69.34	71.97	71.11	69.02	66.53	63.19
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
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	3.88
Other Fuels	1.21	0.85	0.67	0.87	0.77	0.95	1.01	1.03	1.05	1.03	0.97	1.05	1.08	1.13	1.15	1.08
1.A 5																
Liquid Fuels	12.33	10.36	9.97	10.47	11.90	12.18	12.05	10.78	13.98	12.02	12.78	11.46	11.92	13.69	13.84	13.75
Solid Fuels	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gaseous Fuels	0.92	1.58	2.46	1.70	1.41	2.53	3.67	3.99	4.15	4.12	4.03	4.84	4.43	6.70	5.71	4.41
Other Fuels	0.24	0.16	0.08	0.06	0.10	-	-	-	-	-	-	-	-	-	-	-
1.A 5 (energy from non-specified use of feed stocks)																
Liquid	4.79	4.30	4.28	4.02	4.61	4.71	4.65	4.65	4.59	4.64	4.42	4.30	4.37	4.63	4.27	4.32

Emission factors

Emission factors used are partly IPCC default and partly based on national sources. (Table 3.2_18).

Table 3.2_18. Emission factors of small combustion in the ILMARI calculation system

Small combustion boilers < 1 MW	**CH_4 kg/TJ**	**N_2O kg/TJ**	**CO kg/TJ**	**NMVOC kg/TJ**
Oil	10	2	20	5
Coal	300	4	200	200
Natural gas	3	1	50	5
Peat	50	4	200	200
Wood, households and agriculture	200	4	2 100	200
Wood, commercial buildings	10	2	2100	10
References	IPCC Table 1–7 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–8 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–10 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–11 Peat: the same EF as for coal

3.2.3.3 Uncertainties and time-series consistency

Uncertainty in CO_2 emissions was estimated at an upper level (CRF 1.A). Uncertainty in CH_4 and N_2O 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 expert estimates by energy statistics experts for biomass, peat and coal (the significance of which is minor in these categories). The largest uncertainties were estimated for biomass (±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 rather accurately estimated using information on total fuel balance on a national level, and on information on fuel use in large installations (CRF 1.A 1 and 1.A 2), which is also rather accurate. The use of this data and its 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 CH_4 and N_2O are high, because these emissions vary largely between different boilers, furnaces etc. Especially in biomass combustion in small-scale applications, CH_4 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 varies. 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 research study done by VTT in 2005 were used to revise CH_4 and N_2O emission factors, and also uncertainties of these emission factors.

The 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 chapter 3.2.3.5). 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.

3.2.3.4 Source-specific QA/QC and verification

There are numerous automatic and manual QC procedures used in the ILMARI system (see chapter 3.2.1.4).

Each year, the latest inventory calculations (activity data and CO_2 emissions) are cross-checked against the national energy balance. There is a reference calculation based on energy balance, showing activity data (PJ) and CO_2 emissions.

3.2.3.5. Source-specific recalculations

The recalculation of emissions from each sub-sector of 1.A 4 and 1.A 5 was started in the previous inventories and continued in this inventory. The most important changes were the updates of the heating energy calculation system and TYKO submodel. The changes were mostly in the latest years; they were taken to ILMARI calculation and reported to CRF tables for each year. .

The recalculation takes into account the changes in:

- total activity (fuel consumption) with certain fuels
- the allocation of fuels between subsectors
- emission factors for each subsector.

3.2.3.6 Source-specific planned improvements

Disaggregation of stationary and mobile sources in reporting of sector 1.A 4 is considered for transparency.

In 2006, a study to improve the national oil balance was prepared (Torniainen, 2006) and this work provides data that will enable the more accurate estimation of emissions from feedstocks and non-energy use in the future inventories.

3.3 Fugitive emissions from fuels (CRF 1.B)

3.3.1 Overview of the sector

Description

Under fugitive emissions from fuels, Finland reports CH_4 emissions from oil refining and from natural gas transmission and distribution and CO_2, CH_4 and N_2O emissions from flaring at oil refineries and petrochemical industry. Also indirect CO_2 emissions from fugitive emissions from fuels have been calculated from NMVOC and CH_4 emissions for the whole time series.

Quantitative overview

Fugitive emissions from fuels comprise only about 0.3% of total greenhouse gas emissions in Finland. Emissions from oil and gas have decreased 18.4% since the 1990 level (Table 3.3_1).

Key Categories

Oil and natural gas was the only key source of this sector in 2005.

Table 3.3_1 Fugitive emissions from oil and gas (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2																
Flaring (1.B 2 c)	123	115	121	172	72	81	72	122	71	61	65	58	68	63	62	77
CH_4																
Oil refining (1.B 2 a)	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	0.45
Natural gas (1.B 2 b)	0.17	1.6	2.3	3.1	3.4	3.4	3.5	3.0	3.0	2.4	2.2	2.8	2.3	2.5	2.1	2.6
Flaring (1.B 2 c)	0.002	0.002	0.002	0.003	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N_2O																
Flaring (1.B 2 c)	0.004	0.004	0.004	0.005	0.002	0.003	0.002	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Indirect CO_2	103	100	104	100	98.6	96.3	87.4	82.1	76.3	71.4	65.7	64.5	58.7	59.0	54.5	52.6
Total CO_2 eq	238	257	282	346	252	258	243	277	221	192	186	191	184	184	172	194

3.3.2. Solid fuels (CRF 1.B 1)

Emissions from the peat production are reported in LULUCF sector (category Wetlands, CRF 5.D 2) as suggested in GPG LULUCF (IPCC 2003) (see chapter 7.5).

There are no coal mines in Finland.

3.3.3 Oil and natural gas (CRF 1.B 2)

3.3.3.1 Source category description

This source category includes CO_2, CH_4 and N_2O emissions from flaring at oil refineries and 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.

In 2005 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 0.13 Tg CO_2 eq. This is about 0.19% 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.

3.3.3.2 Methodological issues

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 2006) 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. 2006). Calculations are based on measurements for years 1996–2005. Emissions of earlier years has been estimated with Gasum Oy (Hyvärinen E. 2000) in Statistics Finland based on 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 (1996–2005) made by Helsinkikaasu Oy (Riikonen A. 2006) and partly on rough estimates (1991–1994) based on 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 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 Regional Environmental Centres' VAHTI database. Evaporative emissions from cars is based on expert estimation at the VTT Technical Research Centre of Finland (Mäkelä K. 2006) and emissions from petrol distribution chain and refuelling of vehicles on expert estimation of Finnish Gas and Oil Federation. Indirect CO_2 emission was calculated using the equation below. It was assumed that the average carbon content is 85 percent by mass for all categories under sector of solvents and other products use. (Netherlands NIR 2005, EPA 2002).

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

Indirect CO_2 emission from methane emissions were calculated using the equation below.

$$Emissions_{CO_2} = Emissions_{CH4} * 44/16$$

Emission factors and other parameters

Emission factors for calculating emissions from the refining and storage of oil are based on default factor given in the Revised 1996 IPCC Guidelines, since country-specific factors are not available. 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 = 888 kg methane / PJ oil refined).

Activity data

Activity data for oil refining is taken from Energy Statistics (Energy Statistics, Statistical Yearbook 2006). It is the quantity of oil refined.

For emissions from flaring no activity data is 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 is 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.

3.3.3.3 Uncertainty and time series' consistency

Sources of uncertainty for estimates concerning year 2005 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: -the 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 ± 50%

Transmission of gas: 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 category Fugitive emissions from oil and natural gas is around ±26%.

3.3.3.4 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 the emission estimates, the correctness of the calculation formulas has been checked.
- For a sample of the emission estimates, the use of appropriate units throughout the calculations has been checked.
- The adequacy of documentation for internal use and to facilitating 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 to previous estimates (reported under category 1.B 2 b iii Other leakage).

Tier 2 QC:

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

3.3.3.5 Source-specific recalculations

No source-specific recalculations have been done.

3.3.3.6 Source-specific planned improvements

No source- specific improvement has been planned.

3.4 Reference approach

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. This disaggregated data was taken from the background data files of the EB and for 1990 - 1994 from 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. Main focus of the study was in the year 2004, but the most important time series were also revised. There were some remarkable changes especially in 1990 - 1994.

There are some problems in preparing the Reference Approach.

First, in the Reference Approach fuel mapping is different than in Sectoral Approach in our case. In SA peat is included in Other fuels, whereas in RA it is included in Solid fuels. In the previous inventories this summary operation was manually corrected in CRF excel sheets, but this correction is not possible in CRF Reporter. This problem does not have any effect on total CO_2 amounts, but it makes somewhat difficult to compare consumption figures and emissions by CRF fuel categories.

Another problem is lack of transparency in CRF reporter: it is difficult to see how emissions in the RA are actually calculated and how non-energy use and feedstock corrections are included in the comparison between RA and SA. In the previous version of CRF tables calculation was more transparent and it was relatively easy to find out reasons for possible differences between RA and SA.

The difference between RA and SA was -1.0% for 2005 and 2.7% 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.

Another reference calculation based on the energy balance for the 2005 inventory is included in Annex 4. This calculation shows a difference of 2.8%. In addition to the EB sheets, there are CO_2 emissions calculated directly from the EB sheet.

3.5 International bunkers

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

The emissions are calculated using the ILMARI calculation model of Statistics Finland (see closer CRF 1.A). Fuel consumption by transport mode is obtained from the energy statistics and it includes fuel sales to ships and aircrafts going abroad. The country-specific CO_2 emission factors used are the same as for domestic aviation and navigation. The average non-CO_2 emission factors have been calculated from ILMI calculation system, 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 does not follow the IPCC definition of bunkers, thus ILMI data cannot be used as such. The suitability of average emission factors will be studied further in the future.

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. 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 prices. Bunker fuels sales are only available as annual totals.

The in-country and centralized 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.

Appendix_3a

Formulas used in calculation emissions from transport sector (1.A 3).

Road transportation

CO_2 emissions

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

Ey is total CO_2 emissions during the year y
u is fuel type
U is number of fuel types
V is total sales of fuel
O is total use of fuel for other purposes than road traffic
c is emission factor

N_2O and CH_4

This formula applies to all automobiles in the LIISA model.

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

E is total emission
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:

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

E is total emissions
S is gross tonne kilometre
V is 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 gro*ss* 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

(1 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 (excluded icebreakers):

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

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

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

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

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.

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

where ,

Ev,y is total emissions v in the 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

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

St is machinery population in the year *t*
wt is wastage of machinery in the year *t*
Ct is sales of machinery in the year *t*

Appendix_3b

Table 1_3b. Fuel combustion by fuels, PJ.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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**
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	136.7	193.5	168.7	80.6
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
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
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
Other coal	0.02	0.04	0.1	0.2	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Liquid fuels	**377.7**	**365.7**	**363.0**	**348.1**	**358.0**	**348.0**	**353.1**	**353.8**	**363.0**	**364.8**	**351.3**	**356.8**	**362.8**	**364.7**	**363.0**	**356.4**
Heavy fuel oil	71.0	68.3	65.6	61.0	64.9	57.9	60.0	54.1	53.0	54.7	48.9	51.5	52.6	50.4	46.8	42.9
Light fuel oil	105.7	101.6	102.9	101.9	99.7	98.7	99.9	99.8	104.2	103.3	97.5	98.7	97.7	97.5	95.7	91.9
Motor gasoline	86.1	86.1	86.5	81.5	83.4	82.6	79.9	82.0	80.8	80.2	77.4	78.3	79.8	80.2	81.8	80.8
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
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
Refinery gases	23.2	23.2	23.1	20.5	23.0	22.5	23.7	22.3	24.6	24.2	21.8	22.7	24.5	24.6	23.1	23.4
Town gas	0.2	0.1	0.1	0.0	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	0.9	0.9	0.8	0.9	1.3	1.4	0.4
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	5.3
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
Aviation gasoline	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2
Other oil	6.4	5.8	5.7	5.5	5.9	6.2	6.1	5.8	5.5	5.7	5.7	5.0	4.8	5.2	4.9	6.2
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**
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
Other gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.2	2.0	0.7	0.7	0.9	0.7
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**
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
Mixed fuels (MSW/REF/RDF/PDF 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
Other fossil wastes	0.9	0.8	0.7	0.8	0.9	1.0	1.4	1.4	2.5	2.7	1.7	1.6	1.9	1.9	1.6	1.3

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
etc.																
Biomass	**178.5**	**176.0**	**173.4**	**205.8**	**213.6**	**217.1**	**217.0**	**247.0**	**255.7**	**273.7**	**272.1**	**260.7**	**281.2**	**286.7**	**299.0**	**279.7**
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
Other woodfuels	90.3	88.0	85.7	100.0	101.3	104.6	107.7	116.4	129.9	129.9	130.4	133.6	137.9	145.5	151.5	146.8
Biogas	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.4	0.3	0.5	0.6	0.6	0.6	0.6	0.7	1.3
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
Other non-fossil fuels	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.1	0.1	0.1	0.2	0.2	0.9	1.1	0.5	1.1

Table 2_3b. CO_2 emissions from combustion by fuels, Tg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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**
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
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
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
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
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
Liquid fuels	**28.0**	**27.1**	**26.9**	**25.8**	**26.5**	**25.7**	**26.1**	**26.1**	**26.8**	**26.9**	**25.9**	**26.3**	**26.8**	**26.9**	**26.8**	**26.2**
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
Light fuel oil	7.8	7.5	7.6	7.5	7.4	7.3	7.4	7.4	7.7	7.6	7.2	7.3	7.2	7.2	7.1	6.8
Motor gasoline	6.3	6.3	6.3	5.9	6.1	6.0	5.8	6.0	5.9	5.8	5.6	5.7	5.8	5.8	6.0	5.9
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
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
Refinery gases	1.5	1.5	1.5	1.3	1.5	1.5	1.6	1.5	1.6	1.6	1.4	1.5	1.6	1.6	1.5	1.5
Town gas	0.010	0.007	0.007	0.002	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	0.03
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
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
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
Other oil	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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**
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
Other gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.07	0.12	0.04	0.04	0.05	0.04
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**
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
Mixed fuels (MSW/REF/RDF/PDF etc.)	0.04	0.03	0.03	0.03	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.09	0.13	0.15	0.18
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
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**	**30.9**	**32.3**	**30.1**
Black/sulphite liquor	9.5	9.4	9.4	11.4	12.1	12.1	11.7	14.0	13.5	15.5	15.2	13.6	15.3	15.0	15.7	14.0
Other woodfuels	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	15.8	16.4	15.9
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
Hydrogen	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	0.09	0.12	0.05	0.12

4. INDUSTRIAL PROCESSES (CRF 2)

4.1 Overview of sector

Description

Finnish emissions from industrial processes are divided to Mineral products (CRF 2.A), Chemical industry (CRF 2.B), Metal production (CRF 2.C), Consumption of halocarbons and SF_6 (CRF 2.F) and Other production (CRF 2.D). Under Mineral products Finland reports emissions from cement production, lime production, limestone and dolomite use and soda ash use. Under Chemical industry emissions from nitric acid production, ethylene production and hydrogen production are reported. Emissions from metal production include CH_4 emissions from coke production and CO_2 emissions from coke and heavy bottom oil used in the blast furnaces. The 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.

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 chemical industry and storage of chemicals. Also indirect CO_2 emissions from industrial processes have been calculated from NMVOC and methane emissions.

Quantitative overview

Industrial greenhouse gas emissions contributed 8.9% to the total anthropogenic greenhouse gas emissions in Finland in 2005 (Figure 4.1_1). The most important greenhouse gas emissions from industrial processes in Finnish inventory in 2005 were the CO_2 emissions from iron and steel production, the N_2O emissions from the nitric acid production and CO_2 emissions from cement production with the 3.5%, 2.3% and 0.8% shares of the total greenhouse gas emissions, respectively. F-gases emissions comprised together about 1.3% 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 have fluctuated somewhat during the 1990's (Figure 4.1_2). The most significant change is the increase of emissions of F-gases which are now over eightfold compared to the 1990 emissions (Table 4.1_1). The N_2O emissions have remained quite constant. The CH_4 emissions have increased by nearly 80% but their contribution to the total industrial emissions is very small. Industrial CO_2 emissions decreased considerably at the beginning of the 1990's, but have increased since 1996 and are currently approximately at the same level as in 1990.

Table 4.1_1. Trend in greenhouse gas emissions from industrial processes (Gg CO_2 eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2																
A. Mineral Products	1 309	1 123	1 009	911	959	925	959	977	987	1 071	1 124	1 136	1 131	1 184	1 224	1 153
B. Chemical Industry	130	144	108	99	134	116	132	133	122	120	131	127	140	158	172	125
C. Metal Production	1 859	1 869	1 880	1 932	1 995	1 973	2 061	2 328	2 312	2 307	2 333	2 290	2 196	2 459	2 552	2 394
CH_4																
B Chemical Industry	3.94	4.68	4.54	4.13	3.72	4.73	4.84	3.85	5.35	5.46	5.37	5.46	4.78	5.21	6.87	6.86
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	8.61	9.38
N_2O																
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	1 284	1 337	1 420	1 460	1 569
HFCs	**0.02**	**0.05**	**0.10**	**0.10**	**6.52**	**29.33**	**77.30**	**167.8**	**245.2**	**318.6**	**501.7**	**656.9**	**463.4**	**652.1**	**695.1**	**863.80**
PFCs	**0.07**	**0.08**	**0.09**	**0.10**	**0.12**	**0.14**	**0.16**	**0.18**	**0.21**	**27.97**	**22.46**	**20.06**	**13.37**	**14.85**	**12.23**	**9.88**
SF_6	**94.38**	**67.32**	**36.64**	**33.61**	**34.90**	**68.53**	**72.20**	**75.98**	**53.18**	**51.98**	**51.49**	**55.03**	**51.31**	**41.71**	**23.18**	**19.56**
Total	**5 071**	**4 665**	**4 358**	**4 362**	**4 591**	**4 602**	**4 791**	**5 151**	**5 121**	**5 269**	**5 554**	**5 596**	**5 358**	**5 957**	**6 166**	**6 161**

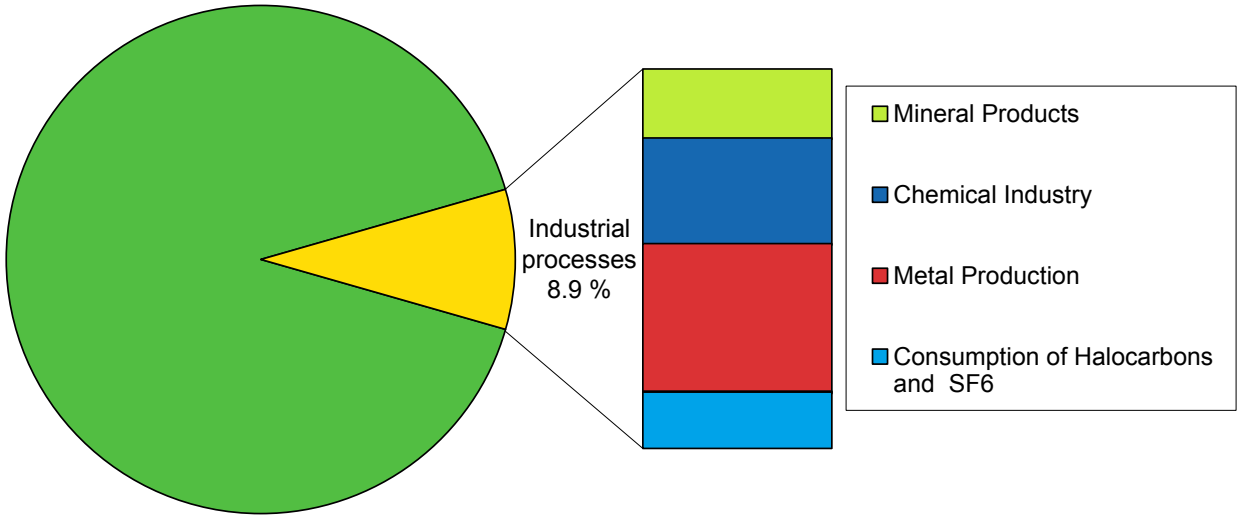


Figure 4.1_1. Emissions from industrial processes compared to total emissions in 2005.

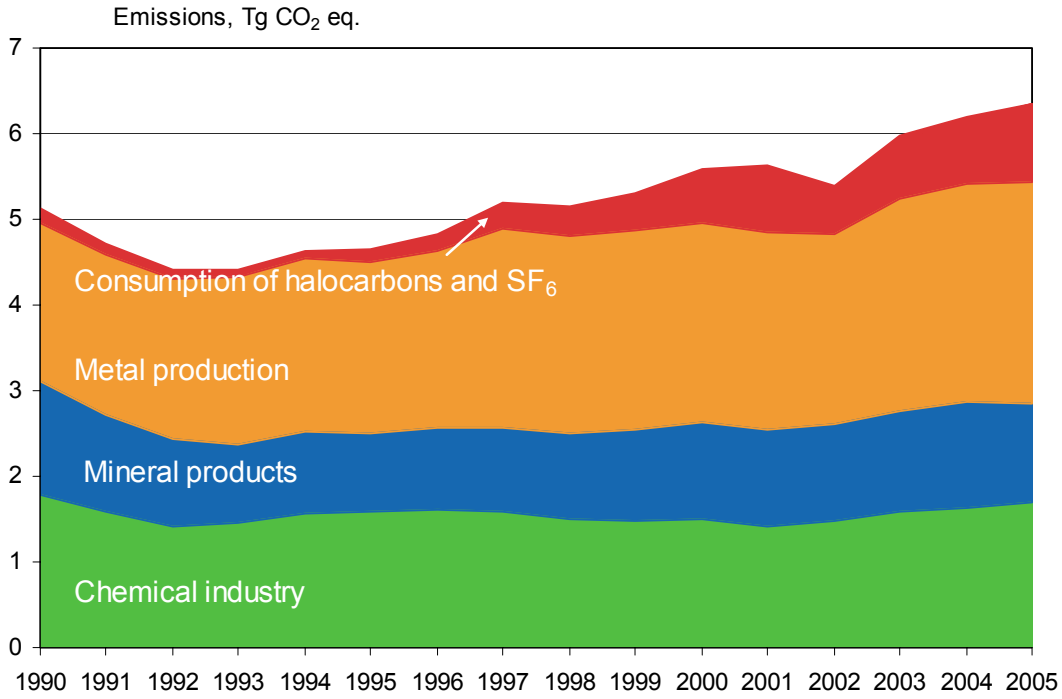


Figure 4.1_2. Total greenhouse gas emission from industrial processes in 1990–2005 in Finland (Tg CO_2 eq.).

Key categories

Key categories in industrial processes in 2005 are summarised in Table 4.1_2.

Table 4.1_2 Key categories in Industrial processes (CRF 2) in 2005 (quantitative method used: Tier 2)

Source Category	**Gas**	**Key source**	**Criteria**
2.B 2 Nitric Acid Production	N_2O	YES	L
2.C Iron and Steel production	CO_2	YES	L
2.F 1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	YES	L, T
2.F 7 Electrical Equipment	SF6	YES	T

4.2 Mineral Products (CRF 2.A)

4.2.1 Source category description

The 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). Soda ash is not produced in Finland. Lime production includes also lime production in iron and steel industry. Limestone and dolomite use includes the use in production of glass, calcium chloride, phosphates, mineral wool, glass wool and in energy industry for sulphur dioxide control. Soda ash use includes also the use in production of glass, pigments, glass wool and sodium silicate.

In the production of cement CO_2 is emitted when an intermediate product, clinker, is produced. In that process limestone is heated to high temperature, which results in emissions, as the main component of limestone, calcium carbonate, breaks down, calcinates, into calcium oxide and carbon dioxide. Limestone contains also small amounts of magnesium carbonate ($MgCO_3$), which will also calcinate in the process causing CO_2 emissions. Also CO_2 emissions from lime production and limestone and dolomite use are due to calcination of calcium and magnesium carbonates at high temperatures (Slioor, 2004).

In addition carbon dioxide is released when soda ash (Na_2CO_3), is heated to high temperatures.

NMVOC emissions from asphalt roofing and road paving with asphalt are reported also (asphalt roofing is included in road paving) in this source category. The NMVOC emissions are calculated at the Finnish Environment Institute. The activity data and emission factors used in calculations are from Fortum Oil and Gas Ltd. (Blomberg 2006). Indirect CO_2 emissions from use of asphalt has been calculated from NMVOC emissions for time series 1990–2005. Indirect CO_2 emission was calculated using equation below. It was assumed that the average carbon content is 85 percent by mass for all categories under sector of solvents and other products use. (Netherlands NIR 2005, EPA 2002).

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

Table 4.2_1. CO_2 emissions from mineral products (Gg).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
2.A 1 Cement production	786	614	510	390	385	394	402	474	479	515	542	540	517	500	520	542
2.A 2 Lime Production	383	380	378	382	395	375	393	358	364	400	425	429	439	513	528	455
2.A 3 Limestone and Dolomite Use	99	93	85	104	147	126	137	125	123	134	135	145	152	148	153	134
2.A 4 Soda Ash Use	18	15	16	16	17	18	18	16	17	19	19	19	20	20	20	19
2.A 6 Road paving (indirect CO_2)	22	21	20	19	15	12	9	4	4	3	3	3	3	3	2	2
2.A Totals	**1309**	**1123**	**1009**	**911**	**959**	**925**	**959**	**977**	**987**	**1071**	**1124**	**1136**	**1131**	**1184**	**1224**	**1153**

4.2.2 Methodological issues

Methods

Emissions from cement and lime production as well as from limestone, dolomite and soda ash use are calculated by multiplying emission factor with activity data. Activity data is collected mainly directly from the industry also industrial statistics has been used. Emissions of the year 2005 have been calculated using production data reported to the Energy Market Authority by companies of Emission Trading. Emission factors are calculated by the industry (cement production and lime production) or are based on IPCC's default factors (limestone and dolomite use and soda ash use). The methods for calculating emissions from cement production and lime production are consistent with IPCC Tier 2 level method. For lime production Good Practice Guidance does not provide different tier levels, but compared with tier levels of cement production the method used corresponds to Tier level 2.

Emission factors

Cement and lime production

Emission factors used in the calculation of emissions from cement production are plant-specific provided by the industry for the whole time series. Previously the emission factors had not been directly collected from the industry on as detailed level as in the present inventory. Annual emission factors vary slightly, since the parameters affecting them vary slightly from year to year (Table 4.2_2). The emission factor for year 2005 is the same as reported to Energy Market Authority in the EU´s Emission Trading Scheme.

Emission factor of cement production is based on the CaO and MgO contents of clinker. Cement kiln dust (CKD) and by pass dust as well as the amounts of CaO and MgO that are calcined already before the process (and therefore do not cause emissions) are taken into account at plants. CKD correction factors vary from year to year and are presented in the next table (Table 4.2_2).

Emission factor for lime production is based on the actual CaO and MgO contents of lime derived by measurements. Emission factor for lime production is calculated from emission and product data of the years 1998–2002. For the remaining part the emission factor is based on an estimate of the CaO content of lime that is less accurate than the measurement based values of 1998–2002. For the years 1990–1997 the mean value of the emission factors of 1998–2002 is used for all lime production.

Limestone, dolomite and soda ash use

Emission factors for calculating emissions from limestone and dolomite and soda ash use are based on IPCC default factors. 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 deemed necessary. In calculating emissions from limestone and dolomite the IPCC's Good Practice Guidance's default emission factors for lime production has been used. For a couple of plants different factors have been used because more detailed knowledge of the composition of limestone is available. The possibility of using Finnish lime production emission factors as a basis for emission estimates of limestone and dolomite use will be studied later. At the moment it is not known if similar limestone is used in lime production and other processes in which limestone is used as raw material. Emission factors for limestone use for dolomite use are 0.417 and 0.428, respectively.

IPCC's (1996 Revised Guidelines) emissions factor for soda ash use is slightly corrected by a factor of 0.99, because it's not likely that sodium carbonate is calcined completely in the various processes. Emission factor is 0.411.

Table 4.2_2. Activity data and emission factors for mineral products (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
2.A 1																
Clinker production	1470	1146	953	727	731	760	767	906	902	964	1017	1015	977	940	1064	1110
EF (t/t)	0.532	0.534	0.533	0.535	0.525	0.517	0.520	0.520	0.527	0.531	0.529	0.528	0.525	0.528	0.485	0.486
CKD Correction Factor	1.003	1.003	1.004	1.004	1.003	1.003	1.006	1.006	1.008	1.007	1.008	1.007	1.007	1.007	1.008	1.000
2.A 2																
Lime production	519	516	513	519	536	509	533	486	498	545	575	578	594	682	710	611
EF (t/t)	0.737	0.737	0.737	0.737	0.737	0.737	0.737	0.737	0.731	0.734	0.739	0.741	0.738	0.753	0.744	0.745
2.A 3																
Limestone Consumption	189	180	163	212	312	264	287	266	256	265	264	284	314	299	314	274
Dolomite Consumption	35	29	26	25	25	25	26	21	25	39	44	44	42	43	48	47
2.A 4																
Sodium Carbonate Consumption	44	37	38	40	42	44	45	38	41	47	45	46	48	49	48	47

Activity data

Activity data for cement and lime production as well as for limestone, dolomite and soda ash use is collected mainly directly from the industry and taken from industrial statistics.

Cement and lime production

In calculating the emissions from cement production the amount of clinker produced annually is used as activity data. The data for years 1990–2005 for clinker production is collected from the industry.

In calculating emissions from lime production 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 calculations. Activity data for the years 1990–1997 is partly collected from the industry and partly taken from industrial statistics and companies' reports. Activity data for years 1998-2003 was received directly from lime producing companies. For the year 2004 part of the activity data was collected from industrial statistics and VAHTI database due to refusal of disclose of a company. For the year 2005 the activity data was received from the Energy Market Authority which grants the emission permits to companies for the EU Emission Trading Scheme and supervises the monitoring and reporting of emission and production data. The received data was compared to data from industrial statistics and the VAHTI database.

Limestone, dolomite and soda ash use

The consumption of limestone and dolomite has been used as activity data when calculating emissions from lime stone and dolomite use. Activity data for 2005 is collected directly from individual companies and the Energy Market Authority. Data for earlier years has been partly taken from industrial statistics and from individual companies.

Consumption of sodium carbonate is used as activity data when calculating emissions from the soda ash use. Activity data is 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.

4.2.3 Uncertainty and time series' consistency

Cement and lime production

For 2005 there are two sources of uncertainty in cement production. Firstly, there are uncertainties on quantity measurements. Secondly, the determination of the CaO and MgO contents of clinker is not completely accurate. Uncertainty was estimated to be ±5 %.

For 2005 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 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 ±4 %.

Due both to lack of knowledge concerning years 1990–1997 and to better knowledge concerning years 1998–2003 the time series for lime production is calculated using partly estimated data. The differences from the inventory of 2005 in the source of data and the methods are described below.

Years 1990–1996: Activity data are partly collected from the industry and partly taken from industrial statistics and companies' reports.

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

Years: 1990–1997: Emission factor is the mean value of the emission factors of 1998–2002.

Years: 1998–2005: Emission factor for all lime production is based on the actual (measured) CaO and MgO contents of lime.

Limestone and dolomite use

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 and some smaller plants may exist that are not included in calculations. Another source of uncertainty is the amount of carbonates that actually reacts 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.

Soda ash use

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 and some plants may exist that are not included in calculations. Another source of uncertainty is the amount of sodium carbonate that actually reacts 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 2005.) 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.

4.2.4 Source-specific QA/QC and verification

General (Tier 1) Quality Control (QC) procedures applied to category Mineral products (CRF 2.A)

- Assumptions and criteria for the selection of activity data and emission factors are documented.
- For a sample portion of emissions, correctness of the calculation formulas has been checked.
- For a sample portion of emissions, the use of appropriate units throughout the calculations has been checked.
- The adequacy of documentation for internal use and to facilitating reviews has been checked.
- The consistency of input data and methods over the time series has been checked. Existing inconsistencies have been documented.
- Known and possible sources of incompleteness, which relate to subcategories CRF 2.A 3 and CRF 2.A 4, have been documented.

Tier 2 QC:

Cement production
- Emission factors have been compared to IPCC's default factor.
- Emission estimates have been compared with estimates based on less specific data.

Lime production:
- Emission estimates have been compared to estimates based on industrial statistics' activity data.
- Emission factors have been compared to IPCC's default factor

4.2.5 Source-specific recalculations

Cement production

One plant informed that they had not taken into account amount of organic carbon from raw materials in year 2004, after that recalculated emissions decreased by 40 Gg.

Lime production

Emissions from lime production have been recalculated another time using improved activity data of one plant for year 2003. Emissions increased by 5 Gg.

Limestone and dolomite use

One chemical plant and two tile producers have corrected their amount of used limestone in 2004 and recalculation increased emissions by 37 Gg.

4.2.6 Source-specific planned improvements

The possibility of using national lime production emission factors as a basis for emission estimates of limestone and dolomite use will be studied in future.

4.3 Chemical Industry (CRF 2.B)

4.3.1 Source category description

In the Finnish inventory this category includes the non-fuel emissions of nitrous oxide from nitric acid production, the methane emissions from ethylene production and carbon dioxide emissions from hydrogen production. (Table 4.3_1). Ammonia, adipic acid, carbides, carbon black, dichloroethylene, styrene and methanol are not produced in Finland.

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 feedstocks of needed hydrogen. From 1993 on there has been no ammonia production in Finland (Table 4.3_1). The CO_2 emissions from these processes have been estimated and included in the inventory.

Indirect CO_2 emissions from chemical industry have been calculated from NMVOC and methane emissions for the whole time series.

Table 4.3_1. Emissions by gas and subcategory (Gg).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
CO_2																
2.B 2 Ammonia Production	44	45	19	-	-	-	-	-	-	-	-	-	-	-	-	-
2.B 5 Hydrogen Production	60	77	66	78	113	94	109	111	106	104	117	113	128	147	159	116
2.B 5 Indirect	30	26	26	18	23	23	24	24	18	18	17	16	15	13	13	9
CH_4																
2.B 5 Ethylene Production	0.19	0.22	0.22	0.20	0.18	0.23	0.23	0.18	0.25	0.26	0.26	0.26	0.23	0.25	0.33	0.33
N_2O																
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	4.14	4.31	4.58	4.71	5.06
2.B Totals in Gg CO_2 eq.	**1790**	**1587**	**1415**	**1463**	**1573**	**1583**	**1600**	**1580**	**1503**	**1472**	**1500**	**1417**	**1482**	**1584**	**1639**	**1701**

Ethylene production is a source of CH_4 emissions. Emissions of CH_4 from ethylene production were approximately 0.33 Gg in 2005, which was only 0.01 % of Finland's total emissions. Ethylene production in Finland has fluctuated from about 180 to 330 Gg ethylene per year between 1990 and 2005.

Nitric acid is produced in Finland in single-stage medium pressure plants. In October 2004 there was a commissioning of a new plant in one existing site and therefore the amount of produced acid is expected to increase in future. The new plant replaced another which was closed in the beginning of year 2005. Emissions of N_2O from nitric acid production were approximately 5.1 Gg in 2005, which was 2.3% of Finland's total emissions. A small part of these emissions is from a plant producing fertilisers. The emissions from fertiliser production are included in the emissions from nitric acid production due to confidentiality reasons. For the same reason, the emissions are not described in more detail. The production of nitric acid has varied from about 430 to 550 Gg nitric acid per year.

Emissions of CO_2 from hydrogen production were approximately 116 Gg in 2005, which was 0.2 % of Finland's total emissions. Hydrogen production does not necessarily cause CO_2 emissions. Emissions occur in processes in which hydrocarbons are used as feedstock. In Finland natural gas is the most common feedstock in hydrogen production. Theoretically all the carbon contained in hydrocarbons will be emitted as CO_2 in the processes. In practice a small amount of feedstock does not react.

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

4.3.2 Methodological issues

Methods

Emissions from ammonia, nitric acid, ethylene and hydrogen production are calculated by multiplying activity data with emission factor.

The NMVOC emissions are based on emission data from the Regional Environment Centres' VAHTI database and collected by the Finnish Environment Institute. Indirect CO_2 emission was calculated using equation below. It was assumed that the average carbon content is 85 percent by mass for all categories under sector of solvents and other products use. (Netherlands NIR 2005, EPA 2002).

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

Indirect CO_2 emission from methane emissions were calculated using the equation below.

$$Emissions_{CO_2} = Emissions_{CH4} * 44/16$$

Emission factors

Nitric acid production: Emission factors are plant specific and are based on measurements started in 1999 and was done by an outside consultant. At one site emission factors has been defined to be 7.6 kg/t and 9.5 kg/t for the whole time series. At other sites emission factors are about 9.2 kg/t. The new plant has a continuous measurement unit. A portable measurement device to measure emissions of the other plants of the company has been purchased and the emissions are now measured periodically. This has improved the emissions factors for 2005 and will improve the accuracy of the emission factors in future.

Ethylene production: The CH_4 emissions have been calculated with the IPCC default emission factor 1 g CH_4/kg ethylene produced.

Ammonia production: The CO_2 emissions have been calculated with the mean value of two IPCC default emission factors (1.55 tonne CO_2/tonne ammonia produced).

Hydrogen production: No default factor for hydrogen production is available in IPCC's 1996 Revised Guidelines or Good Practice Guidance 2000. Emission factor for calculating emissions from hydrogen

production is based on stoichiometric ratios of the chemical reactions. These are corrected by a factor of 0.94 to take into account the fact that the reactants do not usually 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).

Activity data

The annual nitric acid production figures have been obtained from the production plants.

The annual ethylene production figures have been obtained from the production plants and industrial statistics.

The annual ammonia production figures have been obtained from the production plants.

The consumption of hydrocarbons is used as activity data in calculating emissions from hydrogen production. Feedstocks used are natural gas, naphtha and propane. Activity data are collected directly from individual companies. Data for the first half of 1990's have been partly taken from industrial statistics and partly estimated on the basis of other years' data.

The production figures for hydrogen, ethylene and nitric acid in 1990-2005 are presented in Table 4.3_2.

Table 4.3_2. Production of ammonia, hydrogen, ethylene and nitric acid (Gg).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Ammonia	28	29	12	-	-	-	-	-	-	-	-	-	-	-	-	
Hydrogen	5.6	7.0	6.0	7.1	10	7.9	8.9	9.3	9.1	8.7	10	9.5	11	13	23	16
Ethylene	188	223	216	197	177	225	230	183	255	260	256	260	228	248	327	327
Nitric acid	549	480	428	445	461	476	477	480	452	453	451	430	448	477	500	582

4.3.4 Uncertainty and time series' consistency

Uncertainty estimate for nitric acid production was changed for this submission. Uncertainties of the estimate for 1990 were kept unchanged and are still based on work by Monni (2003, 2004). Estimate for 2004 was revised after a visit to the producer, and following discussions. The current estimate reflects the improved measurements done by the producer, as discussed above. Specifically, an estimate of ±15% was obtained (Gåpå 2005). This gives the 95% confidence interval for N_2O emissions from nitric acid production. The estimates now better reflect the history of no emission measurements, and therefore large uncertainty for 1990, and the current circumstances with extensive measurements, and thus a lower uncertainty deduced from that information.

The uncertainty in ethylene production was estimated at around ±20%.

The uncertainty in hydrogen production was estimated at -10…+13 %. Uncertainty is partly due to uncertain activity data. Another factor that causes uncertainty is the lack of knowledge concerning the exact amount of reagents that actually reacts in the various processes.

The data on the emissions has improved in recent years, mainly due to increased availability of measured data. Therefore uncertainties in recent years are smaller than in the beginning of the 1990's.

4.3.5 Source-specific QA/QC and verification

General (Tier 1) Quality Control (QC) procedures applied to category Chemical industry (CRF 2.B)

- Assumptions and criteria for the selection of activity data and emission factors are documented.
- For a sample portion of emissions, correctness of the calculation formulas has been checked.
- For a sample portion of emissions, the use of appropriate units throughout the calculations has been checked.
- The adequacy of documentation for internal use and to facilitating reviews has been assessed.
- The consistency of input data and methods over the time series has been assessed. Existing inconsistencies have been documented.
- Possible sources of incompleteness, which relate to the CRF subcategory 2.B 5 Hydrogen production, have been documented.
- Estimates have been compared to the previous estimates (not relevant if source category included in to the inventory for the first time).

4.3.6 Source-specific recalculations

No source-specific recalculations have been done.

4.3.7 Source-specific planned improvements

Industrial emission sources for CH_4 and the suitability of the IPCC default emission factors should be studied further.

4.4 Metal Production (CRF 2.C)

4.4.1 Source category description

This source category includes in Finnish inventory the CH_4 emissions from coke production (reported in CRF-tables under Iron and steel production) and the CO_2 emissions from coke and heavy bottom oil used in blast furnaces. Earlier these emissions have been included in CRF 1.A 2a. The CO_2 emissions from ferroalloys production in Finland are reported in Iron and steel production, because ferrochromium production is part of an integrated stainless steel plant (Table 4.4_1). In addition the NMVOC emissions from iron and steel production and from secondary aluminium production are reported. There is no primary aluminium production in Finland.

SF_6 emissions from magnesium die casting are included in the inventory. However, since there is only one producer in Finland currently, these data are confidential. Emissions and consumption data were therefore grouped with other confidential SF_6 data, and reported under the 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 also CH_4 emissions from pig iron and sinter production were 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.

Indirect CO_2 emissions from metal production have been calculated from NMVOC and methane emissions for time series 1990–2005.

Table 4.4_1. Emissions by gas and subcategory (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
CO_2																
2.C 1 Iron and steel production- production of steel	1855	1865	1876	1927	1990	1968	2056	2323	2306	2302	2328	2285	2191	2454	2547	2577
2.C Indirect from all processes of a category	3	4	4	5	5	4	4	5	5	5	7	6	5	5	5	5
CH_4																
2.C 1 Iron and steel production	0.24	0.24	0.25	0.44	0.46	0.46	0.46	0.44	0.46	0.45	0.46	0.46	0.46	0.45	0.41	0.47
Totals in Gg CO_2 eq.	**1864**	**1874**	**1885**	**1941**	**2005**	**1982**	**2070**	**2338**	**2321**	**2317**	**2343**	**2299**	**2206**	**2469**	**2560**	**2403**

4.4.2 Methodological issues

Methods

The calculation method of CO_2 emission from iron and steel industry is country specific. Both fuel based emissions and process emissions are calculated in connection with the ILMARI calculation system (see chapter 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 ILMARI system from the use of fuels, excluding coke and heavy bottom oil used in blast furnaces, and subtracted from total CO_2 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 CO_2 emissions for each installation (coke oven, sinter plant, blast furnace, lime kiln, steel converter, rolling mills, power plants/boilers) in each plant are mostly taken from VAHTI database. 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 CO_2 emissions is not complete in the VAHTI system. Emissions for years 1990-1995 have not been reported to VAHTI. Therefore total CO_2 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 is fairly consistent, although some corrections had to be made to the original VAHTI data. This calculation is also done for later years to compare the methodology and results for 1996-2005. Reported totals (by installations) are fairly close to 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 EU ETS (Emission Trading scheme) monitoring plans of the largest iron and steel producers in Finland, these streams belong to very small streams with overall cumulative effect on emission less than 1 % of total CO_2 emissions.

Emissions are reported in CRF categories using the following allocations:

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's air pre-heaters)
CRF 2.A 2	• process emissions from lime production
CRF 2.C 1	• process emissions from iron and steel production (includes ferroalloys production in integrated stainless steel plant)

From 2005 on, all iron and steel plants in Finland report to the ETS. From this submission, also GHG inventory will be using the total CO_2 emissions from ETS data, although the split between process and fuel based emissions will be done in the same way as in the previous calculation.

Personal communications (Perander 2005 and 2006) with iron and steel plant staff showed, that the present method used in GHG inventory gives the best results taking into account the availability of the data for the whole time series. Mass balance approach was in principle seen as a more accurate methodology, but the data is 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 would become available for historical time series, a recalculation could be considered, but at the moment this option seems very unlikely.

The calculation method for CH_4 emissions from coke production is consistent with the IPCC Guidelines.

The NMVOC emissions from iron and steel production and secondary aluminium production are calculated at the Finnish Environment Institute based on emission data from VAHTI database and the Finnish Metal Industries Federation. The emission factors are taken from the Joint EMEP/Corinair Atmospheric Inventory Guidebook. Indirect CO_2 emissions were calculated using the same equations mentioned in Chapter 4.3.2.

Emission factors

Production of steel: The CO_2 emission factors used in the calculation are represented in Table 3.2_5. Plant specific CO_2 emission factors have been used as far as possible.

Production of coke: The emission factor 0.5 kg/t used in calculation of CH_4 emissions from coke production is the IPCC default value (IPCC 1996).

Activity data

Activity data for the calculation and comparison of CO_2 emissions is taken from VAHTI database, Energy statistics (Energy Statistics, 2006) and special surveys by Statistics Finland.

Activity data for the calculation of CH_4 emissions from coke production and is obtained from the Energy Statistics.

Table 4.4_2. Production of coke and steel, Gg

Year	Production of coke	Production of crude steel
1990	487	2861
1991	471	2890
1992	498	3077
1993	874	3256
1994	922	3420
1995	920	3176
1996	910	3301
1997	879	3734
1998	912	3952
1999	900	3956
2000	910	4096
2001	909	3938
2002	912	4003
2003	895	4766
2004	820	4832
2005	894	4738

4.4.3 Uncertainty and time series' consistency

The uncertainty in coke production was estimated at around ±20% in 2005.

The uncertainty in CO_2 process emissions from Iron and steel production was estimated at ±10% in 1990 and 2005. However, the overall uncertainty in Iron and steel production including energy and process emissions, was estimated to be ±5%. This subject and its effect on total GHG uncertainty will be studied further.

4.4.4 Source-specific QA/QC and verification

Comparison of different methodologies (reported and calculated emissions). Comparison to mass/balance approach for certain years. Checking of activity data from several independent sources.

4.4.5 Source-specific recalculations

No source-specific recalculation has been done.

4.4.6 Source-specific planned improvements

No source-specific improvements are planned for now.

4.5 Other Production (CRF 2.D)

4.5.1 Source category description

This source category includes NMVOC and SO_2 emissions from the forest and food industries. In 2005 they amounted 4.9 Gg and 3.2 Gg. The non-fuel based CO_2 emissions from the pulp and paper and food industry are estimated to be negligible in Finland. All N_2O 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 are calculated at the Finnish Environment Institute. Activity data for the calculation is obtained from the Finnish Forest Industries Federation and from the VAHTI database and the emission factors from the Finnish Forest Industries Federation, Report August 1996 and The Finnish Forest Industries Federation, Annual report 2005, Sawmills and board production.

NMVOC emissions from the food industry are calculated at the Finnish Environment Institute. Activity data for calculation of the NMVOC emissions from the food industries is 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. The emission factors are taken from the NPI (1999), Joint EMEP/Corinair Atmospheric Inventory Guidebook (2001) and YTV (1995). Indirect CO_2 emission were calculated using the equation mentioned in chapter 4.3.2

All SO_2 emissions of different sulphur compounds are calculated as SO_2 equivalents.

4.5.3 Uncertainty and time series' consistency

The latest uncertainty analysis for NMVOC has been carried out for 2004 emissions and reported to the UNECE CLRTAP Secretariat. For 2005 NMVOC emissions uncertainty analysis will be made by 15th May 2007 and the documentation will be available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on website http://www.environment.fi > State of the environment > Air > Air pollutant emissions in Finland (In English). According to the analysis the uncertainty for 2004 NMVOC emissions was estimated at -21% - +22%

4.5.4 Source-specific QA/QC and verification

The NMVOC inventory has been prepared under the quality management system for the inventory of air pollutants reported to the UNECE CLRTAP in place at SYKE. The statistical quality checkings described in section 1.6 have been carried out. General quality control (QC) procedures in the IPCC GPG Table 8.1 are in use in compiling and reporting of NMVOC emissions. QC plan was prepared, implemented and its fulfilment was assest.

4.5.5 Source-specific recalculations

Minor changes were done due to the review of VAHTI data base.

4.5.6 Source-specific planned improvements

No source specific improvements are under consideration at the moment.

4.6 Consumption of Halocarbons and SF_6 (CRF 2.F)

4.6.1 Source category description

Under the source category CRF 2.F Emissions of consumption of halocarbons and SF_6 Finland reports the HFC and PFC emissions from all refrigeration and air conditioning equipment based on the vapour compression cycle (CRF 2.F 1), HFC emissions from foam blowing and use of HFC containing foam products (CRF 2.F 2), HFC emissions from technical aerosols, one component polyurethane foam, tear gas and metered dose inhalers (CRF 2.F 4) and SF_6 emissions from manufacturing, use and disposal of electrical equipment (CRF 2.F 8). In addition, HFC-23 emissions from refrigeration and air conditioning, HFC-125 and HFC-134a emissions from fixed fire fighting systems, HFC-23, CF_4, C_2F_6, C_3F_8, c-C_4F_8 and SF_6 emissions from semiconductor manufacturing and SF_6 emissions from magnesium die casting and shoes are reported aggregated in separate sub-category due to data confidentiality (CRF 2.F 9).

Note that the sub-category of emissions from 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. It has been decided not to change the practice of including OCF in the aerosols sub-source category, because this would require recalculation of both the aerosol and foam time series, and because recalculation would not improve emission estimates.

There are no fugitive emissions from manufacturing, because F-gases are not produced in Finland. There is also no manufacturing of other fluorinated gases, such as HFCs, that could lead to by-product emissions (e.g. HFC-23 from HCFC-22 manufacturing). Other point sources that make considerable contribution to emissions elsewhere, but are absent in Finland, include primary aluminium and magnesium industry.

Based on the trend analysis, refrigeration and air conditioning is the only key source in category 2.F.

The share of F-gases from the total greenhouse gas emissions in Finland in 2005 was about 1.3 % (893 Gg CO_2 eq.). Total emissions of F-gases have increased significantly since the 1990. In 2005, emissions were about eight fold compared to emissions in 1995 which was chosen as the base year for F-gas emissions in Finland (Table 4.6_1). A key driver behind this trend has been substitution of ozone depleting substances (ODS) by F-gases in many applications. In Finland introduction of HFC and PFC substances as ODS substitutes took place in mid 1990's which led to rapid growth of emissions towards the end of the decade.

Opposed to a global growing trend, the 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. Usage of PFC-218 (C_3F_8) for servicing refrigeration devices has decreased from 3.6 tonnes in 2000 to 0.33 tonnes in 2005. Simultaneously the amount of PFC-substances used in semiconductor manufacturing processes has decreased in beginning of 2000's due to recent transfers of production from Finland into other countries. The decreasing trend in semiconductor manufacture, however, might be temporary and the emissions from this industry may start to increase again.

Table 4.6_1. Actual emissions of HFCs, PFCs and SF_6, 1990–2005 (CO_2 equivalent Gg).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
HFCs	0.02	0.05	0.10	0.10	6.52	29.33	77.30	167.8	245.2	318.6	501.7	656.9	463.4	652.1	695.1	863.8
PFCs	0.07	0.08	0.09	0.10	0.12	0.14	0.16	0.18	0.21	27.97	22.46	20.06	13.37	14.85	12.23	9.88
SF_6	94.38	67.32	36.64	33.61	34.90	68.53	72.20	75.98	53.18	51.98	51.49	55.03	51.31	41.71	23.18	19.56

4.6.2 Methodological issues

Methods

An overview of models used to quantify emissions of F-gases are presented in Table 4.6_2. Emissions from each category are quantified using 2 or 3 different methods given in IPCC GPG (2000). First of all, there are two flavors 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 –be quantified (decision 2/CP.3). The COP has also decided that 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_2. Summary of 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.
Electrical equipment (CRF 2.F 8)	Tier 3c (country-level mass-balance), Tier 1b SF_6	Tier 1a estimates can not 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 SF6 used is imported not in bulk, but in products (i.e. shoes). Emissions from this source are not reported separately due to confidentiality.
Semiconductor manufacturing (CRF 2.F7)	Tier 1, Tier 1a CHF3, CF_4, C_2F_6, C_3F_8, c-C_4F_8	Tier 1b is not applicable to this category because all gases used are imported in bulk.
Refrigeration and air conditioning (CRF 2.F1)	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)	Tier 2 top-down method is used for all sources in this category, both stationary and mobile. Data is not collected for separate sub-categories because such statistics are either not available or the preparation of such statistics would entail a very high reporting burden on companies, given that such a task would be taken seriously. 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.
Aerosols and one component foam (CRF 2.F4)	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.
Foam blowing (CRF 2.F2)	Tier 2, Tier 1a, Tier 1b HFC-134a, HFC-245fa and HFC-365mfc	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. Import of HFC-245fa and HFC-365mfc into Finland has been detected. It has not been possible to clarify to which use these chemicals have been put after imported to country. It is likely that the gas has been used in experiments. The quantities have been small so far. At the present level of activity, these HFCs are likely to give a negligible contribution to emissions.
Fixed fire fighting systems (CRF 2.F3)	Tier 2, Tier 1a, Tier 1b HFC-125 and HFC-134a	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 of the refrigeration and air conditioning sub-categories (domestic, commercial, industrial, mobile, etc.).

Emissions are calculated by 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. The vertical extent of this system is determined by the height of the structures that hold the refrigerants within. From the principle of conservation of mass, it follows that

emissions = production + imports – exports – destruction ± 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 equipment reaches the end of their 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 top-down Tier 2 approach is recommended in Good Practice Guidance. Emissions are not calculated for each equipment sub-category 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 sub-categories. 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.

More detailed descriptions of calculating emissions with IPCC Tier 1a and b and Tier 2 methods (potential and actual emissions) are presented in appendix in the end of the 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 for as long as possible, and then switched to HFCs. Open-celled foams (soft foams) have not been produced in Finland with HFCs.

Actual emissions are calculated by IPCC Tier 2 described in more detailed in the Appendix of the Chapter 4. Potential emissions were calculated according to 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.

Emissions model used was from Good Practice Guidance (p. 3.85).

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

where $f = 0.5$,

a = Tier 1b potential emission in 2004 and
b = Tier 1b potential emission in 2005.

A more detailed description of the model is given in the Appendix in the end of the Chapter 4.

SF_6 from electrical equipment (CRF 2.F 8)

The source category covers SF_6 emissions from manufacturing, use and disposal of electrical equipment. IPCC Tier 3c, Tier 1a and 1b were used in calculation.

The 2005 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 in 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 2003 and 2004 inventory were reported with Tier 3c method over three successive years of data.

In 2005, when data from three latest years was used, the model suggested a negative value for emission estimate. This is, due to the fact, that most of the quality of SF_6 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 year 2005 were calculated with same model but the estimate was based on 2005 activity data only.

A detailed account of the approach is given in the Appendix in the end of the Chapter 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 fighting systems
– CHF3, CF4, C2F6, C3F8, c-C4F8 from semiconductor manufacturing
– SF_6 from magnesium die casting, semiconductor manufacturing and shoes.

Semiconductors are reported with IPCC Tier 1 method (equations 3.31 and 3.32 in Good Practice Guidance) For reporting SF6 from shoes "adiabatic property applications" is used, (equation 3.23 in 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 quantities released in fires and quantities released due to system malfunction. These quantities are directly reported as emissions. HFC-23 from refrigeration and air conditioning are reported with IPCC Tier 2 methodology and SF_6 from magnesium die casting is reported by using "direct reporting" (equation 3.12 Good Practice Guidance p. 3.48).

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 Good Practice Guidance. The standard deviations were chosen based on expert judgement).

N = normal distribution, with mean (m) and standard deviation (s) given in parenthesis N(m,s).

i	Foam type	$f_{M,i}$	$f_{B,i}$
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)

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 use of CO_2 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 IPCC GPG (2000) referring to Gamlen et al. (1986). Both the value for emission factor, 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 Good Practice Guidance (p. 3.74).

Activity data

HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F.1)

Data on refrigerant imports was obtained through a survey conducted in February–August 2006. Six companies reported imports. These include all major importers and distributors of refrigerants in Finland. Frequently some equipment manufacturers that use larger quantities of refrigerants in their production also import refrigerants. This was also the case in 2005. The total quantity of bulk refrigerants imported in 2005 was 662 816 kg. This quantity is 7 % larger than the quantity imported in 2004 and a bit smaller than the quantity imported in 2003.

The total quantity of bulk refrigerants exported in 2005 was 3 223 kg, less than half of that exported the year before. Decreasing trend has continued since 2001 and may be explained by some of the bigger companies giving up the refrigerant sales business. In 2005, only three companies reported bulk exports. Closer analyse of respondents showed that the low quantity is not due to non-response. Few of the companies that had previously exported refrigerants had indeed answered the questionnaire but reported no exports this year. Most of the imported refrigerant is 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 Statistic Finland. The proportion p is based on a survey of vehicle importers. Conducted in February–April 2006, companies were asked to provide data for 2005. Average charges were obtained from a 1999 survey of Finnish vehicle importers (Oinonen 2000 pp. 26–27). In year 2005 the imported used vehicles were taken into account in emission estimates for the first time. The number of imported used cars was obtained from Statistic Finland and the proportion of vehicles equipped with MACs was assumed to be the same as in newly registrated vehicles.

In case of MACs, the inventory will be based on an assumption that the quantity exported was much smaller than the quantity imported, and that exports may thus be treated as negligible.

Refrigerants are also imported and exported *inter alia* in domestic refrigeration and air conditioning equipment, heat pumps, commercial refrigeration equipment and air conditioning units. 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 final piece of information needed to quantify the emissions model are the destructed refrigerant quantities. The quantity destructed was imputed, inferred from original reported quantities, based on the assumption that non-respondents were a random sample of all respondents.

Table 4.6_3 summaries the refrigerant activity data. Note that all kinds of refrigerants are included in the reported quantities, not just those consisting of or containing HFCs or PFCs. Respondents provide actual quantities identified by 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_3. Summary of refrigerant activity data.

	Number of reporting companies	Quantity (kg)
Bulk refrigerants imported	6	662 816
Bulk refrigerants exported	3	3 223
Refrigerants in equipment imported	30	172 925
Refrigerants in equipment exported	21	26 935
Refrigerants used in manufacturing equipment	32	40 154
Refrigerants used in installation and conversion of equipment	255	107 747
Destructed refrigerant	92	25 688

HFCs from foam blowing (CRF 2.F 2)

Activity data for calculating emissions from foam blowing is presented in Table 4.6_4. Data is 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 to previous years. This was due to establishment of a new production plant by the biggest manufacturer in Finland in beginning of the year 2004. In 2005 the same manufacturer replaced HFC-134a blowing agent with CO_2 in it's processes which led to notable decline of chemical imports, emissions from manufacture and product exports in this sector. Originally, the manufacturer aimed to transfer into use of CO_2 in 2003, prior the production capacity growth, but this was not possible due to technical problems.

Note that the calculation model (see Appendix in the end of the Chapter 4) requires data from previous inventories. These are described in Oinonen (2000, 2003 and 2004).

Table 4.6_4. Foam blowing activity data for 2005.

Activity	Blowing agents	Number of reporting companies	Quantity (kg)
Bulk import	HFC-134a, HFC-365mfc	1	C
Imported in polyol	HFC-134a, HFC-245fa, HFC-365mfc	3	4 950
Imported in products	HFC-134a	1	C
Used in manufacturing	HFC-134a	5	7 700
Exported in products	HFC-134a	2	C

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

Data is obtained from an annual survey of Finnish companies manufacturing, importing and exporting aerosol products (MDI, sprays for dust removal, tear gas, one component foam).

CRF 2.F 8 SF_6 from electrical equipment

Annual survey of Finnish companies manufacturing, importing and exporting electrical equipment. The 2005 survey did not produce data from all known actors on this field of industry. Some missing data was imputed based on the previous year's survey which had complete coverage.

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.

SF_6 is no longer used in running shoes or in magnesium die casting. Although, there is no longer import or sale of SF_6 containing shoes, there will be some emissions from SF_6 "banked" in shoes sold in previous years. As the use of SF_6 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 SF_6 containing shoes has stopped (after inventory year 2007).

In 2005 a diminutive quantity of SF_6 was imported for use of magnesium die casting but this use is expected to terminate.

4.6.3 Uncertainty and time series' consistency

CRF 2.F 1 HFCs and PFC-218 from refrigeration and air conditioning

Uncertainty of the emission estimates have been quantified using Monte Carlo simulation (method described in Oinonen 2003, 2004). The same methodology was applied to the 2005 inventory. As a summary, the simulation suggests a 95% confidence interval for the level of emissions from refrigeration and air conditioning in 2005 ranging from 338 to 449 tonnes. A Monte Carlo estimate for the mean of emissions was 356 tonnes and the median of output distribution equal to 342 tonnes.

Simulation results suggest that most of the uncertainty was due to uncertainty of the destructed refrigerant quantities (mainly HFC-125 and HFC-134a). Also, uncertainty of the factor alpha wherein the uncertainty originates from the assumed average lifetime of equipment (for more details see Appendix in the end of the chapter 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 1999 inventory (estimates for 1990–1998), a simple dynamical model in combination with 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 dynamical 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 of the sub-source categories of 2.F 1. From then on, it has been continued use and refinement of the method. 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 the Figure 4.6_1 below.

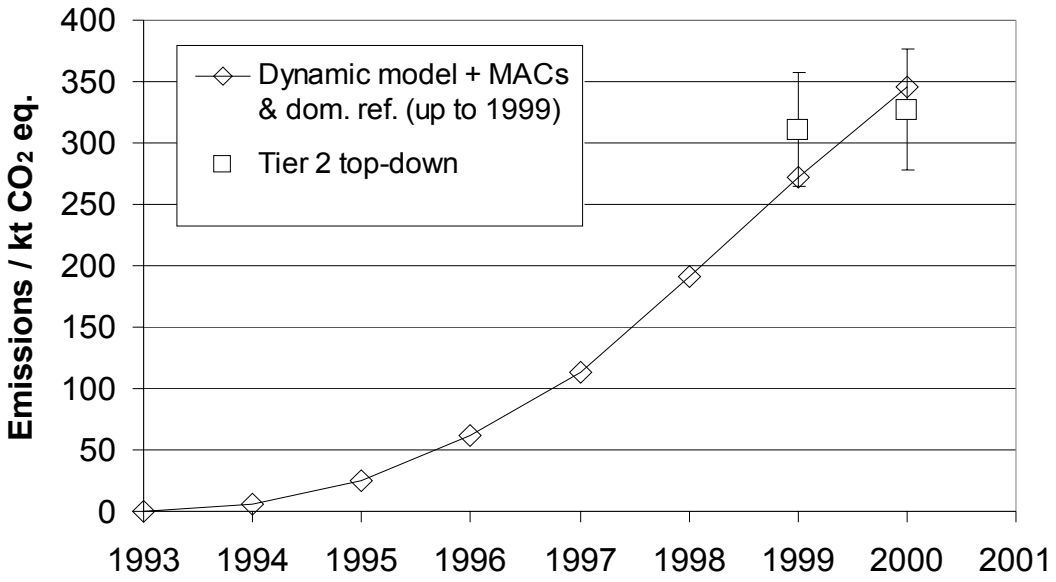


Figure 4.6_1. Emissions calculated with dynamic model and Tier 2 top-down method for two over-lapping years (1999 and 2000).

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 emission evolved during 1990s: a rapid growth during the latter part of the decade, and subsequent stabilisation to the current level.

This trend is depicted in the Figure 4.6_2 below. At first, the largest deviations of the emission estimates from the trend curve seem occur in years 2001 and 2002. However, when these deviations are presented in relation to emission level (Figure 4.2_3), it can be seen that the deviation of inventory years 2001 and 2002 are comparable to previous fluctuations.

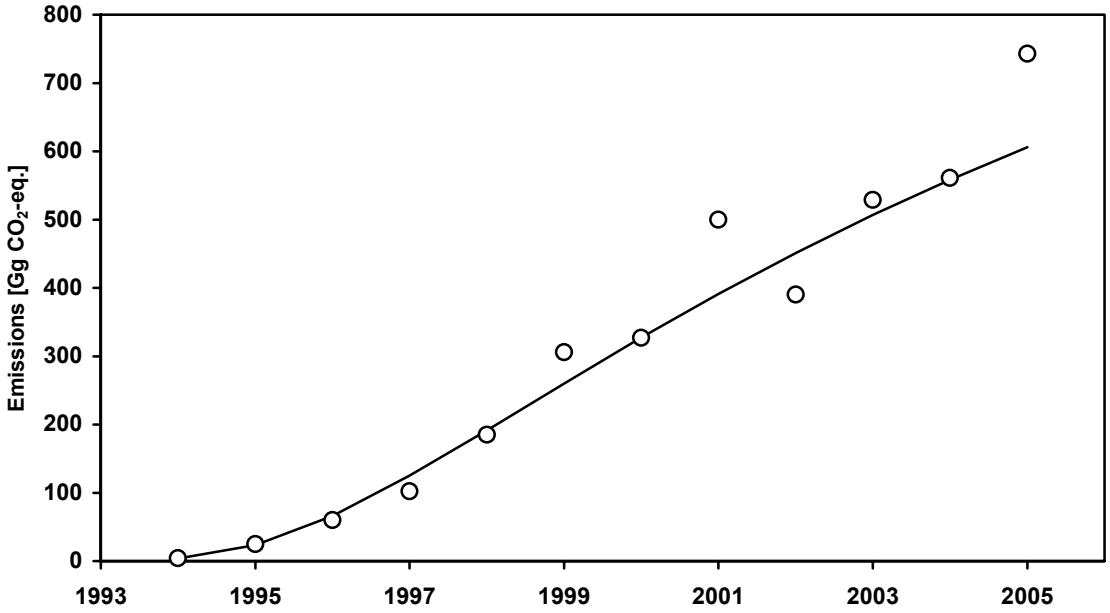


Figure 4.6_2. Emission estimates for category 2.F.1 reported in inventory reports (open circles) and the emission trend curve.

Figure 4.6_3. Deviations of reported emissions (open squares) 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 reported data. As indicated in 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 fivefold to term *M*.

The changes in activity data are correlated to changes in business activities of 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 lead to more detailed analysis of survey respondents and non-respondents and to conclusion that some of the inter-annual variation is due to missing data.

Nearly all of the importers, exporters and manufacturers have provided a survey response each year. On that account, the missing data concerns mainly installation and service of equipment. This also supports the previous assumption where most of the changes in emission estimates where directed to the term *N*. To arrive at estimates for quantities affected by non-response missing data has 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.

In order to impute missing data, it has to be 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 less 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 was not imputed.

The procedure used in non-response analysis and data imputation has been described in detail in Oinonen 2004. Also data imputation has 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 7.15 tonnes with a give-or-take of about 3.5 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 of appliance foam.

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

For the year 2005 Tier 2 actual emissions from aerosols totalled 77 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. Uncertainty model can be expressed with following equation:

$$\mathrm{Var}[x] \approx (1-f)^2\,\mathrm{Var}[a] + f^2\,\mathrm{Var}[b] + (b-a)^2\,\mathrm{Var}[f],$$

where $f = 0.5$, a = Tier 1b potential emission in 2004 in Mg and b = Tier 1b potential emission in 2005 in Mg, and Var[x] denotes variance of x. Values used for the variances were $\mathrm{Var}[f] = 0.02^2$, $\mathrm{Var}[a] = \mathrm{Var}[b] = 5^2\ \mathrm{Mg}^2$.

Substituting values into previous equation yield:

$$\mathrm{Var}[x] \approx (1-0.5)^2 \times 5^2\ \mathrm{Mg}^2 + (1-0.5)^2 \times 5^2\ \mathrm{Mg}^2 + (89.613 - 71.321\ \mathrm{Mg})^2 \times 0.02^2$$
$$\mathrm{Var}[x] \approx 12.51\ \mathrm{Mg}^2$$

The Good Practice Guidance recommends that uncertainties be expressed as two times the standard deviation. The uncertainty is thus $2 \times (12.51\ \mathrm{Mg}^2)^{1/2} \approx 7$ Mg, and the emission estimate (77 ± 7) tonnes

CRF 2.F.7 SF_6 from electrical equipment

A new method Tier 3c was adopted in year 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 Finnish electrical equipment industry. Industry's own annual estimate of SF_6-emissions is approximately 0.3 Mg. The differences in previous inventories (prior to 2003) have been analysed and discussed with the industry.

In 2003 and 2004 the SF_6 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. In 2005, however, the emissions expressed as a three years running mean gave a negative value for emission estimate. This is a results from the fact that most of the imported gas is stored in equipment which leads to growing storage term in model's mass balance. Over time, the gas "banks" grow and finally exceed the imports which leads to negative value as an output. Therefore, 2005 emissions are reported with the same mehthod (T3c) but calculations based on one year activity data.

To assess the impact of change of the observed time period the emission estimates for inventory years 2003 and 2004 were obtained from archived calculation spread sheets. 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 given reasons, no need for recalculation was seen necessary to correct the time series at this point. The need for recalculation will be reconsidered in 2007.

For the year 2005 Tier 3c -model emission estimate was 0.102 tonnes. The uncertainty of the emission estimate was studied with a scenario tree analysis. Start values of 0.076 tonnes, 0.102 tonnes and 1.28 tonnes for Tier 3c -emission estimate were used to produce low, normal and high emission scenarios. Giving a median of 0.16 tonnes, the scenario tree analysis suggests that the value calculated with Tier 3c –model is a slight underestimate. The median value of scenario tree analysis was also close to Finnish electrical equipment industry's emission estimate (1.92 tonnes). It is not known with certainty whether equipment is being disposed of, and how much emission is generated during decommissioning. In scenario tree analysis also low, normal and high rate for disposal emissions were assumed. Using the upper limit for equipment use and low rate for disposal the analysis suggest that the emissions from electrical equipment were not more than approximately 7 tonnes in 2005.

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 lead 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 2.34 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 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 has been changes in trends of shoe sales, semi-conductor manufacturing and magnesium die casting. Use of SF_6 in shoes and magnesium die casting, was first growing in beginning of 2000's and later on the activities declined. Finally, SF_6 was phased out in shoes in 2004 and in magnesium die casting in 2005. Generally, there is a growing trend in use of PFCs in semiconductor manufacturing processes but in Finland the amount of used gases has remained rather steady. This is most probably due to production transfers into other countries. There are several trends, that effect emissions from this category, operating simultaneously and it is hard to estimate how the emissions 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 selection of activity data and emission factors are documented and argumented in notes and in NIR under the sectoral descriptions.
  - Numeric values of assumptions of different parameters are also presented in spread sheets of calculation applications and included in uncertainty simulations of emissions.

- Correctness of the calculations has been checked.
  - Each year 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 correctiveness of used formulas and accuracy of calculations.
  - It is checked that the outcomes of spread sheet calculation applications are similar to those of manually produced .
  - 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 is stored to facilitate reviews.

- Consistency of input data and methods over the time series
  - Existing inconsistencies or data caps are documented in NIR.
  - In categories where different methods have been used over time the need for recalculation is assessed and presented in NIR

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

Specific (Tier 2) Quality Control procedures:

- Emission comparison
  - Results for each category were compared to those obtained using a simpler model; i.e. actual emissions (T2 and T3) were compared to potential emissions (T1) (CRF table 2(II)).
  - Emission estimates for each category were compared to corresponding estimates by industry if those were available
  - Trends were graphed and explained for all sources.

- Quality of activity data
  - Activity data for 2005 were compared to corresponding data for 2003 and 2004 to see any significant changes in reported data. If changes were noted the correctiveness of data was checked with the survey respondent.
  - Nearly all data is 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.

- Uncertainty Estimates
  - Uncertainties were quantified for all source categories.
  - The assumptions on which uncertainty estimations were based on 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

As depicted in last NIR the questionnaire for refrigeration and air conditioning data collection was examined prior to survey in spring 2006. There were, however, no changes made in questions themselves or the structure of the questionnaire. On the questionnaire form some clarifications were made in instructions on how to fill in the questionnaire and which data should be included in each category. Additionally, a cover note, that explained why data is collected and how the inventory is carried out, was send to the respondents

together with the questionnaire. The aim of informing and instructing respondents was to reduce uncertainty of activity data.

For calculating SF_6 emissions from electrical equipment the inventory is being discussed with the Finnish industry, which are carrying out their own, more detailed, data gathering. The emission estimates have been compared to industry's own estimates each year and the two estimates have been in same order of magnitude. The T3c-model currently used to estimate SF6 emissions from electrical equipment utilizes data gathered by industry in addition to data collected by inventory institute via survey. The dialogue is ongoing and aim to improved emission estimates in this source category.

Statistics for one by one imports of used vehicles to Finland have become available recently. Inventory year 2005 was the first time when it was possible to take cognisance of the refrigerant quantities imported in mobile air conditioning systems of these vehicles. The affect of these imports to the emission estimates of previous years will be assessed next year. The statistics are available from year 2000 but the imports are estimated to be negligible prior 2002 when the taxation of imported vehicles was lightened.

Potential ways of verifying the level of F-gases emissions will be looked at.

Appendix_4

Models used in calculation emissions from category CRF 2.F:

HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

Potential emissions

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 yield (all values in tonnes)

$$X_{1a} = \begin{bmatrix} 20.529 \\ 115.370 \\ 242.276 \\ 101.603 \\ 2.965 \\ 1.792 \end{bmatrix} - \begin{bmatrix} 0.025 \\ 0.298 \\ 1.999 \\ 0.320 \\ 0.000 \\ 0.213 \end{bmatrix} - \begin{bmatrix} 0.260 \\ 0.875 \\ 2.098 \\ 0.534 \\ 0.181 \\ 0.013 \end{bmatrix} = \begin{bmatrix} 20.224 \\ 114.197 \\ 238.179 \\ 100.749 \\ 2.784 \\ 1.566 \end{bmatrix}.$$

The sum of the elements of X_{1a} is equal to 477.719 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 yield (all quantities in tonnes)

$$X_{1b} = \begin{bmatrix} 20.529 \\ 115.370 \\ 242.276 \\ 101.603 \\ 2.965 \\ 1.792 \end{bmatrix} + \begin{bmatrix} 10.380 \\ 11.500 \\ 146.679 \\ 1.196 \\ 0.000 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 0.025 \\ 0.298 \\ 1.999 \\ 0.320 \\ 0.000 \\ 0.213 \end{bmatrix} - \begin{bmatrix} 2.500 \\ 5.232 \\ 15.963 \\ 3.222 \\ 0.000 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 0.260 \\ 0.875 \\ 2.098 \\ 0.534 \\ 0.181 \\ 0.013 \end{bmatrix} = \begin{bmatrix} 28.124 \\ 120.465 \\ 368.895 \\ 98.723 \\ 2.784 \\ 1.566 \end{bmatrix}.$$

The sum of the elements of X_{1b} is equal to 620.557 tonnes.

Estimates expressed in Gg CO_2-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 1000:

$$X_{1a,eq} = X_{1a} G / 1000 = \begin{bmatrix} 20.244 \\ 114.197 \\ 238.179 \\ 100.749 \\ 2.784 \\ 1.566 \end{bmatrix} * \begin{bmatrix} 650 & 2800 & 1300 & 3800 & 140 & 7000 \end{bmatrix} / 1000 = 1037.$$

$$X_{1b,eq} = X_{1b} G / 1000 = \begin{bmatrix} 28.124 \\ 120.465 \\ 368.895 \\ 98.723 \\ 2.784 \\ 1.566 \end{bmatrix} * \begin{bmatrix} 650 & 2800 & 1300 & 3800 & 140 & 7000 \end{bmatrix} / 1000 = 1222.$$

The quantities correspond to 8% and 9% increase from previous year, 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 2005 yield a value of 21,6 %. Substituting these values in above equation yield

$$\alpha = 1 - \frac{1}{(1+0{,}216)^{10}} \approx 0{,}859.$$

Actual emissions are then

$$X_2 = \begin{bmatrix} 28.124 \\ 120.465 \\ 368.895 \\ 98.723 \\ 2.784 \\ 1.566 \end{bmatrix} - \left(\begin{bmatrix} 4.707 \\ 31.400 \\ 32.879 \\ 29.724 \\ 0.711 \\ 0.338 \end{bmatrix} + \begin{bmatrix} 1.936 \\ 6.869 \\ 24.091 \\ 5.635 \\ 0.000 \\ 0.000 \end{bmatrix} + \begin{bmatrix} 10.380 \\ 11.500 \\ 146.679 \\ 1.196 \\ 0.000 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 2.500 \\ 5.232 \\ 15.963 \\ 3.222 \\ 0.000 \\ 0.000 \end{bmatrix} \right) \times 0.859 = \begin{bmatrix} 16.196 \\ 82.208 \\ 207.673 \\ 70.090 \\ 2.173 \\ 1.276 \end{bmatrix}.$$

The sum of the elements of T_2 is equal to 379.616 tonnes. Emissions were thus nearly the same as in 2003 only 2% lower .

Estimates expressed in Gg CO_2-equivalent are

$$X_{2,eq} = X_2 G / 1000 = \begin{bmatrix} 16.196 \\ 82.208 \\ 207.673 \\ 70.090 \\ 2.173 \\ 1.276 \end{bmatrix} * \begin{bmatrix} 650 & 2800 & 1300 & 3800 & 140 & 7000 \end{bmatrix} / 1000 = 786.$$

Expressed in CO_2-equivalents, emissions were 22 % higher than in 2004.

<u>SF_6 from electrical equipment (CRF 2.F .8)</u>

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's call it briefly *S*)

$m_{in} - m_{out} = m_{acc}$, (Assuming generation within S is zero.) (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 import of gas–containing equipment and containers. Thus

$m_{in} = i = i_e + i_c$, (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 form of exports and emissions

$m_{out} = e + x = e_e + e_c + x$, (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

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

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 of be: (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.

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

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

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.

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 are defined as follows (remembering that generation and destruction does not take place within *S*):

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

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

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 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 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:

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

Emissions model used is from 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 2004and
b = Tier 1b potential emission in 2005.

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.

Equation above thus assumes that consumption – as defined by Tier 1b potential emissions – equal 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 import (import in containers) and import and export 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 UNFCCC terminology), which is why they don't appear in (2) and (3).

Equation (3) defines a and b of equation (1) as sums of the elements of X_{1b} calculated for 2004 and 2005, respectively.

Since all variables of (2) and (3) are vectors with 2 elements (quantities of HFC-134a and HFC-152a) expressed in mass units, CO_2-equivalent emissions are obtained by calculating the scalar product of X_{1a} and X1b 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 sector

Description

The solvent and other product use contribute a small amount to greenhouse gas emissions in Finland. The only direct greenhouse gas source in the solvent and other product use is use of N_2O in industrial, medical and other applications reported under CRF category 3.D (Other). In Finland, N_2O is used in hospitals and by dentists to relieve pain and for detoxification.

Under CRF categories 3.A (Paint application), 3.B (Degreasing and dry cleaning), 3.C (Chemical products, manufacture and processing) and 3.D (Other) Finland reports indirect greenhouse gas emissions (NMVOCs) and also indirect CO_2 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 metal and electronics industries and dry-cleaners. Under CRF category 3.C Finland reports NMVOC emissions from pharmaceutical, leather, plastic, textile industries, rubber conversion and manufacture of paints. The activities reported under CRF category 3.D (Other) causing NMVOC emissions are 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.

The compiling of NMVOC emission data from 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 Comission for Europe Convention on Long-Range Transboundary Air Pollution (UNECE CLRTAP).

Quantitative overview

Indirect CO_2 emissions were the most important greenhouse gas emissions from solvent and other product use in Finnish inventory in 2005. Quantity of N_2O emissions as CO_2 equivalent from the use of N_2O was less than half of the indirect CO_2 emissions in this sector (Table 5.1_1).

NMVOC emissions from the solvent and other product use are almost 20% of the total NMVOC emissions of Finland.

There is a decrease in trend in CRF category 3 Emissions from Solvent and other product use (Figure 5.1_1). The N_2O emissions from the CRF category 3 have been almost same during the 1990's, but concurrently NMVOC emissions have decreased 45%.

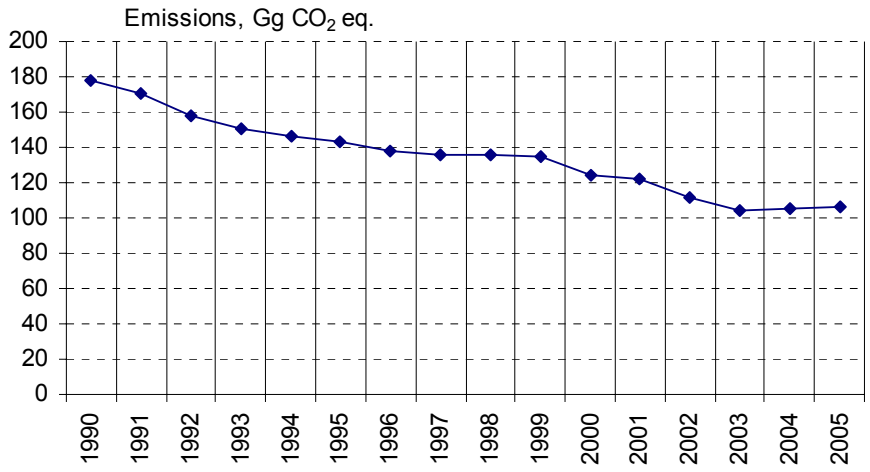


Figure 5.1_1. Trend in GHG emissions from solvents and other product use in 1990–2005 (Gg CO_2 eq.)

Table 5.1_1. N_2O, NMVOC and indirect CO_2 emissions in 1990-2005 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
N_2O (Gg N_2O)																
Other	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
NMVOC (Gg NMVOC)																
Paint application	27.5	26	22	20.5	20	19	18	18	18	17.9	19.25	17	15.8	14.66	14.57	13.89
Degreasing and dry cleaning	2.6	2.3	2.1	1.8	1.7	1.5	1.3	1.3	1.3	1.2	1.26	0.72	0.99	0.99	0.78	0.93
Chemical products, manufacture and processing	3.95	3.5	3.3	3.4	3.45	3.4	2.55	2.45	2.55	2.2	1.93	2.5	3.82	3.08	3.94	3.52
Other	18.55	16.85	15.8	14.05	12.8	11.55	11.6	10.9	11.1	10.9	9.51	11.16	9.6	10.27	10.17	9.03
Indirect CO_2 from NMVOC (Gg CO_2 equivalents)	116	107	95.0	87.5	83.5	78.0	73.6	71.8	72.5	70.8	70.3	69.0	66.5	63.8	64.8	60.2
Total emissions[1] (Gg CO_2 equivalents)	**178**	**171**	**158**	**150**	**147**	**143**	**138**	**136**	**136**	**135**	**125**	**122**	**111**	**104**	**105**	**107**

[1] Total emissions is the sum of the N_2O emissions and the indirect CO_2.

Key categories

There are no key categories in sector CRF 3 in the Finnish inventory.

5.2 Paint application (CRF 3.A), Degreasing and dry cleaning (CRF 3.B) and Chemical products, manufacture and processing (CRF 3.C)

5.2.1 Source category description

No N_2O emissions occur in these source categories.

Paint application is the biggest source of NMVOC emissions of the CRF category 3. Emissions have been calculated from the use of paint and varnish in industry and households. Most of Finnish paint producers or importers are members of the Association for Finnish Paint Industry and the use of paint is calculated in the Association using amount and solvent content of sold paint and varnish.

Degreasing and dry cleaning is a minor source of NMVOCs. Chlorinated organic solvents are used in metal and electronics industries to clean surfaces of different components and in dry cleaners.

The NMVOC emissions are also emitted from use of solvents in different industrial processes. In Finland these kind of processes are in pharmaceutical industry, leather industry, plastic industry, textile industry, rubber conversion and manufacture of paints and inks.

5.2.2 Methodological issues

Methods

Indirect CO_2 emissions from solvents and other product use have been calculated from NMVOC emissions for time series 1990–2005. Indirect CO_2 emissions were calculated using the equation below. It was assumed that the average carbon content is 60 percent by mass for all categories under sector of solvents and other products use. (Netherlands NIR 2005, EPA 2002).

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

Paint application (CRF 3.A)

NMVOC emissions are based on the emissions calculated by the Association for Finnish Paint Industry, a questionnaire sent to non-members of this association and emission data from the Regional Environment Centres´ VAHTI database. Questionnaires are sent to those companies which are not obligated to report NMVOC emissions from their production processes to the Regional Environment Centres. The emissions are calculated at the Finnish Environment Institute based on the emission and/or activity data information from the survey. These questionnaires have been sent for five inventories, starting from summer 2002 when the emissions of year 2001 were collected. Before that time the amount of emissions of non-members was estimated as 15 percent of emissions of members.

Degreasing and dry cleaning (CRF 3.B)

The NMVOC 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.

Chemical products, manufacture and processing (CRF 3.C)

The emissions are foremost from emission data of the Regional Environment Centres' VAHTI database. There are also sent questionnaires to companies in textile, plastic and paint industry in which they inform either amount of used solvent or emissions of their production processes.

Emission factors

For calculating NMVOC emissions from Paint application solvent content of a produced or imported paints are used as emission factor. For calculating NMVOC emissions from degreasing and dry cleaning emission factor of 0.7 kg/kg imported solvent is used. The emission factor is an expert estimation by the VTT Technical Research Centre of Finland (Arnold, 1998). For calculating NMVOC emissions from Chemical products, manufacture and processing the solvent content information collected from the survay is used as emission factor.

Activity data

Paint application (CRF 3.A)

Activity data for use of paint is collected from the questionnaire sent to paint manufacturing companies which are not members of the Association for Finnish Paint Industry.

Degreasing and dry cleaning (CRF 3.B)

The amount of imported chlorinated solvents is from ULTIKA, import statistics of Finland. Amount of products containing chlorinated chemicals are expert estimation based on information of the publication of VTT (Arnold, 1998). The amount of solvent waste is from VAHTI database.

Chemical products, manufacture and processing (CRF 3.C)

Activity data of the use of solvents is collected from those companies which are not obligated to report NMVOC emissions from their production processes to the Regional Environment Centres´ VAHTI database.

5.2.3 Uncertainty and time series' consistency

The latest uncertainty analysis for NMVOC has been carried out for 2004 emissions and reported to the UNECE CLRTAP Secretariat. For 2005 NMVOC emissions uncertainty analysis will be made by 15th May 2007 and the documentation will be available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on website http://www.environment.fi > State of the environment > Air > Air pollutant emissions in Finland (In English). According to the analysis the uncertainty for 2004 NMVOC emissions was estimated at -21% - +22%.

5.2.4 Source-specific QA/QC and verification

The NMVOC inventory has been prepared under the quality management system for the inventory of air pollutants reported to the UNECE CLRTAP in place at SYKE. The statistical quality checkings described in section 1.6 have been carried out. General quality control (QC) procedures in the IPCC GPG Table 8.1 are in use in compiling and reporting of NMVOC emissions. QC plan was prepared, implemented and its fulfilment was assest.

5.2.5 Source-specific recalculations

Minor changes were done due to the updating of the VAHTI database.

5.2.6 Source-specific planned improvements

National speciation of NMVOC compounds will be developed during 2007-2008. Also, the inventory of NMVOCs from products will be more accurate (2007-2008) based on availability of data from the National Product Register.

5.3 Other (CRF 3.D)

5.3.1 Source category description

The N_2O emissions in this category are from the medical use of N_2O. In 2005 these emissions totalled 46.5 Gg CO_2 eq. The activities causing NMVOC emissions under this category are printing industry, preservation of wood, use of pesticides, glass and mineral wool enduction, domestic solvent use and fat and oil extraction.

5.3.2 Methodological issues

Methods

The N_2O emissions are calculated by Statistics Finland. Tier 2 calculation method is consistent with the IPCC Guidelines. In the estimation of the N_2O emissions sales data is obtained from the companies delivering N_2O 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 assumption that all used N_2O is emitted to atmosphere the same year it is produced or imported to Finland. Very small part of emisssions is estimated due to non response.

The NMVOC emissions are based on the emission data of the Regional Environment Centres' VAHTI database, a questionnaire to presses and oil mills that do not report their emissions to VAHTI database, activity data from the Finnish Environment Institute's Chemical Divisions database and emission calculation of the Finnish Cosmetics, Toiletry and Detergents Association. Indirect CO_2 emissions from this category have been calculated using the equation given in chapter 5.2.2.

Emission factors

Emission factors for use of pesticides (80 kg/t) and preservation of wood (100 kg/t) are country specific based on expert estimation at the Finnish Environment Institute's Chemical Division. Emission factors used on results of questionnaires are mostly solvent content of used chemicals.

Activity data

For estimation of N_2O emissions production or importation data is obtained from companies for the years 1990, 1998 and all years starting year 2000. In 2005 one company informed that they had begun exporting and that has been also taken into account in calculations.

Activity data as amount of sold creosote for NMVOCs from preservation of wood is from Finnish Environment Institute's Chemical Division (Mäkelä, 2006). Activity data for NMVOC emissions from pesticide use is from the Finnish Food Safety Authority (EVIRA, 2006).

5.3.3 Uncertainty and time series' consistency

The uncertainty of emissions from N_2O use in 2005 was estimated at-34% - +39%.

The latest uncertainty analysis for NMVOC has been carried out for 2004 emissions and reported to the UNECE CLRTAP Secretariat. For 2005 NMVOC emissions uncertainty analysis will be made by 15th May 2007 and the documentation will be available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on website http://www.environment.fi > State of the environment > Air > Air pollutant emissions in Finland (In English). According to the analysis the uncertainty for 2004 NMVOC emissions was estimated at -21% - +22%.

5.3.4 Source-specific QA/QC and verification

Data is compared to data of previous years.

5.3.5 Source-specific recalculations

No recalculations have been made since last inventory submission.

5.3.6 Source-specific planned improvements

No source specific improvements are at the moment under consideration.

6. AGRICULTURE (CRF 4)

6.1 Overview of sector

Description

Agricultural greenhouse gas emissions in Finland consist of CH_4 emissions from enteric fermentation of domestic livestock and CH_4 and N_2O emissions from manure management. In addition, direct and indirect N_2O emissions from agricultural soils are included. Direct N_2O 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 N_2O emission sources include atmospheric deposition and nitrogen leaching and run-off to watercourses.

The following improvements and corrections were made for this submission: animal numbers and crop yield data was updated according to the latest statistics, weights of some cattle species were corrected on the basis of new data. Few changes were made on the distribution of manure management system for cattle. Also, area of organic soils was corrected for the whole time series because previous value did not include organic grassland.

Rice is not cultivated in Finland and savannas do not exist in Finland. Field burning of agricultural residues is taking place in Finland only occasionally on small scale (data not available) and the emissions from this source are estimated to be negligible

Quantitative overview

Finland's agricultural greenhouse gas emissions reported in agriculture sector in 2005 were 5.6 Tg CO_2 equivalents in total. The changes in the emissions compared to last submission are due to updating of some calculation parameters and activity data. Agriculture is the third largest greenhouse gas emission source category after energy sector and industrial processes with the around 8% share of total greenhouse gas emissions in 2005 (Figure 6.1_2). The proportion of CH_4 emissions from enteric fermentation was 28%, CH_4 emissions from manure management was 5%, N_2O emissions from manure management was 9% and N_2O emissions from agricultural soils was 58% from the total agricultural emissions.

CO_2 emissions from agricultural soils are reported in the LULUCF sector (chapter 7) under Cropland and Grassland categories (including CO_2 emissions from liming). Emissions from energy use of agriculture (e.g. fuel combustion, heating of buildings etc.) are calculated and reported in reporting category Energy (chapter 3) and are not included in emissions reported Agriculture sector (Figure 6.1_1). Emissions from energy use of agriculture were 1.9 Tg CO_2 in 2005 and emissions from the Land Use, Land Use Change and Forestry sector 5.9 Tg CO_2 eq. in 2005 (reported in LULUC 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 2005 was 19.6 %. (13.4 Tg CO_2)

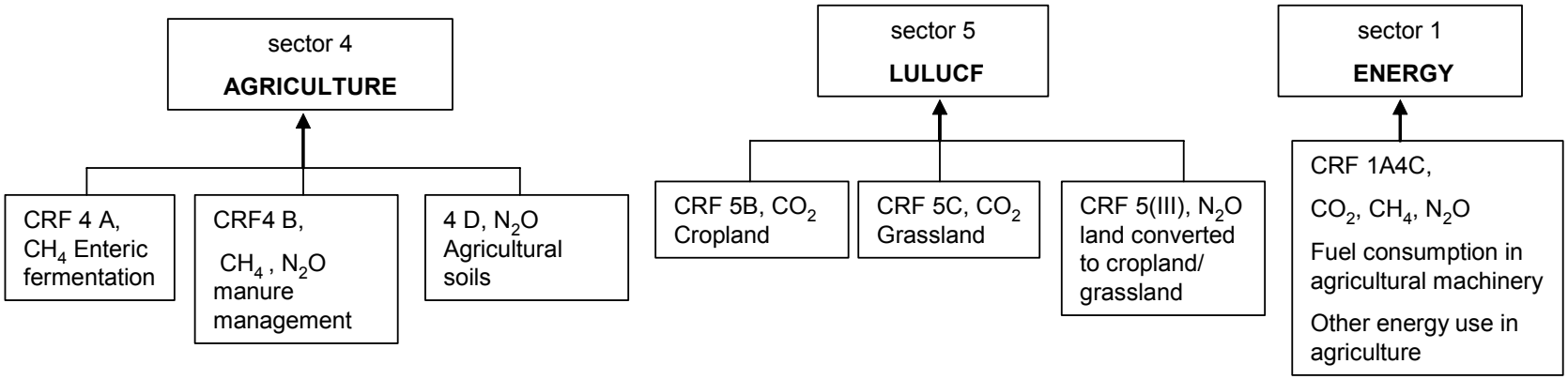


Figure 6.1_1. Emissions from agricultural sources and their reporting categories in the national greenhouse gas inventory.

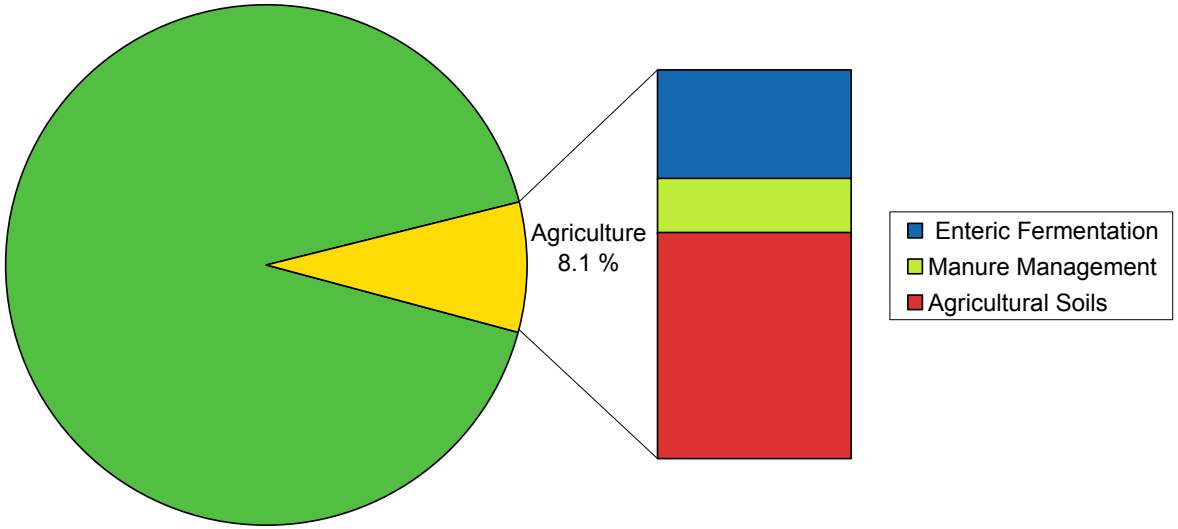


Figure 6.1_2. Agricultural emissions (sector Agriculture) from the total greenhouse gas emissions in 2005.

Emissions in Agriculture sector have decreased about 22% over the period of 1990-2005 (Figure 6.1_3). 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 caused also a decrease in the livestock numbers except in the number of horses and swine that has increased in the recent years. The reduced use of nitrogen fertilisers and improved manure management resulting from the measures taken by the farmers as a part of an agri-environmental program aiming to minimise nutrient loading to water courses has also decreased the emissions in Agriculture sector.

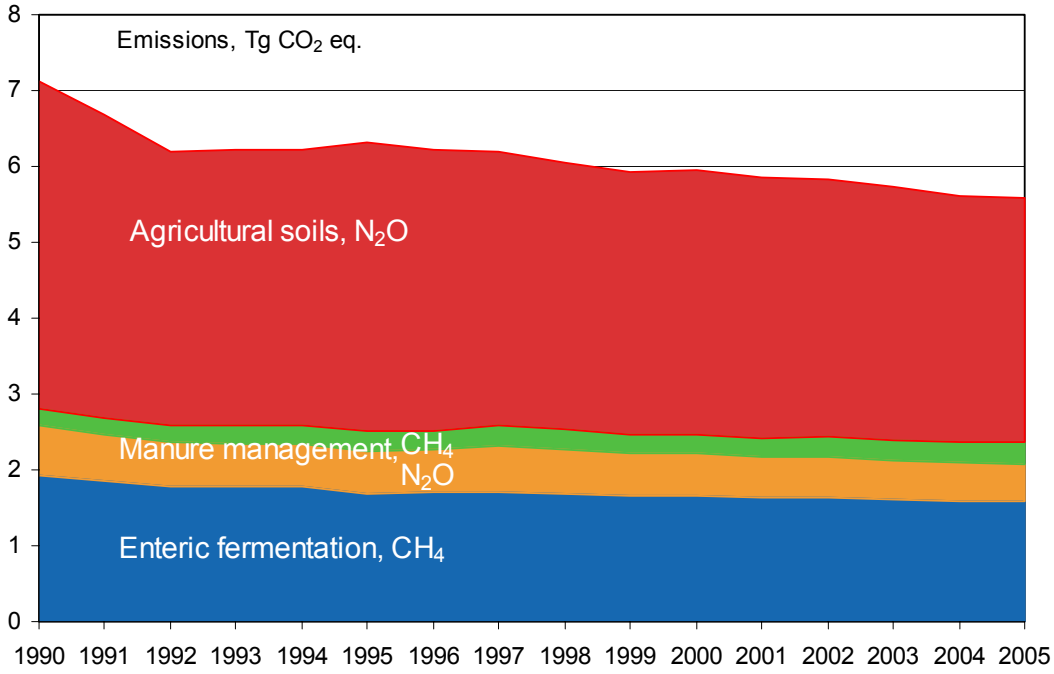


Figure 6.1_3. Trend in agricultural emissions by source categories in 1990-2005 (Tg CO_2 eq.).

Some inter-annual variation between the years can be noticed from the time series (Table 6.1_3). This is mainly caused by fluctuation in activity data between the years e.g. because of changes in animal numbers, which is largely affected by agricultural policy. Especially CH_4 and N_2O 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 e.g. by the amount of synthetic fertilisers sold annually, animal numbers and crop yields of cultivated crops which may have large variation between the years.

Table 6.1_1. Finland's agricultural greenhouse gas emissions by source and gas in 1990-2005.

Year	Enteric fermentation (Gg)	Manure Management (Gg)		Agricultural soils (Gg)	Total CH_4 emissions (Gg)	Total N_2O emissions (Gg)	Total emissions (Gg CO_2 eq.)
	CH_4	CH_4	N_2O	N_2O	CH_4	N_2O	CH_4,N_2O
1990	91.34	10.94	2.15	13.87	102.28	16.02	7113.82
1991	87.88	10.47	1.97	12.91	98.36	14.88	6677.83
1992	85.10	10.41	1.86	11.67	95.52	13.53	6201.18
1993	84.89	10.66	1.83	11.76	95.55	13.59	6219.354
1994	85.00	11.04	1.83	11.71	96.04	13.54	6215.49
1995	80.38	11.74	1.83	12.31	92.12	14.14	6317.66
1996	80.76	11.86	1.86	11.91	92.62	13.77	6214.09
1997	81.74	12.50	1.94	11.68	94.24	13.61	6198.90
1998	79.92	12.36	1.90	11.38	92.29	13.28	6054.79
1999	78.73	12.21	1.82	11.11	90.93	12.93	5918.77
2000	78.59	12.38	1.80	11.27	90.97	13.07	5960.84
2001	77.53	12.01	1.72	11.08	89.54	12.79	5846.34

2002	77.89	12.65	1.70	10.94	90.54	12.64	5818.38
2003	76.57	12.96	1.67	10.77	89.53	12.44	5736.31
2004	75.56	12.95	1.63	10.48	88.51	12.12	5614.53
2005	75.08	13.22	1.61	10.41	88.29	12.02	5579.57

Key categories

Agricultural key categories in 2005 calculated with IPCC Tier 2 method were CH_4 emissions from enteric fermentation, direct N_2O emissions from agricultural soils (animal production and sludge spreading) and indirect N_2O emissions from agricultural soils. All of these categories are key due to both level and trend analysis.

6.2 Enteric Fermentation (CRF 4.A)

6.2.1 Source category description

This source category includes emissions from cattle (dairy cows, suckler cows, bulls, heifers and calves), horses, pigs, sheep, goats and reindeer. Emissions from poultry and fur animals have not been estimated.

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 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 also other animals may be remarkable emission sources if their number is large (Pipatti 1994).

Methane emissions from enteric fermentation of domestic livestock comprised 28% of total agricultural emissions in Finland, being 75.1 Gg in 2005. Emissions have decreased 18% since 1990 due especially to decreasing number of cattle (Table 6.2_1). The number of dairy cattle, for example, declined from 490 000 in 1990 to 319 000 in 2005. Emissions from other livestock decreased during 1990-2001 but have been increasing slightly since 2002 due to increasing number of swine and horses (Table 6.2_1).

Table 6.2_1. CH_4 emissions (Gg) from enteric fermentation in 1990-2005 by animal type.

Year	Cattle					Other livestock							Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	P	F	R	
1990	47.58	0.88	8.45	11.42	14.62	2.07	0.70	0.03	0.82	NE	NE	4.76	91.34
1991	43.68	1.31	8.27	11.26	14.56	2.02	0.73	0.03	0.87	NE	NE	5.17	87.88
1992	42.06	1.74	8.19	11.02	13.90	1.95	0.74	0.02	0.88	NE	NE	4.61	85.10
1993	42.31	2.07	7.98	11.36	13.26	1.91	0.82	0.02	0.88	NE	NE	4.29	84.89
1994	42.28	2.05	8.33	11.42	12.99	1.95	0.82	0.03	0.87	NE	NE	4.26	85.00
1995	40.97	1.85	6.30	10.07	12.94	2.10	1.08	0.03	0.90	NE	NE	4.14	80.38
1996	40.48	1.98	6.67	10.75	12.62	2.09	0.97	0.03	0.94	NE	NE	4.24	80.76
1997	41.16	2.07	6.95	10.74	12.55	2.20	1.02	0.04	0.98	NE	NE	4.03	81.74
1998	40.54	1.96	6.54	10.45	12.51	2.10	0.86	0.04	1.01	NE	NE	3.90	79.92
1999	40.05	1.90	6.75	10.34	11.98	2.03	0.72	0.04	1.01	NE	NE	3.89	78.73
2000	40.46	1.80	6.61	10.31	11.64	1.94	0.71	0.04	1.03	NE	NE	4.05	78.59
2001	40.07	1.77	6.50	10.25	11.58	1.89	0.68	0.04	1.05	NE	NE	3.70	77.53
2002	39.99	1.83	6.89	10.12	11.31	1.97	0.70	0.03	1.06	NE	NE	3.97	77.89
2003	38.81	1.84	7.07	10.00	11.03	2.06	0.72	0.03	1.08	NE	NE	3.91	76.67
2004	38.32	2.03	6.87	9.71	10.65	2.05	0.81	0.04	1.10	NE	NE	4.00	75.56
2005	37.84	2.28	6.70	9.48	10.63	2.10	0.74	0.03	1.15	NE	NE	4.12	75.08
Share of total (%) in 2005*	50.4	3.0	8.9	12.6	14.2	2.8	1.0	0.1	1.5	-	-	5.5	

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 IPCC Tier 1 and Tier 2 methodologies presented in the Revised IPCC Guidelines (IPCC 1997) and IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000).

CH_4 emissions from enteric fermentation for horses, swine and goats have been calculated with 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 in the end of the Chapter 6. The contribution of emissions from these animal categories to the total emissions from enteric fermentation is not significant

In Tier 2 method the emissions have been calculated like in Tier 1 method above, but the emission factors have been calculated by using the equations presented in IPCC (1997) and IPCC (2000). The Tier 2 method has been used for cattle, since emissions from cattle has been recognised as a key source in Finnish inventory. CH_4 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*Y_m* 365 days/year)/(55.65 MJ/kg CH_4). The same methodology has been used for estimating GE and EF for sheep. Equations used for calculating GE for sheep and reindeer are presented in more detail in the Appendix at the end of the Chapter 6.

Activity data

Animal numbers are presented in Table 6.2_2.

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 in 1st of May (cattle, swine, poultry) and it has been reported consistently over the time series.

The number of *horses* (number in the 31st December) was received from the Finnish Trotting and Breeding Association (Suomen Hippos, http://www.hippos.fi/hippos/englanti/).

The number of *fur animals* was received from Finnish Fur Breeders Association and it describes the number of pelts produced annually. (http://www.stkl-fpf.fi/)

The number of *reindeer* was received from the Yearbook of Farm Statistics and describes the number of counted reindeer left alive during the reindeer herding year.

Table 6.2_2. Number of livestock and fur animals in Finland in 1990-2005 (x1000).

Year	Cattle[1]	Horses[2]	Swine	Sheep	Goats	Poultry[3]	Reindeer	Fur animals[4]
1990	1359.7	45.4	1381.4	103.3	5.90	9662.5	239.1	5157.2
1991	1309.9	48.1	1344.3	106.7	5.35*	8928.9	259.6	3282.5
1992	1273.2	49.1	1297.9	108.4	4.80	9356.1	231.6	2596.8
1993	1252.3	49.0	1272.7	120.4	4.80	9639.2	215.3	2848.6
1994	1233.0	48.3	1298.3	121.1	5.70	9905.7	214.3	2880.3
1995	1147.9	49.9	1400.3	158.6	6.00	10357.7	208.1	3284.1
1996	1145.6	52.0	1395.4	149.5	6.50	9951.4	212.9	3748.6
1997	1142.4	54.6	1467.0	150.1	8.00	10826.6	202.6	4151.6
1998	1117.1	56.1	1401.0	128.3	8.10	11049.6	196.1	4321.6
1999	1086.8	56.2	1351.3	106.6	7.90	11033.6	195.4	3967.8
2000	1056.6	57.4	1297.6	99.6	8.60	12569.5	203.4	3705.1
2001	1037.3	56.6	1260.8	96.0	7.40	10553.6	185.7	3360.5
2002	1025.4	58.6	1315.0	95.9	6.60	10734.0	199.7	3540.5
2003	1000.1	60.2	1375.0	98.4	6.80	10997.1	196.7	3410.3
2004	969.2	61.1	1364.6	108.9	7.30	10405.1	201.1	3668.0
2005	959.0	63.8	1401.0	89.7	6.9	10538.2	207.2	3530.0

[1] Includes dairy cows, suckler cows, bulls (>1 years), heifers and calves (<1 years). The number presented describes the numbers in the 1st of 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 was not available, 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 years 1990 and 1992 was used.

Emission factors and other parameters

IPCC default emission factors were used for calculating CH_4 emissions from enteric fermentation of swine, goats and horses (Tier 1 method). National emission factors were calculated with the Tier 2 method for cattle by using IPCC equations. Cattle category has been divided into the following sub-categories: dairy cows, suckler cows, bulls, heifers and calves for which separate emission factors have been calculated, respectively.

IPCC gives no default emission factor for reindeer, thus it has been calculated by using national methodology for estimating gross energy intake of reindeer from the basis of their forage. The same equation has been used for sheep also.

The equations used for calculating emission factors are presented in the Appendix at the end of the Chapter 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_3. Emission factors for cattle are updated annually. EF´s for other animal groups will be updated if more national data will become available.

Table 6.2_3. Emission factors for each animal category in 2005 used for calculating CH_4 emissions from enteric fermentation.

Animal category	Emission factor (kg CH_4 / animal/yr)	EF type	Method for calculating EF
Dairy cow	118.70	National	IPCC, Tier 2
Suckler cow	65.92	National	IPCC, Tier 2
Bull	62.13	National	IPCC, Tier 2
Heifer	56.17	National	IPCC, Tier 2
Calf	32.32	National	IPCC, Tier 2
Reindeer	19.90	National	National
Swine	1.50	IPCC default	IPCC, Tier 1
Sheep	8.20	National	National
Goat	5.00	IPCC default	IPCC, Tier 1
Horse	18.00	IPCC default	IPCC, Tier 1

Additional information needed for calculating emission factors for each cattle species are 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).

Number of cattle by sub-categories is presented in Table 6.2_4. Cattle weights and mature weight of dairy cow, suckler cow and bull are presented in Table 6.2_5 (Source: Nousiainen, J.pers.comm., MTT Agrifood Research Finland). The amount of milk produced per dairy cow and fat content of milk are presented in Table 6.2_6. Data of milk production (l/animal/yr) has been received from the Yearbook of Farm Statistics (2005). 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 1990-2005 being 1620 kg/yr (Source: Nousiainen, J. pers.comm., MTT Agrifood Research Finland). Average daily weight gain for cattle was estimated to remain constant in 1990-2005 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_4. Number of cattle in sub-categories in 1990-2005 (Source: Information Centre of the Ministry of Agriculture and Forestry).

Year	Dairy cows Number (x 1000)	Suckler cows Number (x 1000)	Bulls (>1 year) Number (x 1000)	Heifers Number (x 1000)	Calves (<1 year) Number (x 1000)
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

Table 6.2_5. Cattle live weights and mature weights 1990-2005 (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
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	567	650	706	550	988	434	217

Table 6.2._6. Data of milk properties used for calculating CH_4 emissions from enteric fermentation in 1990-2005.

Year	Fat content of milk[1)] (%)	Milk production/ dairy cow[2)] (kg/yr)
1990	4.35	5713
1991	4.35	5788
1992	4.34	5781
1993	4.38	5817
1994	4.35	6045
1995	4.34	6161
1996	4.33	6173
1997	4.32	6368
1998	4.31	6412
1999	4.24	6636
2000	4.23	6990
2001	4.23	7140
2002	4.22	7331
2003	4.24	7469
2004	4.23	7626
2005	4.16	7330

[1] Source: Publication of the Ministry of Agriculture and Forestry (Tietokappa). Assumed to be same for dairy cow and suckler cow.
[2] Source: Yearbook of Farm Statistics 2005 (Coefficient 1.03 used to express l/animal/yr as kg/animal/yr).

6.2.3 Uncertainty and time series' consistency

Uncertainty in CH_4 emissions from enteric fermentation of domestic livestock was estimated at -20 to +30% in 2005. Uncertainty estimates of animal numbers were based on knowledge of reliability and coverage of data collection. For example, cattle has individual earmarks that enable very accurate assessment of animal numbers (uncertainty of ±3%), but uncertainty in animal numbers for other species in farms is higher (±5%). The uncertainty in animal numbers is estimated to be the highest for reindeer (±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 national emission factor has been used.

The uncertainty in Tier 2 method for estimating emissions from enteric fermentation of cattle was assessed by estimating uncertainty in each calculation parameter (except coefficients, whose importance was expected minor), and combining uncertainties using Monte Carlo simulation.

Uncertainty in animal weight, weight gain and milk production for each animal sub-group was estimated utilising knowledge of deviation in weights of 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 energy content of forage used in Finland.

For other species than cattle the IPCC default uncertainty of ±50% is used for EF, expect 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 uncertainty analysis has been presented in Monni & Syri (2003), Monni (2004) and Monni et al. (in press). [Monni, S., Perälä, P. and

Regina, K. Uncertainty in agricultural CH_4 and N_2O emissions from Finland - possibilities to increase accuracy in emission estimates. Mitigation and adaptation strategies for global change (in press)]

As there are no changes in calculation methods during 1990-2005, 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 have 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

General (Tier 1) Quality Control (QC) procedures applied to category Enteric fermentation (CRF 4.A):

QA/QC plan for agricultural sector includes the QC measures based on 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. QC checklist is used during the inventory.

Tier 2 QC for activity data:

Activity data for livestock has been cross-checked with DREMFIA-model of MTT Economic Research.

Tier 2 QC for emission factors:

New national data for emission factors will be compared with emission factors used in the inventory for evaluating the applicability of current factors to Finland's circumstances.

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 yet for the agricultural inventory yet. However, a special adjustments case-study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The experiences of this exercise have been taken into account in the development of the inventory.

6.2.5 Source-specific recalculations

Recalculation of this source category was made because weights of heifers and calves for 2002-2004, weight of bull for 2004 and mature weight of bull in 2003-2004 were corrected according to the latest data. Also, the number of swine in 1990 and sheep EF for the year 2004 was corrected.

6.2.6 Source-specific planned improvements.

Improvements of this source category could include changing the method to be based on national data on feed consumption of cattle. Other improvements are development the QA/QC measures and uncertainty analysis.

6.3 Manure Management (CRF 4.B)

6.3.1 Source category description

This emission source covers manure management of domestic livestock. Finland reports both nitrous oxide (N_2O) and methane (CH_4) 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.

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 ammonia 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 e.g. on the amount of organic material in the manure and climatic conditions.

Nitrous oxide and methane emissions from manure management were 1.6 Gg and 13.2 Gg in 2005, respectively. Nitrous oxide emissions from manure management were about 9% and methane emissions about 5% of total agricultural emissions in 2005. Nitrous oxide emissions from manure management have decreased 25% over the time period 1990-2005 (Table 6.3_1). Methane emissions from manure management have been fluctuating during 1990-2005 but overall there is an increase of 21% in the emissions in 2005 compared to 1990 (Table 6.3_2). This is due to 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 manure management systems used. Slurry-based systems increase methane emissions per animal tenfold compared to the solid storage or pasture (IPCC 2000).

Table 6.3_1. N_2O emissions from manure management in 1990-2005 by animal type (emissions from pasture not included, they are reported under 4D 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	0.04	0.002	0.05	0.16	0.26	0	2.15
1991	0.61	0.02	0.17	0.13	0.22	0.40	0.04	0.002	0.06	0.15	0.17	0	1.97
1992	0.58	0.03	0.18	0.13	0.20	0.36	0.04	0.002	0.06	0.15	0.13	0	1.86
1993	0.55	0.04	0.17	0.13	0.19	0.34	0.04	0.002	0.06	0.16	0.15	0	1.83
1994	0.55	0.04	0.18	0.13	0.18	0.34	0.04	0.002	0.06	0.16	0.15	0	1.83
1995	0.54	0.03	0.12	0.11	0.18	0.38	0.06	0.002	0.06	0.16	0.18	0	1.83
1996	0.52	0.03	0.13	0.12	0.18	0.40	0.05	0.002	0.06	0.16	0.21	0	1.86
1997	0.51	0.03	0.14	0.12	0.18	0.42	0.05	0.003	0.07	0.17	0.24	0	1.94
1998	0.49	0.03	0.13	0.12	0.18	0.40	0.05	0.003	0.07	0.17	0.25	0	1.90
1999	0.48	0.03	0.14	0.12	0.17	0.37	0.04	0.003	0.07	0.17	0.24	0	1.82
2000	0.47	0.03	0.14	0.12	0.17	0.36	0.04	0.003	0.07	0.19	0.22	0	1.80
2001	0.45	0.03	0.13	0.12	0.17	0.34	0.03	0.003	0.07	0.17	0.20	0	1.72
2002	0.42	0.03	0.14	0.12	0.17	0.33	0.03	0.002	0.07	0.17	0.21	0	1.70
2003	0.38	0.03	0.14	0.12	0.17	0.35	0.04	0.002	0.07	0.18	0.21	0	1.67
2004	0.35	0.03	0.14	0.12	0.16	0.33	0.04	0.003	0.07	0.17	0.22	0	1.63
2005	0.33	0.03	0.14	0.11	0.16	0.34	0.03	0.002	0.08	0.17	0.22	0	1.61
Share of total (%) in 2005*	20.2	1.9	8.5	7.1	9.9	21.3	2.0	0.2	4.8	10.8	13.4		

* 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_2. CH_4 emissions from manure management in 1990-2005 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	1.80	0.44	0.02	11.74
1996	3.07	0.05	0.48	0.54	0.66	4.71	0.03	0.001	0.07	1.73	0.50	0.02	11.86
1997	3.24	0.06	0.50	0.54	0.65	4.95	0.03	0.001	0.08	1.88	0.55	0.02	12.50
1998	3.31	0.06	0.48	0.52	0.65	4.73	0.02	0.001	0.08	1.92	0.57	0.02	12.36
1999	3.38	0.07	0.49	0.52	0.62	4.56	0.02	0.001	0.08	1.91	0.53	0.02	12.21
2000	3.54	0.07	0.48	0.52	0.61	4.37	0.02	0.001	0.08	2.18	0.49	0.02	12.38
2001	3.70	0.07	0.47	0.51	0.60	4.25	0.02	0.001	0.08	1.83	0.45	0.02	12.01
2002	3.89	0.07	0.50	0.51	0.59	4.63	0.02	0.001	0.08	1.86	0.47	0.02	12.65
2003	3.96	0.08	0.51	0.50	0.57	4.84	0.02	0.001	0.09	1.91	0.45	0.02	12.96
2004	4.10	0.09	0.50	0.49	0.55	4.81	0.02	0.001	0.09	1.80	0.48	0.02	12.95
2005	4.24	0.10	0.49	0.48	0.55	4.93	0.02	0.001	0.09	1.83	0.47	0.02	13.22
Share of total (%) in 2005*	32.1	0.7	3.7	3.6	4.2	37.3	0.1	0.01	0.7	13.8	3.6	0.2	

* 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

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 at the end of the Chapter 6. The amount of nitrogen excreted annually per animal has been divided between different manure management systems and multiplied with a specific emission factor (IPCC default value) for each manure management system. Manure management systems reported in the inventory are slurry, solid storage and pasture (Table 6.3_6). N excretion during the year per animal (cattle, sheep, swine, horses, poultry, fur animals) and the distribution of manure management systems are national values (Tables 6.3_3 - 6.3_6). 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 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. Equations used for calculating CH_4 emissions from manure management are presented in the Appendix at the end of the Chapter 6.

Activity data

Animal numbers used for calculating nitrous oxide and methane emissions from manure management are the same used for calculating methane emissions from enteric fermentation (see Table 6.2_2). The distribution of

different manure management systems was received from published literature (MKL 1993; Seppänen & Matinlassi, 1998) and by expert judgement. 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 typical forage system (Tables 6.3_3 - 6.3_5). For goats, national value for Nex (Ministry of the Environment 1998) has been kept as such because new data was not available. For reindeer, value for goats has been used because no national data was available.

Table 6.3_3. Annual average N excretion per animal (kg N/animal/year) for cattle.

Year	Dairy cow		Suckler cow		Bull (>1 year)		Heifer		Calf (<1 year)	
	Nex (kg N)	Number (x1000)	Nex (kg N)	Number (x1000)	Nex (kg N)	Number (x1000)	Nex (kg N)	Number (x1000)	Nex (kg N)	Number (x1000)
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	108.2	324.4	62.9	30.8	64.1	110.5	49.0	173.1	36.2	330.4
2005	109.9	318.8	63.0	34.6	65.0	107.8	49.0	168.8	36.0	329.0

Table 6.3_4. Average annual N excretion per animal for swine and fur animals (kg N/animal/year).

Year	Swine		Mink and fitch		Fox and racoon	
	Nex (kg N)	Number (x1000)	Nex (kg N)	Number (pelts produced annually	Nex (kg N)	Number (pelts produced annually)
1990	16.8	1394.1	1.2	3161851	2.1	1995303
1991	17.1	1344.3	1.3	1804886	2.2	1477646
1992	16.8	1297.9	1.3	1505198	2.3	1091601
1993	16.8	1272.7	1.3	1576245	2.2	1272308
1994	17.4	1298.3	1.3	1659534	2.2	1220807
1995	18.9	1400.3	1.3	1639390	2.2	1644720
1996	19.8	1395.4	1.3	1944663	2.3	1803904
1997	19.8	1467.0	1.3	1807695	2.3	2343891
1998	19.8	1401.0	1.3	1828210	2.3	2493410
1999	18.9	1351.3	1.3	1646025	2.3	2321781
2000	19.5	1297.6	1.3	1732710	2.3	1972340
2001	18.6	1260.8	1.3	1497859	2.3	1862643
2002	18.6	1315.0	1.3	1496609	2.3	2043902
2003	18.6	1375.0	1.3	1407662	2.3	2002592
2004	18.1	1364.6	1.3	1426000	2.3	2242000
2005	18.1	1401.0	1.3	1355007	2.3	2174675

Table 6.3_5. Average annual N excretion per animal for sheep and horses (kg/animal/year).

Year	Sheep		Horses	
	Nex (kg N)	Number (x1000)	Nex (kg N)	Number (x1000)
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	58.1	61.1
2005	9.3	89.7	58.1	63.8

Table 6.3_6. Fraction of manure managed in each manure management system (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgria); MTT Agrifood Research Finland).*

	1990	1993	1995	1997	2000	2003	2005
Cattle							
Dairy cows							
Pasture	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Slurry	0.22	0.24	0.25	0.28	0.32	0.40	0.45
Solid storage	0.50	0.48	0.47	0.44	0.40	0.32	0.27
Suckler cows							
Pasture	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Slurry	0.03	0.03	0.03	0.08	0.16	0.18	0.19
Solid storage	0.61	0.61	0.61	0.56	0.48	0.46	0.45
Bulls (age over 1 year)							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.30	0.30	0.40	0.40	0.40	0.40	0.40
Solid storage	0.70	0.70	0.60	0.60	0.60	0.60	0.60
Heifers							
Pasture	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Slurry	0.20	0.23	0.24	0.24	0.24	0.24	0.24
Solid storage	0.47	0.45	0.43	0.43	0.43	0.43	0.43
Calves (under 1 year)							
Pasture	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Slurry	0.20	0.23	0.26	0.26	0.26	0.26	0.26
Solid storage	0.47	0.44	0.42	0.42	0.42	0.42	0.42
Other livestock							
Swine							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.45	0.52	0.57	0.57	0.57	0.60	0.60
Solid storage	0.55	0.48	0.43	0.43	0.43	0.40	0.40
Sheep							
Pasture	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Goats							
Pasture	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Slurry	0.00	0.00	0.01	0.01	0.01	0.01	0.01

	1990	1993	1995	1997	2000	2003	2005
Solid storage	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Horses							
Pasture	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Reindeer							
Pasture	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry							
Laying hens							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.02	0.02	0.02	0.02	0.02
Solid storage	1.00	1.00	0.98	0.98	0.98	0.98	0.98
Chickens							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.02	0.02	0.02	0.02	0.02
Solid storage	1.00	1.00	0.98	0.98	0.98	0.98	0.98
Cockerels							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Solid storage	1.00	1.00	0.99	0.99	0.99	0.99	0.99
Broiler hens							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Solid storage	1.00	1.00	0.99	0.99	0.99	0.99	0.99
Broilers							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Solid storage	1.00	1.00	0.99	0.99	0.99	0.99	0.99
Turkeys							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Solid storage	1.00	1.00	0.99	0.99	0.99	0.99	0.99
Other poultry							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	1.00	1.00	1.00	1.00	1.00	1.00	1.00

*Sum of fractions may differ from 1 due to roundings.

Emission factors and other parameters

Nitrous oxide

The IPCC default emission factors have been used for each manure management system. Manure management systems included in the inventory are pasture, solid storage and slurry (Table 6.3_6). Annual nitrogen excretion per animal and in the case when animals are kept less than 1 year in farms (swine, poultry), replacement of animals with new ones has been taken account in the calculations.

Table 6.3_7. IPCC default emission factors for N_2O from manure management and related uncertainties

Manure management system	Emission factor (kg N_2O-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 sub-category has been calculated by using the IPCC Tier 2 methodology (IPCC 2000, Eq. 4.17). Equations are presented in Appendix at the end of the Chapter 6. In calculation of emission factors, both IPCC default values and national data have been used. Emission factors are presented in Table 6.3_8.

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. Same values for gross energy intake (GE) for cattle has 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 Sweden as described in Dustan (2002). No information about VS_i for reindeer was available so IPCC default value for goats was used. For fur animals, VS_i value is based on expert judgement being 0.17 kg/head/day. No default value for Bo for fur animals exists, so 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_8. National emission factors used for calculating CH_4 emissions from manure management.

Animal category	Emission factor (kg CH_4/head/year)
Dairy cows	9.18
Suckler cows	2.84
Bulls	4.52
Heifers	2.82
Calves	1.68
Swine	3.52
Sheep	0.19
Goats	1.12
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

Animal numbers and related uncertainties used for manure management were the same as for enteric fermentation. Estimation of uncertainty in N_2O emission factor for manure management is rather complicated. Some studies (e.g. Amon et al. 2001; Hűther 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 negatively skewed distribution based on above mentioned studies, to implicate the possibility of smaller emissions than estimated. Uncertainty in emission factors of N_2O 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 CH_4 emission factor for manure management for all species (±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), completed 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 N_2O.

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. (in press). [Monni, S., Perälä, P. and Regina, K. Uncertainty in agricultural CH_4 and N_2O emissions from Finland - possibilities to increase accuracy in emission estimates. Mitigation and adaptation strategies for global change (in press)]

The amount of N excreted annually by the reindeer is very uncertain. Currently, because of lack of data, value for goats has been used. Also, B_o and VS_i for fur animals and VS_i for reindeer are uncertain. However, the amount of these emissions is very small and therefore the contribution to the total uncertainties also small.

6.3.4 Source-specific QA/QC and verification

General (Tier 1) Quality Control (QC) procedures applied to category Manure management (CRF 4.B):

QA/QC plan for agricultural sector includes the QC measures based on guidelines of 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. QC checklist is used during the inventory.

Tier 2 QC for activity data:

Activity data for livestock has been cross-checked with DREMFIA- model of MTT Economic Research.

Tier 2 QC for emission factors:

New national data for emission factors will be compared with emission factors used in the inventory for evaluating the applicability of current factors to Finland's circumstances.

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 special adjustments case-study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The experiences of this exercise have been taken into account in the development of the inventory.

6.3.5 Source-specific recalculations

Recalculation has been made because of the correction of N excretion for swine in 2004. Also, changes in the distribution of manure management systems as well as some minor changes in activity data were reasons for recalculating the time series.

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.

6.4 Agricultural Soils (CRF 4.D)

6.4.1 Source category description

This source category includes direct and indirect nitrous oxide emissions from agricultural soils. 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 NH_3 and NO_x as well as N leached from synthetic fertilisers, manure and sewage sludge applied to soils.

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 enhance the formation of nitrous oxide emissions (Smith et al., 2004). Nitrous oxide emissions arise also as a result of the mineralisation of soil organic matter, which is particularly intensive in cultivated organic soils.

Nitrous oxide emissions from agricultural soils are a significant emission source comprising 58% of total agricultural emissions in 2005. The emissions have decreased 25%, from 13.9 Gg in 1990 to 10.4 Gg in 2005 (Table 6.4_1). The main reasons causing this reduction are the decrease in animal numbers which affects the amount of nitrogen excreted annually to soils, decrease in the amount of synthetic fertilisers sold annually and decrease in the area of cultivated organic soils. Some parameters, e.g. the annual crop yields affecting the amount of crop residues produced annually, cause the fluctuation in the time series but this fluctuation does not have much effect on the overall N_2O emissions trend.

Table 6.4_1. Direct and indirect nitrous oxide emissions from agricultural soils by source category (Gg).

Year	Direct emission sources							Indirect emissions sources		Total
	S	MS	MP	C	N	O	SW	A	L	
1990	4.46	1.24	0.53	0.61	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	0.52	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	0.51	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	0.38	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	0.54	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	0.55	0.02	3.61	0.01	0.59	1.38	10.94
2003	3.11	1.16	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	0.58	1.34	10.48
2005	2.92	1.16	0.47	0.52	0.01	3.41	0.01	0.59	1.31	10.41
Share of total (%) in 2005*	28.1	11.1	4.5	5.0	0.1	32.8	0.1	5.7	12.6	

* 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

6.4.2 Methodological issues

Methods

Nitrous oxide emissions from agricultural soils have been calculated by using IPCC methodology. Both direct and indirect emission sources have been included. Detailed equations are provided in Appendix at the end of Chapter 6.

Direct emissions have been calculated using equation 4.20 in 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 fraction used as feed and 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 ($Frac_{GASF}$, $Frac_{GASM}$) as well as N leached ($Frac_{LEACH}$) are subtracted from the amount on 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. N_2O emissions from crop residues, N-fixation and cultivation of organic soils are also included into 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 EF´s for both crop types.

Activity data

Activity data is national and received mainly from annual agricultural statistics of the Ministry of Agriculture and Forestry (Table 6.4_2). 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 used for calculating CH_4 emissions from enteric fermentation and CH_4 and N_2O emissions from manure management (Table 6.2_2). 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 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 received from the VAHTI database of Finland's environmental administration (Table 6.4_3). Crop yields of cultivated plants have been received from agricultural statistics (Ministry of Agriculture and Forestry) (Table 6.4_4). Vegetables grown in the open have also been included into the emission estimate of crop residues. Vegetable yields have been received from literature (Puutarhayritysrekisteri 1994, Yearbook of Farm Statistics 2004) (Table 6.4_5). The area of cultivated organic soils has been received from MTT Agrifood Research Finland (Table 6.4_6) and has been estimated on the basis of Myllys & Sinkkonen (2004) and Kähäri et al. (1987).

Table 6.4_2. Activity data sources for calculating nitrous oxide emissions from agricultural soils.

Activity data	Data source
The number of cattle, sheep, goats, poultry, reindeer	The Information Centre of the Ministry of Agriculture and Forestry (Matilda Database, The Yearbook of Farm Statistics)
The number of horses	Finnish Trotting and Breeding Association (http://www.hippos.fi)
The 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
The amount of sewage sludge applied annually in agricultural soils	VAHTI- the Compliance Monitoring Data System of Finland's environmental administration
Crop statistics	The Information Centre of the Ministry of Agriculture and Forestry (Matilda Database, The Yearbook of Farm Statistics, Puutarhayritysrekisteri)
Model for ammonia emission estimate	VTT Technical Research Centre of Finland, Savolainen et al. (1996), agricultural experts (updated in 2005)
The area of cultivated organic soils	MTT Agrifood Research Finland

Table 6.4_3. Nitrogen input to soils via synthetic fertilisers, manure and sewage sludge application (Mg N a^{-1}) (fraction lost as NH_3 and NO_x has not been subtracted).

Year	Synthetic fertilisers[1]	Manure[2]	Sewage Sludge[3]
1990	228470	117661	2202
1991	202462	111944	1749
1992	163229	107417	1532
1993	168199	106165	1404
1994	169138	108140	2063
1995	195460	110031	1316
1996	179529	112849	1548
1997	169345	116976	1696
1998	169928	115101	575
1999	162700	112229	644
2000	167276	112027	513
2001	165621	109555	725
2002	160403	111233	616
2003	159288	110719	754
2004	154708	109585	437
2005	149562	110332	437*

[1] Sales of fertilisers on farms. Source: Yearbook of Farm Statistics 2001 (year 1990, 1991), 2004 (1992-2004)
[2] Includes manure applied to agricultural soils as well as deposited on pastures.
[3] Source: Finnish Environment Institute, VAHTI-database
*Data not available at the time of inventory preparation, assumed to be the same as in 2004

Table 6.4_4. Total yields of the most important crops in Finland in 1990-2005 (Gg a^{-1}).

Year	WW	SW	R	B	O	MC	T	Pe	Po	S	C
1990	137.4	489.5	244.2	1720.2	1661.8	37.1	117.0	9.1	881.4	1125.0	0.2
1991	149.1	281.4	28.2	1778.8	1154.9	27.5	94.9	28.3	672.1	1042.8	0.1
1992	35.2	177.1	26.6	1330.6	997.6	29.4	132.6	29.1	673.2	1049.0	0.1
1993	62.1	296.4	62.9	1678.9	1202.3	29.8	127.4	30.0	777.2	996.0	0.2
1994	42.3	295.1	22.2	1858.1	1149.9	23.6	107.9	13.9	725.6	1096.9	0.4
1995	52.5	327.0	57.7	1763.5	1097.2	30.1	127.9	10.9	798.0	1110.0	0.2
1996	108.4	350.9	86.9	1859.6	1260.8	31.0	89.4	13.3	765.7	896.6	0.2
1997	83.7	380.4	47.3	2003.5	1243.4	48.5	92.9	13.1	754.1	1360.0	0.2
1998	95.9	301.0	49.3	1316.2	975.1	35.4	63.9	4.2	590.7	892.0	0.1
1999	30.9	223.2	23.6	1567.7	990.1	43.7	88.3	7.2	791.1	1172.1	0.2
2000	147.5	390.8	108.2	1984.8	1412.8	51.0	70.9	11.7	785.2	1046.0	0.2
2001	97.1	391.8	64.1	1786.0	1287.1	32.9	100.8	11.5	732.8	1105.2	0.2
2002	84.7	483.9	73.1	1738.7	1507.8	38.0	102.8	11.1	780.1	1066.3	0.2
2003	117.7	561.3	72.8	1697.4	1294.5	35.6	93.6	10.2	617.4	892.3	0.4
2004	165.0	617.3	62.4	1724.7	1002.4	36.7	74.8	5.6	619.4	1048.6	0
2005	44.8	756.4	32.4	2101.9	1073.3	41.4	105.6	8.1	742.7	1183.3	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_5. Total yields the most important vegetables grown in the open in Finland 1990-2005 (Gg a^{-1}).

Year	Garden pea	White cabbage	Cauliflower	Carrots	Red beet	Swede	Celeriac	Total
1990	5.762	21.080	4.354	31.385	10.720	9.308	1.693	84.302
1991	4.768	20.560	4.359	38.052	11.331	11.970	1.592	92.632
1992	5.388	20.094	4.953	29.730	10.716	9.285	1.846	82.012
1993	6.529	17.592	4.017	36.224	9.582	10.021	1.522	85.487
1994	5.087	23.056	4.442	59.229	13.737	14.829	2.024	122.404
1995	6.366	24.304	4.801	61.343	11.016	12.505	1.471	121.806
1996	9.044	23.116	4.149	53.264	11.732	13.066	1.352	115.723
1997	7.601	28.722	4.577	67.895	14.797	18.314	1.562	143.468
1998	5.206	18.659	4.051	52.336	8.341	10.944	1.500	101.037
1999	6.598	22.392	4.663	61.799	13.575	14.742	0.839	124.608
2000	6.486	20.381	4.913	64.049	12.710	10.101	1.425	120.065

Year	Garden pea	White cabbage	Cauliflower	Carrots	Red beet	Swede	Celeriac	Total
2001	6.571	17.705	4.450	58.310	13.995	11.918	1.123	114.072
2002	6.923	19.960	4.217	58.428	12.449	10.095	1.244	113.316
2003	5.836	18.997	3.973	59.423	12.620	11.531	1.008	113.388
2004	5.896	17.989	3.244	56.987	11.976	15.452	1.096	112.64
2005	4.200	19.281	3.825	67.028	14.009	14.127	0.840	123.31

Table 6.4_6. Area of cultivated organic soils in Finland in 1990-2005 (ha).

Year	Total area of cultivated organic soils, ha	Organic soils on cereals, ha	Organic soils on grass, ha
1990	368929	184464	184464
1991	362571	181286	181286
1992	356214	178107	178107
1993	349857	174929	174929
1994	343500	171750	171750
1995	337143	168571	168571
1996	330786	165393	165393
1997	324429	162214	162214
1998	318071	159036	159036
1999	311714	155857	155857
2000	305357	152679	152679
2001	299000	149500	149500
2002	292643	146321	146321
2003	286286	143143	143143
2004	279929	139964	139964
2005	276750	138375	138375

Emission factors and other parameters

IPCC default emission factors have been used for calculating N_2O emissions from agricultural soils (Table 6.4_7). However, emission factors for organic soils on grass and cereals are based on national data (Monni et al. (in press).

The amount of nitrogen applied to soils has been corrected with a fraction of nitrogen volatilised as NH_3 and NO_x from the synthetic fertilisers ($Frac_{GASF}$) and fraction of nitrogen volatilised as NH_3 and NO_x from manure and sewage sludge ($Frac_{GASM}$) as well as with the fraction of nitrogen leached from applied synthetic fertilisers, manure and sewage sludge ($Frac_{LEACH}$) (Table 6.4_8). The amount of nitrogen volatilised has been used for calculating indirect N_2O emissions from atmospheric deposition. The amount of nitrogen leached has been used for calculating indirect N_2O emissions from leaching and run-off. Values for $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ are national values differing from IPCC default values on purpose. It is estimated that nitrogen leaching is less than IPCC default value in Finnish conditions (according to Rekolainen et al. (1993) value is 15% and this has been used in the inventory). 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 for each animal group. Ammonia volatilisation during stable, storage and application were included with specific emission factor in each phase. $Frac_{GASM}$ is the proportion of total NH_3-N of the total N excreted. Emission factors describing the amount of NH_3 volatilised in each phase has been taken from ECETOC (1994), Grönroos et al. (1998). Support for using these values is found e.g. 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 $Frac_{GASF}$ 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 evaporates 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 $Frac_{GASF}$ 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). A project to measure ammonia emissions from fertilisation will commence in Finland in 2005. The $Frac_{GASF}$ value used may be revised in future submissions based on the results of the project.

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_9).

Table 6.4_7. Emission factors used for calculating direct and indirect nitrous oxide emissions from agricultural soils.

Emission source	Emission factor	Reference
Direct soil emissions		
Synthetic fertilisers	0.0125 kg N_2O-N/kg N	IPCC (2000), Table 4.17
Animal wastes applied to soils	0.0125 kg N_2O-N/kg N	IPCC (2000), Table 4.17
N-fixing crops	0.0125 kg N_2O-N/kg dry biomass	IPCC (2000), Table 4.17
Crop residue	0.0125 kg N_2O-N/kg dry biomass	IPCC (2000), Table 4.17
Cultivation of organic soils on cereals	11.7 kg N_2O-N/ha/yr	Monni et al. (in press)
Cultivation of organic soils on grass	4.0 kg N_2O-N/ha/yr	Monni et al. (in press)
Indirect emissions		
Atmospheric deposition	0.1 kg N_2O-N/kg NH_3-N & NO_x-N deposited	IPCC (2000), table 4.18
Nitrogen leaching and run-off	0.025 kg N_2O-N/kg N/yr	IPCC (2000), table 4.18
Animal production		
N excretion on pasture range and paddock	0.020 kg N_2O-N/kg N/yr	IPCC (1997)
Other sources		
Sewage sludge spreading	0.0125 kg N_2O-N/kg N load	IPCC (1997) (EF_1)

Table 6.4_8. 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_9. Residue to crop ratio, dry matter fraction and nitrogen content of crops included into the inventory.

Crop	$Res_i/Crop_i$	$Frac_{DM}$	$Frac_{NCR}$
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)] 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, 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)] IPCC default value used.

6.4.3 Uncertainty and time series' consistency

Uncertainty in N_2O 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 emission generating process and high natural variability which make estimation of average annual emission factor difficult.

Activity data and related uncertainties used for calculating N_2O emissions from agricultural soils were partly the same as in the calculation of N_2O emissions from manure management (CRF 4.B). Uncertainty estimates of other activity data were based on expert judgement.

Emission factors used in the Finnish inventory for direct and indirect N_2O emissions from agricultural soils are the IPCC default values. The uncertainty estimates were previously based on uncertainty ranges given by the IPCC (1997). For 2005 inventory submission, uncertainty estimates were revised based on measurement data. For organic soils, mean of measured emission factor was close to the IPCC emission factor used. The range of annual average emission factors obtained from different soils revealed that uncertainty may be larger than previously estimated. Uncertainty estimate was thus changed from ±80% to (–70...+170%). For national EF for cultivated organic soils on cereals, value 11.7 kg ha^{-1} and organic soils on grasses 4.0 kg kg ha^{-1} has been used. For the 2006 submission, uncertainty in the shares of area were 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 $1–A$.

For mineral soils, measurements indicated that emissions may be notably larger than estimated by using the IPCC emission factor. The uncertainty estimate was thus changed from ±88% to (–90 to +380%) (see Monni et al. (in press)) for more details.

Different sensitivity studies have revealed strong sensitivity of the agricultural inventory to the uncertainty of N_2O emission factor for agricultural soils. In Finland, also the uncertainty in the whole greenhouse gas emission inventory containing all sectors and gases is highly sensitive to the estimated uncertainty of the emission factors for N_2O emissions from agricultural soils.

6.4.4 Source-specific QA/QC and verification

General (Tier 1) Quality Control (QC) procedures applied to category Agricultural soils (CRF 4.C):

QA/QC plan for agricultural sector includes the QC measures based on guidelines of 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. QC checklist is used during the inventory.

Tier 2 QC for activity data:

Activity data for livestock has been cross-checked with DREMFIA-model of MTT Economic Research.

Tier 2 QC for emission factors:

New national data for emission factors will be compared with emission factors used in the inventory for evaluating the applicability of current factors to Finland's circumstances.

Agricultural inventory has been reviewed 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 special adjustments case-study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The experiences of this exercise have been taken into account in the development of the inventory.

6.4.5 Source-specific recalculations

Recalculations have been made in this source category because value for crop yield of sugar beet was updated for 2004 according to the latest statistics. Also, area of organic soils was corrected for the whole time series because area of grassland was accidentally excluded from the total area. Changes in the distribution of manure management systems also affect emissions from agricultural soils and caused recalculation of the time series.

6.4.6 Source-specific planned improvements

Data on the distribution of different manure management systems should be improved. Also, data on manure and synthetic fertiliser application methods should also be collected regularly. Application technology has an effect on NH_3 volatilisation. NH_3 affects indirectly the N_2O formation (indirect N_2O emissions).

The area of cultivated organic soils is poorly known in Finland. Current area estimate is based on publications of Myllys & Sinkkonen (2004) and Kähäri et al. (1987) on a basis of the results of soil analysis. Methodology for estimating annual area of cultivated organic soils should be improved. Co-operation with Finnish Forest Research Institute will continue in order to ensure consistency in land area estimates between agricultural soils and forest soils.

Appendix_6

Equations used in calculation of greenhouse gas emissions from Agriculture sector.

1) Equations for calculating CH_4 emissions from enteric fermentation of horse, swine and goat

IPCC Tier 1 approach, equations 4.12 and 4.13 in IPCC 2000,

Methane emission (Gg/year) = emission factor *(EF)* (kg/animal/year) x number of animals/(10^6 kg/Gg)

Total CH_4 emissions = $\sum_i E_i$

Index $_i$ = sums all livestock categories and sub-categories

E_i= emissions for the i^{th} livestock categories and sub-categories

2) Equations for calculating CH_4 emissions from enteric fermentation of cattle

In IPCC Tier 2 approach, emission factor for each cattle sub-category has been calculated according to the Equation 4.14 in IPCC Good Practice Guidance (IPCC 2000):

$EF=(GE*Y_m*$ *365 days/year)/(55.65 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)

National value for gross energy intake (GE) of cattle has been used. Value of GE for each cattle sub-group has been calculated by using slightly modified version of Eq. 4.11 in 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 in the original IPCC equation, also the following terms exist which have now been excluded: $NE_{mobilised}$, NE_w, *and* NE_{wool}

Equations for calculating NE_m, NE_a, NE_l, NE_p and NE_g are as follows:

$$NE_m= Cf_i * (\text{Weight})^{0.75}$$
$$NE_a= [C_{ap} * t_p/365 + C_{ao} * (1-(t_p/365)) * NE_m$$
$$NE_l = M_y/365 * (1.47 + 0.40 * \text{Fat})$$
$$NE_p = C_p * NE_m$$
$$NE_g = 4.18*\{0.0635*[0.891*(BW*0.96)*(478/(C*MW))]^{0.75} * (WG * 0.92)^{1.097}\}$$
$$NE_{ma}/DE = 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE)$$
$$NE_{ga}/DE = 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE)$$

where,

Cf_i = Coefficient, IPCC default value 0.335 for dairy cattle and 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, IPCC default value 0.17 used
C_{ao} = Coefficient for stall, IPCC default value 0.00 used
M_y = The amount of milk produced per year, kg a^{-1}/cow, 7730 kg used for dairy cows and 1620 for sucklercows
Fat = Fat content of milk (%), value 4.16 used
C_p = Pregnancy coefficient, 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), for adult dairy cow 657 kg used, 706 kg for suckler cow and for adult bull 988 kg used
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 IPCC default value for methane conversion rate (Y_m= 0.06) has been used.

3) CH_4 emissions from enteric fermentation of sheep and reindeer

EF=(GEY_m* 365 days/year)/(55.65 MJ/kg CH_4) (IPCC)*

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)

Equation for calculating GE for sheep and reindeer (McDonald et al. 1988):

*GE (MJ/kg)=0.0226*crude protein (CP)+0.0407*ether extract (EE)+0.0192*crude fibre (CF) +0.0177*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 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 (rehuksikkö) 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.

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 (MJ/kg) for lichen * kg dm lichen+ GE (MJ/kg) for hay * kg dm hay)/365 days

EF for both animal types has been calculated from the IPCC equation above. EF is an average of male and female reindeer being 19.9 kg CH_4/animal/yr

Sheep

The emissions 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 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 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 GE (MJ/kg dm) to get GE (MJ/animal/yr).

National emission factor for sheep is 8.2 kg CH_4/animal/yr.

4) Equations for calculating N_2O emissions from manure management

N_2O 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 N_2O-N/kg N)
S = Manure management system

T = Species/category of livestock

Annual average N excretion has been received from MTT Agrifood Research Finland. 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 IPCC Tier 2 approach, emission factor for each cattle sub-category has been calculated according to the Equation 4.17 in 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, m^3 CH_4/kg VS (IPCC default values used)
MCF_{jk} = Methane conversion factors for each manure management system j by climate region k
MS_{ijk} = Fraction of animal species/category i´s manure handled using manure system j in climate region k

For cattle, VS has been calculated with IPCC equation (IPCC 2000, Eq. 4.16). For other animals (swine, sheep, goats, horses and poultry) IPCC default values for VS has been used. For reindeer no data available so VS value for goats was used. For fur animal VS value is based on expert judgement.

$$VS\_cattle = GE * (1\ \text{kg-dm}/18.45\ \text{MJ}) * (1-DE/100) * (1-ASH/100)$$

where,

GE = Gross energy intake (MJ/animal/day) (see methane emissions from enteric fermentation)
DE = Digestible energy (%) (see methane emissions from enteric fermentation)
ASH = Ash content of manure (%) (IPCC default values used)

Data about the distribution of different manure management systems has been received from literature (Seppänen & Matinlassi, 1998). For MCF coefficient, 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 (Chapter 6.3).

Direct emissions (IPCC 2000, Eq.4.20)

N_2O emissions from synthetic fertilizers (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
$Nex_{(T)}$ = 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*):*

$$N_2O_{CR} = \sum_i[Crop_i* Res_i/Crop_i* Frac_{Dmi} * Frac_{NCRi}] * EF * 44/28$$

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)

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).

N_2O 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

N_2O emissions from sewage sludge applied to soils (IPCC 2000, Eq.4.20, modified):

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

where,

N_{sludge} = Amount of nitrogen applied annually in sewage sludge, Gg
EF = Emission factor (0.0125 kg N_2O-N/kg N load)

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

N_2O emissions from cultivated organic soils (IPCC 2000, Eq.4.20,modified):

$N_2O_{FOS} = F_{OS} * EF * 44/28$

F_{OS} = Area of organic soils cultivated annually, ha (50% assumed as cereals and 50% grasses)
EF = Emission factor (11.7 kg N_2O-N/ha/year for cereals and 4.0 kg N_2O-N/ha/year for grasses)

Area of cultivated organic soils has been received from MTT Agrifood Research Finland and is based on expert judgement and soil analysis.

Indirect emissions

N_2O emissions from atmospheric deposition (IPCC 2000, Eq. 4.32):

$N_2O_{indirect\_G} = [(N_{fert} * Frac_{GASF}) + (\Sigma(N_{(T)} * Nex_{(T)}) + N_{sludge}) * Frac_{GASM}] * EF * 44/28$

where,

N_{fert} = The amount of synthetic fertilisers consumed annually (Gg N/year)
$Frac_{GASF}$ = The fraction of synthetic fertilisers that volatilizes as NH_3 and NO_x
$N_{(T)}$ = Number of head of livestock species/category T in the country
$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)
N_{sludge} = Amount of nitrogen applied annually in sewage sludge, Gg N/year
$Frac_{GASM}$ = The fraction of animal manure that volatilises as NH_3 and NO_x
EF = Emission factor (0.01 kg N_2O-N / kg NH_4-N & NO_X-N)

N_2O emissions from leaching and run-off (IPCC 2000, Eq. 4.34, modified):

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

where,

N_{fert} = The amount of synthetic fertiliser consumed annually (Gg N/year)
$N_{(T)}$ = Number of head of livestock species/category T in the country
$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)
N_{sludge} = Amount of nitrogen applied annually in sewage sludge, Gg N/year
$Frac_{LEACH}$ = The fraction of N input that is lost through leaching or runoff.
EF= Emission factor (0.025 kg N_2O-N / kg N load)

National value 0.15 for $Frac_{LEACH}$ has been used (See Pipatti, 2001).

7. LAND USE, LAND USE CHANGE AND FORESTRY (CRF 5)

7.1 Overview of sector

Description

In year 2007 submission Finland reports carbon stock changes and greenhouse gas emissions from Forest land, Cropland, Grassland and Wetlands (peat extraction areas). In Forest land category all the carbon pools (living biomass, dead organic matter and soil) are reported. In Cropland and Grassland as well as Forest land categories carbon stock changes in soil are reported separately for mineral and organic soils. N_2O emissions from agricultural soils are reported under Agriculture sector. In addition CO_2 emissions from liming of agricultural soils, direct N_2O emissions from nitrogen fertilisation on forest land and CO_2, CH_4 and N_2O emissions from biomass burning (on forest land) are reported. Also CO and NOx emission from forest fires are included in reporting. CO_2 emissions from peat extractions areas are reported in the Wetlands category (CRF 5.D) and non-CO_2 emissions in the CRF category 5 (II).

Emissions and removals from Land Use, Land Use Change and Forestry (LULUCF) sector are not yet reported separately for land remaining in the same land use category and land converted to another land use category. The method to estimate land-use conversions is under development. CO_2 and N_2O emissions from land use transition 'Forest land converted to other land-use categories' are reported as Information Item.

The LULUCF sector reporting does not include emission estimates from the Settlements (CRF 5.E) and Other land (CRF 5.F) land use categories. In those categories only area data is reported. Reporting of these categories is optional for the Party. Non-CO_2 In addition N_2O emissions from drainage of forest soils and wetlands (CRF 5(II)), other than those from peat extraction, are not reported. Reporting of CRF 5 (II) is optional for the Party. Finland has not reported so far the N_2O emissions from disturbance associated to land use conversion to cropland due to the lack of reliable area data.

Land areas and land use categories used in the Finnish Inventory

Land areas used in the inventory reporting are consistent with the land use categories given in IPCC GPG LULUCF (IPCC 2003) (Table 7.1_1). The total land area for years to be reported is the Finland's official land area issued annually by the National Land Survey of Finland (Table 7.1_1). In 2004 the Ministry of Agriculture and Forestry set up a working group whose one of the tasks was to propose the follow-up system of land use and land-use changes taking into consideration the requirements of the UNFCCC reporting and the Kyoto protocol. Working group suggested in it's report national definitions for all the IPCC land use categories and summarised the potential data sources (Ministry of Agriculture and Forestry 2005:5).

The area estimates of land-use categories are based on the Finnish National Forest Inventories (NFI) carried out by the Finnish Forest Research Institute, except the area of cropland which comes from the official statistics compiled by the statistics unit of the Ministry of Agriculture and Forestry and area of peat extraction, which comes from the Association of Finnish Peat industry and from Finland's environmental administration. The NFI is a sampling based forest inventory and it covers all land use classes, not only forest land. 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 the different parts of Finland. Finnish forests have been measured by National Forest Inventories nine times. The 10th inventory started in 2004 and the measurements will be completed in 2008. More detailed description about the National Forest Inventories, applied methods and the data are available in the Appendix 7 in the end of this chapter.

Forest land. The FAO TBFRA 2000 definition is applied. Forest is a land with tree crown cover of (or equivalent stocking level) of more than 10 per cent and 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 per cent 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. Parks and yards, e.g., are excluded regardless that they would meet Forest land definition (Forest Resources… 2000). The FAO definition for forest land covers Finnish national definition of productive forest land, a part of the poorly productive forest land, and forest roads. Area estimates are derived from NFIs data.

Cropland. Cropland refers to the official area of arable land. The area is reported by the statistics unit of the Ministry of Agriculture and Forestry and can be found in Yearbook of Farm Statistics. For the first time also permanent horticultural crops, greenhouses and kitchen garden are also classified as Cropland in this submission.

Grassland. The arable land concept in the NFI deviates from that applied in official statistics (Yearbook of Farm Statistics) on arable land. The arable land of NFI includes, e.g., the ditches associated to agricultural land and abandoned arable land while only the 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 purposes and where natural reforestation is possible or is already going on. The difference of these areas is classified as Grassland.

Wetlands. Wetlands includes peat extraction areas and areas which don't fulfil the definition of Forest land, Grassland or Cropland. The peat extraction area for years 1990–2005 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 GPG LULUCF (IPCC 2003).

Settlements. The combined area of NFI build-up land, traffic lines and power lines. Only the total area of Settlements is reported. Area estimates are derived from NFIs data.

Other land. Other land includes mineral soils on poorly productive forest land and unproductive land. Typically they are rocky lands and treeless mountain areas. Only the total area of other land is reported.

The land use classification is revised compared to the submission of 2006:

- Small roads and other small areas with tree cover inside cropland were before in the category Other land, but now they are placed in the Grassland category. The ground for the change is that these areas better fit into Grassland category by their characteristics.
- Permanent horticular crops, greenhouses and kitchen gardens were before in the category Settlements, now they are classified as Cropland.

Table 7.1_1. The areas of IPCC land-use classes in 1990–2005.

	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total land area
				1 000 ha			
1990	21961	2277	665	3205	1139	1212	30458
1991	21967	2307	622	3188	1166	1208	30459
1992	21973	2292	626	3173	1191	1205	30459
1993	21979	2283	623	3156	1217	1202	30459
1994	22041	2308	581	3102	1228	1200	30459
1995	22103	2147	724	3046	1241	1199	30459
1996	22165	2127	726	2991	1252	1197	30459
1997	22227	2130	706	2935	1265	1196	30459
1998	22285	2171	647	2878	1278	1194	30453
1999	22344	2181	617	2834	1284	1193	30452
2000	22403	2192	586	2788	1291	1191	30452
2001	22460	2192	567	2743	1298	1190	30448

	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total land area
				1 000 ha			
2002	22518	2209	530	2700	1302	1188	30447
2003	22396	2218	529	2811	1309	1183	30447
2004	22275	2225	531	2924	1313	1178	30447
2005	22128	2241	520	3030	1320	1171	30411

Forest land converted to other land use categories

Finland is not ready to report emission and removals in categories land converted to other land in last 20 years. Method is under development. Area estimates of annual land use transitions are available for years 1990–2005 (Table 7.1_2). In this submission, Finland reports CO_2 and N_2O emissions from land use transitions from Forest land to other land as information items. Included categories are transitions from forest land to cropland, to wetlands and to settlements. Area converted to cropland is based on the statistics on area treated with other than silvicultural fellings resulting land use change (Forest statistical… 2006). Fellings done for road construction were taken off the compiled statistics. Conversion to wetlands relate to drained forest land mires, which are restored for biodiversity reasons by removing trees and filling ditches. Areas base 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 base on NFI.

Methods are still under development and results presented here and CRF tables are therefore preliminary.

Table 7.1_2. Converted areas (ha) and emissions (Gg) from category Forest land converted to other land-use categories in 1990–2005.

	Total area (ha)	Total emissions (Gg)	
		CO_2	N_2O
1990	9 623	1064.7	0.000090
1991	8 936	946.9	0.000090
1992	9 776	1088.9	0.000090
1993	12 939	1623.0	0.000090
1994	19 356	2709.4	0.000090
1995	11 861	1440.9	0.000090
1996	11 977	1444.0	0.000090
1997	11 756	1410.2	0.000090
1998	13 015	1627.7	0.000090
1999	11 611	1387.0	0.000090
2000	15 498	2045.1	0.000090
2001	18 013	2483.2	0.000062
2002	18 620	2588.8	0.000062
2003	18 445	2551.6	0.000062
2004	22 294	3191.0	0.000062
2005	16 371	2195.0	0.000062

Quantitative overview

The LULUCF sector in 2005 as a whole acted as a carbon dioxide sink of more than 30 million CO_2 because total emissions arising from the sector are smaller than the total removals (Figure 7.1_1, Table 7.1_3). LULUCF sector in Finland has been a net sink of CO_2 during the whole time series. A large sink is mainly due to the fact that total increment of the growing stock on forest land has been higher than the total drain. In 2005 a net sink in living biomass on Forest land was over 37 Tg CO_2. The striking rise in CO_2 uptake between 2004 and 2005 is the result of the NFI10 increment estimate that is applied for 2005. Increment of growing stock rose 12 % from NFI9 (86.7 million m^3) to NFI10 (97.1 million m^3 (Korhonen et al. 2006)). NFI10 estimates base on two year's measurements, that is two fifth of all sample plots to be measured in NFI10, so NFI10 estimates are preliminary. Dead organic matter pool on Forest land was also a CO_2 sink of -3.4 Tg in 2005 as well as mineral forest soils (-3.6 Tg CO_2).

On the contrary the organic forest soils were rather large source of emissions in 2005 (6.5 Tg CO_2). Other emission sources in the Forest land category were N_2O fertilization on forest land (0.011 Tg CO_2 eq) and forest fires (0.02 Tg CO_2 eq).

In Cropland category mineral soils were a sink of -1.6 Tg CO_2 and organic soils a source of 4.9 Tg CO_2 in 2005. In addition emissions from liming in agricultural soils made up about 0.27 Tg CO_2 in 2005. Mineral soils on Grassland category were a source of 2.3 Tg and organic soils a source of 0.06 Tg CO_2 in 2005. In Cropland and Grassland categories mineral soils have been sometimes sinks sometimes sources during the 1990-2005 (Table 7.1_3, Figure 7.1_2). This is due to changes in areas of different crop types. Emissions from peat extraction areas, reported under Wetland category, were in 2005 a source of 0.7 Tg CO_2 eq.

Table 7.1_3. Greenhouse gas emissions and removals from LULUCF sector in 1990–2005 (Gg CO_2 eq.) (positive figures indicate emissions, negative removals).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Forest land																
Biomass	-28566	-42078	-34522	-31704	-21168	-19918	-26079	-21504	-21327	-21800	-21108	-24017	-22779	-21338	-21227	-37184
Dead organic matter	-6891	-7147	-8086	-8402	-9183	-10035	-10707	-10487	-10203	-10228	-9629	-8944	-8403	-8012	-7998	-3408
Mineral soil	-2344	-2427	-2522	-2622	-2730	-2848	-2975	-3101	-3223	-3341	-3450	-3547	-3634	-3675	-3714	-3572
Organic soil	9995	9880	9420	8796	8759	8726	8423	9781	10015	9457	8918	8420	7877	7302	6755	6511
Cropland																
Mineral soil	214	-1290	-1194	-1265	-1340	501	782	469	44	-176	-465	-614	-993	-1186	-1357	-1569
Organic soil	6584	6472	6358	6244	6131	6015	5894	5771	5658	5547	5423	5311	5195	5080	4966	4916
Grassland																
Mineral soil	-1744	-698	-491	179	1189	1009	513	923	1671	2329	2909	3169	2645	2957	3139	2274
Organic soil	96	88	82	78	65	85	87	80	69	65	62	60	56	54	52	58
Wetland																
Organic soil*	599	607	633	643	663	670	683	694	693	699	693	685	708	652	623	702
Biomass burning	23	11	41	2	31	22	19	44	5	25	15	12	26	29	13	20
N fertilisation	27	20	9	3	12	6	8	13	9	14	13	11	12	11	12	11
Liming	618	431	273	448	449	386	453	467	428	429	326	395	422	278	252	265
Total CO_2 eq	**-21389**	**-36130**	**-29998**	**-27598**	**-17122**	**-15381**	**-22899**	**-16851**	**-16162**	**-16981**	**-16293**	**-19060**	**-18868**	**-17848**	**-18486**	**-30933**

*Include CO_2, N_2O and CH_4 emissions from peat extraction areas.

The high fluctuation in biomass removals in Forest land category during the period 1990-2005 is mainly caused by the variation in the total drain of the growing stock. Note that the drain consists of cutting removals, harvest residues and natural mortality of trees. The variation is caused by the variation of harvest of the trees which is very much affected by the international market situation in forest industry products. The cuttings were in low level in the first half of the 1990's, the lowest drain in the period was 44.65 mill. m^3 in 1991. In the second half they increased considerably, the highest drain was 69.97 mill. m^3 in 2000. The drain in 2000's has been fairly stable. The low cutting level in the beginning of the 1990's can be seen as high CO_2 sink in biomass (Figure 7.1_2). Due to the quiet roundwood market in 2005, the drain was 2.5 mill. m^3 lower than in 2004.

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 77.72 mill. m^3 in the eight national forest inventory NFI8 (1986-1994) to 86.69 mill. m^3 in NFI9 (1996-2003). The increment has still rosen and the preliminary NFI10 increment estimate is 97.1 mill. m^3. The increased total increment has compensated the changes in biomass sink. However, the increased level of the cuttings has increased the annual production of the dead organic matter, particularly when the level of the cutting increased in the mid of 1990's (Table 7.1_2). When the cuttings levelled off, the decomposition of the dead organic matter levelled off also the CO_2 sink of the dead organic matter in 2000's.

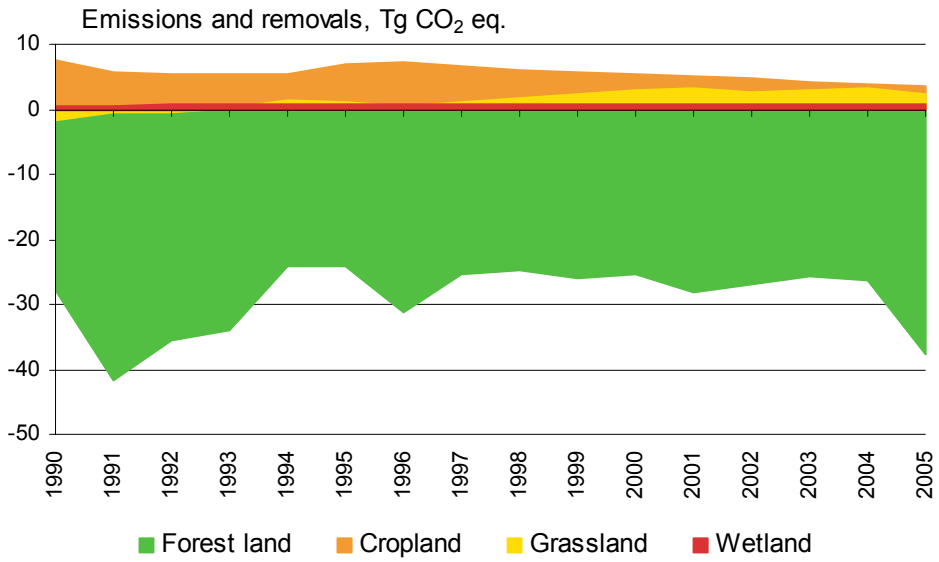


Figure 7.1_1. Net emissions and removals in LULUCF sector in 1990–2005 by land use categories, Tg CO_2 eq. Positive figures are emissions, negative figures removals.

The increased forestry activities can been seen also as the increased CO_2 sink of the mineral soil (Figure 7.1_2). The variation in organic soil emission and sinks in the period 1990-2005 is caused mainly by two factors, 1) the slight changes in the area of the drained peatland and 2) the increase of the growing stock on organic soils. The first factor has slightly increased the total emissions caused by peat decomposition. The second factor has increased CO_2 sink of the organic soil caused by fine root litter of the trees.

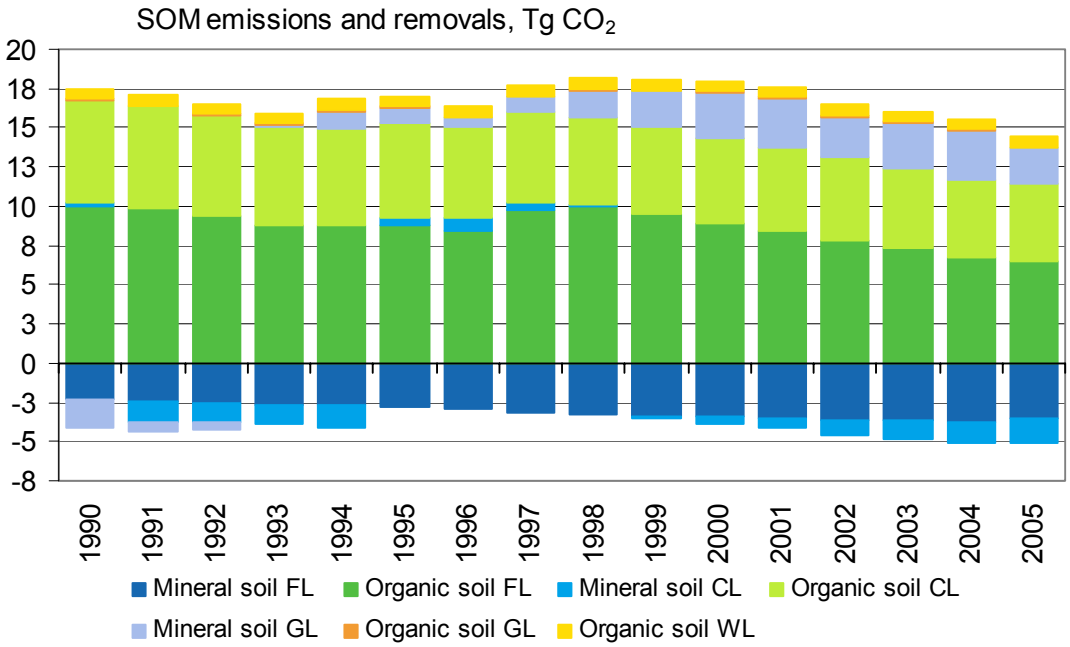


Figure 7.1_2. Emissions (positive sign) and removals (negative sign) from soil organic matter in different land use classes during the 1990-2005, Tg CO_2. (FL = Forest land, CL=Cropland, GL=Grassland, WL=Wetland = peat extraction areas)

Key Categories

In 2005 the key categories in LULUCF sector were:

- 5.A 1 CO_2 from carbon stock change in living biomass on Forest land (L,T)
- 5.A 1 CO_2 from carbon stock change in mineral soils on Forest land (L)
- 5.A 1 CO_2 from carbon stock change in organic soils on Forest land (L,T)
- 5.B 1 CO_2 from carbon stock change in mineral soils on Cropland (L,T)
- 5.B 1 CO_2 from carbon stock change in organic soils on Cropland (L,T)
- 5.C 1 CO_2 from carbon stock change in mineral soils on Grassland (L,T).
- 5.D 2 CO_2 from peat extraction areas

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 using the FAO TBFRA 2000 definition. Forest is a land with tree crown cover of (or equivalent stocking level) of more than 10 per cent and 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 per cent 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, e.g., are excluded regardless that they would meet Forest land definition. The assessment is done in field measurements since year 1998. A study was conducted to asses FAO forest / other wooded land / other land for land those field plots for which NFI assessment was not available (for data from years 1996 and 1997 and for NFI8 data 1986–1994). FAO Forest land includes national 'Productive forest land' where the mean annual increment of growing stock over the rotation is at least 1 m^3/ha, and a part of 'Poorly productive forest land' where it is less than 1 m^3/ha but more than 0.1 m^3/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 the CRF 5.A.1.

The following carbon dioxide stock uptakes and releases are assessed in the year 2005 submission: 1) above and below ground biomass of growing stock 2) litter and dead wood (= dead organic matter) and 3) soil organic matter (Table 7.2_1, Figure 7.2_1). 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. Carbon uptake and release of growing stock correspond the mean annual increment and annual drain of trees.

Changes in 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 measured emission factors were combined with modelling. In the modelling approach carbon stock changes of litter, dead wood and soil organic matter are driven by tree litter production and the consequent decomposition of it was evaluated with Yasso model (Liski et al. 2005). The litter production consisted of litter falling from living trees, cutting residues as well as natural mortality of trees. On organic soils also litter production by understorey vegetation was 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 CO_2 changes of different pools are given in Table 7.2._1.

Table 7.2_1. Emissions and removals from Forest land Carbon pools in 1990–2005 (Tg CO_2) (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
Mineral soils																
Biomass	-15.6	-27.1	-20.1	-17.8	-8.4	-7.4	-12.4	-7.4	-6.6	-7.1	-6.5	-9.2	-8.1	-6.8	-6.8	-19.8
Dead organic matter	-4.4	-4.7	-5.6	-5.9	-6.5	-7.2	-7.8	-7.5	-7.2	-7.2	-6.7	-6.1	-5.6	-5.2	-5.2	-2.3
Soil organic matter	-2.3	-2.4	-2.5	-2.6	-2.7	-2.8	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	-3.6	-3.7	-3.7	-3.6
Organic soils																
Biomass	-13.0	-15.0	-14.4	-13.9	-12.7	-12.6	-13.7	-14.1	-14.7	-14.7	-14.6	-14.8	-14.7	-14.5	-14.4	-17.4
Dead organic matter	-2.5	-2.4	-2.5	-2.5	-2.7	-2.8	-2.9	-3.0	-3.0	-3.0	-3.0	-2.9	-2.8	-2.8	-2.8	-1.1
Soil organic matter	10.0	9.9	9.4	8.8	8.8	8.7	8.4	9.8	10.0	9.5	8.9	8.4	7.9	7.3	6.8	6.5

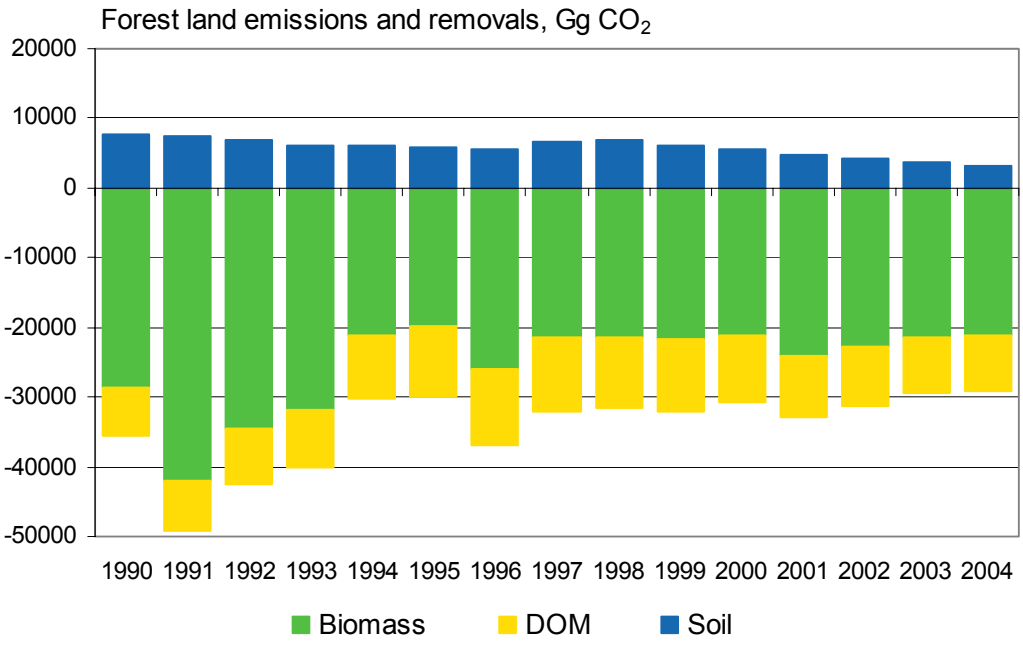


Figure 7.2_1. Emissions (positive figures) and removals (negative figures) from Forest land carbon pools in 1990-2005.

7.2.2 Methodological issues

Carbon stock changes in living biomass

Methods

The Finnish method applied for calculating the change in carbon stock in living tree biomass is consistent with the Method I (so called default method) in 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 (m^3) based on the National Forest Inventory of Finland (NFI) and on annual statistics on cutting removals (m^3)(Tomppo 2000).

*CO_2 emissions/removals = (carbon uptake by tree growth - 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).

CO_2 balance of the trees from 1990 to 2005 is presented in Table 7.2._2. The annual increment of trees has increased almost steadily wherefore the CO_2 uptake has also increased. The total drain of trees is very much affected by commercial fellings and the global market situation. The demand of the timber products was low in the beginning of 1990's wherefore fellings were also at low level and the CO_2 sink of trees high. The fellings since the mid of 1990's have been exceptionally high compared to a long-term average. Strong fluctuation in the CO_2 sink in the of 1990's is very much affected by these facts. The decreased CO_2 release in 2005 is the result of quiet roundwood markets. One reason to that was the production stoppage caused by the forest industry's seven-week lock-out.

The striking rise in CO_2 uptake between 2004 and 2005 is the result of the NFI10 increment estimate that is applied for 2005. Increment of growing stock rose 12 % from NFI9 (86.7 million m^3) to NFI10 (97.1 million m^3)(Korhonen et al. 2006). NFI10 estimates base on two year's measurements, that is two fifth of all sample plots to be measured in NFI10, and so NFI10 estimates are preliminary.So note, that for years 1999–2004 the NFI9 increment estimate is directly applied as well the NFI10 estimate for 2005. No interpolation is made between the years even though it would be reasonable to get somewhat smoother time serie. Because of this there is leap in uptake between the year 2004 and 2005. If interpolation had been made, the whole time series would have to be recalculated. At the moment Finnish Forest Research Institute has an ongoing project to develope a method for carbon stock changes in biomass. It was seen that before the final decision on the method no changes will be made to this part of the inventory.

Table 7.2_2. Carbon dioxide uptake and release of growing stock in 1990–2005 (Tg CO_2).

Year	Uptake	Release	Balance
1990	100.7	72.1	28.6
1991	100.7	58.6	42.1
1992	101.2	66.7	34.5
1993	102.1	70.4	31.7
1994	101.7	80.6	21.2
1995	103.0	83.1	19.9
1996	103.0	77.0	26.1
1997	107.4	85.9	21.5
1998	111.8	90.4	21.3
1999	112.2	90.4	21.8
2000	112.2	91.1	21.1
2001	112.2	88.2	24.0
2002	112.2	89.5	22.8
2003	112.2	90.9	21.3
2004	112.2	91.0	21.2
2005	124.9	87.8	37.2

Emission factors and other parameters

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

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. The new method will apply tree and site specific biomass models.

Activity data

Forest land area

In this submission the Forest land area, as well areas of other land-use categories, was recalculated. In section '7.1 Overview of sector', is described the way land area is allotted for land-use categories and which are the information sources. The main data source is the NFI, excluding the area of Cropland and Peat extration areas. Description of NFIs and principles of area estimation method are given in Appendix 7.

At first, NFI8, NFI9 and NFI10 sample plot data were classified into IPCC land use categories. Proportions of land use categories to land area were calculated for South and North Finland for inventory mid-years and linearly interpolated to the years between them (Table 7.2_4). NFI7 data was applied for North Finland as ancillary data to cover years both sides of 1990. The FAO Forest/ Other wooded land/ Other land classification is not applied in the NFI7 data. Thus, the area of poorly productive forest land was separately for mineral and organic soils divided into Forest land and Other wooded land. Same proportions as in NFI8 were applied.

Table 7.2_4. Proportion of IPCC land-use categories of land area in inventory mid-years.

	Inventory cycle	**Mid-year**	**Forest land**	**Cropland**	**Grassland**	**Wetlands**	**Settlements**	**Other land**
			Proportion of land area, %					
South Finland	NFI8	1988	73.9	15.5	0.8	3.4	5.7	0.8
	NFI9	1998	74.6	14.4	1.1	2.6	6.7	0.7
	NFI10	2005	74.9	14.2	0.7	2.6	7.1	0.6
North Finland	NFI7	1983	70.3	2.4	0.3	18.2	1.3	7.5
	NFI8	1993	70.0	2.6	0.5	17.5	2.1	7.3
	NFI9	2002	73.1	2.3	0.4	14.9	2.0	7.3
	NFI10	2005	70.5	2.5	0.6	17.3	1.9	7.2

Estimated proportions and official land area were applied to produce areas of land use categories. The National Land Survey of Finland gives annually the land area and inland water area, which Finland has elected to apply in GHG inventory as a total land area (Table 7.1_1). The obtained Cropland area was replaced with statistics on Cropland area (Yearbook of Farm Statistics), and the remnant area was summed to the area of Grassland. Peat extraction areas are classified in NFI as Settlements, therefore area on statistics was deducted from estimated area of Settlements and added to the Wetland area.

Area of mineral soils and peatlands (organic soils) on Forest land was also estimated as described above. These areas are given in Table 7.2_5.

Table 7.2_5. Areas of mineral soils and peatlands on Forest land in 1990–2005 (1 000 ha).

Year	**South Finland**		**North Finland**		**Total**
	Mineral soil	Peatland	Mineral soil	Peatland	
1990	8 775	2 682	7 297	3 206	21 961
1991	8 744	2 692	7 316	3 214	21 967
1992	8 713	2 702	7 335	3 223	21 973
1993	8 682	2 711	7 355	3 231	21 979
1994	8 673	2 728	7 364	3 276	22 041
1995	8 664	2 744	7 373	3 322	22 103
1996	8 655	2 761	7 382	3 367	22 165
1997	8 646	2 777	7 391	3 414	22 227
1998	8 635	2 793	7 398	3 459	22 285
1999	8 678	2 813	7 366	3 487	22 344
2000	8 721	2 833	7 335	3 515	22 403
2001	8 763	2 852	7 302	3 542	22 460
2002	8 807	2 872	7 269	3 569	22 518
2003	8 780	2 870	7 332	3 415	22 396

Year	South Finland		North Finland		Total
	Mineral soil	Peatland	Mineral soil	Peatland	
2004	8 752	2 866	7 393	3 264	22 275
2005	8 714	2 860	7 443	3 111	22 128

Increment of growing stock

The volume increment of the growing stock is estimated using measurements on field sample plots of the NFI (Table 7.2_6). For this submission, the data comes from NFI8, NFI9 and NFI10. The increment figures concern increment of the tree stem volume. An average increment of five years preceding the measurement time is applied (see Appendix 7).

For years 1990–2004, increment estimates are from NFI8 and NFI9. Increment estimate for whole country is a sum of increments of Forestry Centre regions. NFI8 and NFI9 progressed by Forestry Centre regions (see Figure 1, Appendix_7), and for each region, the increment from that inventory (NFI8 or NFI9) which is nearest the year at issue, was applied. The increment for 2005 is a NFI10 estimate.

The increment was sub-divided into the increments of trees on mineral soils and organic soils (Table 7.2_6). 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_1). FAO forest land is a sub-set of the previous one but includes in practice the entire increment of the growing stock. In the continuation, the negligible increment component on non FAO forest land will be taken into account. 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. This increment component is also very small but will consider in the continuation.

Table 7.2_6. Increment of growing stock in 1990–2005 (million m^3/yr).

	Mineral soils			Peatlands			Total
	pine	spruce	decid.	pine	spruce	decid.	
1990	25.0	23.5	11.3	8.1	4.0	5.5	77.5
1991	25.0	23.5	11.3	8.1	4.0	5.5	77.5
1992	25.3	23.2	11.5	8.3	4.2	5.5	77.9
1993	26.0	22.5	12.1	8.4	4.3	5.4	78.7
1994	26.1	21.8	12.3	8.6	4.3	5.3	78.4
1995	26.3	21.8	12.7	8.7	4.4	5.5	79.4
1996	26.3	21.8	12.7	8.7	4.4	5.5	79.4
1997	27.5	22.0	13.3	9.5	4.7	5.8	82.8
1998	29.1	22.3	13.7	10.1	5.0	6.1	86.3
1999	29.3	22.3	13.8	10.2	5.0	6.1	86.7
2000	29.3	22.3	13.8	10.2	5.0	6.1	86.7
2001	29.3	22.3	13.8	10.2	5.0	6.1	86.7
2002	29.3	22.3	13.8	10.2	5.0	6.1	86.7
2003	29.3	22.3	13.8	10.2	5.0	6.1	86.7
2004	29.3	22.3	13.8	10.2	5.0	6.1	86.7
2005	35.6	22.2	15.7	11.8	5.5	6.3	97.1

Drain of growing stock

Drain is the decrease in 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. Recently commercial removals have been 53–56 million m³ annually (Finnish Statistical Yearbook of Forestry 2006). 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 59 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 into those *harvesting losses*, including those from silvicultural measures, during 1966–71. The results were presented as per cents of the total felled stemwood volumes (cf. 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.

The volume of *unrecovered natural losses* was estimated by the NFI on the basis of the follow-up of some 3000 special NFI permanent sample plots from 1985 to 1995. The estimated unrecovered natural losses are 2.8 million m³/yr. Recently, the drain in total have been 68–70 million m³/yr.

This information on removals, fellings and drain are 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 for uplands and peatlands. 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 groups and separately for intermediate fellings and regeneration fellings as well as mineral soils and peatlands. These figures were estimated for years 1990–2005. The growing stock drain was take from the Forest Statistics Information Service databases (METINFO), also published in the Finnish Statistical Yearbook of Forestry. 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 growing stock was divided to strata of mineral soils and peatlands and to intermediate and regeneration fellings applying the yearly METINFO areas treated with fellings, the NFI9 estimates of proportions of felling types on mineral soils and peatlands, and the NFI9 estimates of average removals in intermediate and regeneration fellings.

1. The annual METINFO areas were divided to mineral soils and peatlands 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 METINFO growing stock drain (without natural removals) to the particular strata (Table 7.2_7).

As in the case of the increment, the drain of the growing stock is computed for the combined national 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., natural mortality of the trees is same as the increment of the trees. This means that the increment minus drain is about zero and does not affect the CO_2 balance of the growing stock.

Table 7.2_7. The drain in 1990–2005 (million m^3/yr).

Year	Mineral soils			Peatland			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	23.6	23.5	10.5	3.3	3.3	3.2	67.3

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 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_2). Mathematical formulations of the processes are described in Appendix 7 in the end of the Chapter 7. Before Yasso simulation three steps of preliminary preparations had to be done:

i) calculation of input data and division in three different decomposition compartments (non-woody litter, fine woody litter and coarse woody litter)
ii) estimation of the parameters to each decomposition compartment with environmental condition concerned (southern and northern part of Finland)
iii) estimation of the initial values of model state variables.

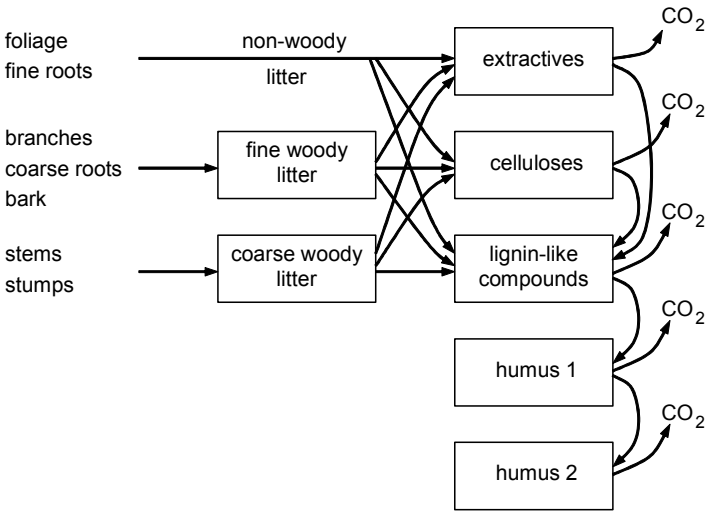


Figure 7.2_2. Flow chart of Yasso model.

Input data for the model consisted of annual litter production from living tree biomass, natural mortality of trees and harvesting residues. 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. Initial state of the model was estimated with l00 years initiating period, with reasonable and smoothly increasing litter input.

Soil organic matter included organic carbon in soils (including peat). The examined soil depth was not defined, instead the SOM stock was assumed to be described with 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 model compartments fine woody litter, coarse woody litter, extractives, celluloses and lignin-like compound.

Dead wood included the rest 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.

Stock changes in forest soil carbon were reported as 5 years moving averages.

Organic soils

Carbon stock changes in peatlands in above ground were estimated with Yasso model as in the mineral soils. Below ground stock changes were assessed only in drained peatlands, while below ground carbon stocks in undrained peatlands were assumed to be unchanged.

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 mortality. The decomposition of below ground SOM was estimated by multiplying the site-type-specific emission values (Minkkinen et al., manuscript, Table 7.2_8) by the corresponding area estimates provided by the NFI. Similarly as in mineral soils, tree litter compartments were produced from biomass data concerning drained peatlands. Annual litter production from ground vegetation was estimated according to Laiho et al. (2003, Table 7.2_9).

Table 7.2_8. Carbon emissions (g C m^{-2} a^{-1}) due to heterotrophic soil respiration from drained peatlands (Minkkinen et al., manuscript). For names of site types, see Laine (1989). A Finnish abbreviations of names are given in parenthesis.

Name of site type group	Area 2005 (1000 ha)	Average emission	stdev
Herb-rich type (Rhtkg)	768	425.7	25.7
Vaccinium myrtillus type (Mtkg)	1 102	312.1	20.2
Vaccinium vitis-idaea type (Ptkg)	1 709	242.3	15.6
Dwarf shrub type (Vatkg)	965	218.9	15.4
Cladina type (Jätkg)	35	185.2	9.1

Table 7.2_9. Litter production of ground vegetation in drained peatlands (milj. kg C km^{-2} 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	

Activity data

Biomass data for each tree compartment (except fine roots) was 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 years between the measurements linear interpolation was used. 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).

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

The litter production from each tree biomass compartment was calculated using litter production rate coefficients (Table 7.2_10) as follows

$$litter_i = r_i * W_i,$$

where r_i is litter production rate of compartment i and W_i is biomass of compartment i (kg). The litter production from ground vegetation in organic soils was estimated according to Laiho et al. (2003, Table 7.2_9). In mineral soils litter production from ground vegetation was not assessed due to the uncertainties related to estimation of its biomass compartments.

Natural mortality of trees was assessed from NFI measurements (see Chapter 7.2.2). The data consisted of stem volumes, which were converted to biomass with expansion factors (BEFs) presented by Lehtonen et al. (2004a). Harvesting residues were calculated from compiled statistics on fellings, including also estimates of domestic use of firewood (Finnish Statistical... 2006, METINFO). Harvested tree volumes were converted to biomass similarly as natural mortality data. Industrial energy consumption of harvesting residues was taken into consideration as a reduction in litter input for 2005 (Metsäenergian tuotannon... 2006). Both natural mortality and harvesting residues data were produced separately for mineral and organic soils.

Parameterisation of the Yasso model used in inventory was based on studies of Liski et al. (2005, 2006) and Peltoniemi et al. (2004) (Table 7.2_11). Different decomposition rates due to temperature differences was accounted for by simulating south and north Finland separately. The 50 years average temperature was used in parameterisation. Initial state of the model was estimated with a 100 years initiating period starting from year 1823 with assumption of having then 5 % smaller growing tree biomass stock than observed in year 1923. Straightforwardly litter production and natural mortality of trees were also assumed to be 5 % smaller in year 1823. Harvesting intensity in year 1823 was assumed to be half of the level observed in year 1923. In the beginning of the initiating period the model was in equilibrium state. The increase in growing stock and harvesting intensity was assumed to be constant in the initiating period. From year 1923 onwards the model was run with litter input estimated on the basis of activity data.

Table 7.2_10. Litter production rates from biomass compartments of trees (Liski et al. 2006, Starr et al. 2005, Lehtonen et al. 2004b, Muukkonen et al. 2004).

Tree species	Needles	Branches	Bark of stems	Bark of stumps	Roots >2mm	Fine roots
pine, south	0.245	0.02	0.0052	0.0029	0.0184	0.85
pine, north	0.154	0.02	0.0052	0.0029	0.0184	0.85
pine, drained peatlands	0.33	0.02	0.0052	0.0029	0.0184	0.85
spruce, south	0.1	0.0125	0.0027	0	0.0125	0.85
spruce, north	0.05	0.0125	0.0027	0	0.0125	0.85
deciduous, south	0.79	0.0135	0.0029	0.0001	0.0135	0.85
deciduous, north	0.79	0.0135	0.0029	0.0001	0.0135	0.85

Table 7.2_11. Parameters used in 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
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

7.2.3 Uncertainty and time series' consistency

Uncertainty for Carbon stock changes in living biomass

This section explains the preliminary assessment of uncertainty for the CO_2 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 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.) The calculation yields age class specific mass increments 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 an assumption that the off-diagonal elements of the covariance matrix are zero. This method and the assumption of uncorrelatedness is 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

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

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 used also 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*, *CC*). *DRAIN* and V[*DRAIN*] are 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 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 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

$$V[Crelease] \approx DRAIN^2 BEF^2 V[CC] + BEF^2 CC^2 V[DRAIN] + CC^2 DRAIN^2 V[BEF]. \quad (4)$$

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.

Table 7.2_12 Calculation explaining the uncertainty estimate for the net carbon sink due to tree growth and fellings in 2005.

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 NFI.

Age class	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]
Years	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	3 027	37 753	2 110	52 968	0.862	0.0338	1 572	16 991	1 355	96 206	0.544	0.0030	1 076	12 431	585	7 199
20-29	0.705	0.0010	8 827	165 491	6 223	163 844	0.860	0.0072	1 667	23 609	1 433	37 597	0.551	0.0017	1 437	18 482	792	9 183
30-39	0.710	0.0008	8 584	135 437	6 095	124 770	0.841	0.0033	2 482	46 230	2 087	52 783	0.554	0.0009	1 626	19 746	901	8 384
40-49	0.702	0.0012	7 463	135 952	5 239	134 530	0.820	0.0009	2 413	38 694	1 978	31 232	0.556	0.0005	2 028	29 526	1 128	11 042
50-59	0.701	0.0008	6 268	89 915	4 394	77 279	0.816	0.0008	2 339	29 105	1 908	23 867	0.552	0.0006	1 256	14 838	694	5 539
60-69	0.710	0.0008	4 633	70 382	3 290	51 688	0.791	0.0006	3 218	39 295	2 545	31 097	0.554	0.0010	1 063	11 900	589	4 803
70-79	0.708	0.0006	4 495	63 007	3 183	44 277	0.784	0.0005	3 075	42 603	2 411	31 109	0.545	0.0005	525	6 554	286	2 096
80-89	0.707	0.0008	3 797	45 807	2 684	34 309	0.777	0.0005	2 696	34 889	2 095	24 858	0.545	0.0005	374	3 717	204	1 180
90-99	0.704	0.0008	2 793	34 716	1 966	23 579	0.782	0.0007	1 737	18 642	1 358	13 495	0.544	0.0008	270	2 993	147	946
100-119	0.703	0.0005	3 175	28 288	2 232	18 925	0.784	0.0005	2 044	20 767	1 603	14 678	0.544	0.0008	158	1 450	86	450
120-139	0.698	0.0008	1 635	14 024	1 141	9 097	0.782	0.0013	913	8 401	714	6 206	0.544	0.0008	58	520	31	157
140-	0.690	0.0008	2 137	22 010	1 474	14 222	0.788	0.0007	1 515	27 311	1 194	18 616	0.544	0.0008	20	98	11	29
Total			56 835	842 783	40 032	749488			25670	346536	20682	381744			9890	122255	5453	51009

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

Dominant	INC	V[INC]	DW	V[DW]	CC	V[CC]	C-uptake	V[C-uptake]
Species	1000 m^3	$(1000\ m^3)^2$	Gg	$(Gg)^2$			Gg	$(Gg)^2$
Pine	56 835	842 783	40 032	749 488	0.519	0.00067	20 776	1 281 028
Spruce	25 670	346 536	20 682	381 744	0.519	0.00067	10 734	390 876
Deciduous	9 890	122 255	5 453	51 009	0.505	0.00064	2 754	31 964
Total	92 395	1 311 574	66 166	1 182 241			34 264	1 703 868

Table 7.2_12 continue

Table 7.2_12 continue

Step 2. Estimate C-release and its variance.
Step 2.1. Start with the drain estimates and their variance (Finnish Statistical Yearbook of Forestry 2006 and Sevola 2005).

Drain component	DRAIN 1000 m^3	V[DRAIN] $(1000\ m^3)^2$
Commercial felling	52 572	0.277
Contract sawing	940	0.003
Firewood	5 172	0.067
Harvesting losses	5 742	0.330
Natural mortality	2 900	0.084
Total	67 326	0.761

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 1000 m^3	V[DRAIN] $(1000\ m^3)^2$	BEF Mg/m^3	V[BEF] $(Mg/m^3)^2$	CC	V[CC]	C-release Gg	V[C-release] $(Gg)^2$
67 326	0.761	0.716	0.0002	0.518	0.00046	24 967	1 337 148

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] $(Gg)^2$
34 264	1 703 868	24 967	1 337 148	9 297	3 041 016

Step 4. Conclusions.
Step 1,2 and 3 yield following relative standard errors:

C-uptake 3.8 %
C-release 4.6 %
Net C-uptake 18.8 %

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 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 and litter data. The initialisation effect decreased significantly after few years simulation. Peltoniemi et al. reported standard deviation to be 2.6 Tg C a^{-1} in analysing carbon stock changes of Finland 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. 2005) was added to the uncertainty of simulated results, producing uncertainty estimate 1.3 Tg C a^{-1} in mineral soils.

Further, the uncertainty in estimating the decomposition of peat on drained peatlands, basing on the standard deviation of emission coefficients reported by Minkkinen (manuscript) (see Table 7.2_12), was added to the total variance estimate. The rate of decomposition of moss litter, being formed partly from Sphagnum species and partly from other moss species, is not known well enough and the parameters applied in the Yasso model may result in over estimated rates of decomposition.

Time series' consistency

Areas of Forest land, Grassland, Wetlands, Settlements, and Other land have been recalculated for the year 2005 only.The whole time serie will be updated to 15th March submission. The area estimation method was changed. The reasons for this were i) the new method takes advantage of both old and new NFI data, and ii) it avoids abrupt leaps due to the change from one set of NFI data to an other. This method will be applied in future for more accurate Forestry Centre regions when more NFI10 data will become available.

Forest land area and growing stock increment estimates base on NFI assessments. The definitions of national land classes (see Appendix 7) have stayed same in different inventories as well tree measurement techniques. Some uncertainty is in the Forest land area time series anyhow. After two years measurements in NFI9, the FAO definition 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 NFI9 filed assessment and measurements. For 1990–2004 data of whole inventory periods of NFI8 and NFI9 were applied, that is about 66 000 filed plots on forestry land. For 2005 estimates only two fifth of all field plots of NFI10 are applied.

7.2.4 Source-specific QA/QC and verification

Quality control for category Forest land includes the QC measures based on IPCC (IPCC 2000, Table 8.1).

National Forest Inventory data have gone through 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 to old ones.
3. Before field surveying, field personnel has had a training period to ascertain
   - that measurers are able to use equipments 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 were checked
   - that all sample plots are measured
   - that no required information is missing
   - to find errors (if find 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 to results of previous inventories. If big or unexpected changes were find, reasons for that were clarified and explained.

A quality manual for NFI is in preparation.

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

7.2.5 Source-specific recalculations

Time series for Forest land area was recalculated. In the previous submission, area of Forest land was estimated by Forestry Centre regions from NFI8 and NFI9 data, that means in two time points. The area of each region which was the nearst to inventory year was counted in. Due to the method, there seemed not to be any change in areas in 1990–91 (all NFI8 data) and 1999–2004 (all NFI9).

In this submission, also NFI7 data and new NFI10 data are applied (see Appendix 7 e.g. for differences between NFI9 and NFI10). Proportions of land use categories, instead of actual areas, were estimated from

NFI data for South and North Finland. Proportions for all inventory years were interpolated linearly between NFI mid-years. This method produce smoother time series than previous method.

7.2.6 Source-specific planned improvements

The main improvement object is to distinguish areas converted from other land use categories to Forest land from areas remaining Forest land. The aim is to report converted areas in the submission 2008 to the UNFCCC.

In this submission, data from two years' measurements of NFI10 were applied for 2005. Thus, reliable results were able to estimate only for large regions, like South and North Finland. More data will be available as NFI10 progress, and this enables to calculate estimates for smaller regions, e.g. Forestry Centre regions. In NFI10 the measurements are carried out in whole country every year, and updated forest land area and tree biomass results are possible to compute annually from this submission onwards.

Biomass models for pine, spruce and deciduous trees are developed for Finland. The models were not yet available for this submission because testing of them is unfinished. Implementation of new biomass models causes changes in estimation of carbon stock chages in living biomass. The question under consideration is, are the biomass models appropriate enough to estimate increment of biomass? Or is the Method II, stock change method, more proper? At the moment, research work is carried out to solve this problem. The new or improved current method will be applied in the 2008 submission.

The uncertainty assessments for changes of all biomass pools are under development, and are expected to be available by 2008.

7.3 Cropland (CRF 5.B)

7.3.1 Source category description

The area of cropland comprises of the area under grass (≤ 5 years), other crops and set-aside. Permanent horticular crops, greenhouses and kitchen gardens are classified also to Cropland category. The CO_2 emissions from cultivation of mineral and organic soils and agricultural lime application are reported under the category CO_2 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 CO_2 emitted from soils is dependent on soil carbon balance. Soil carbon balance is affected e.g. by the type and amount of organic material input, disturbance, soil properties and climatic variables (IPCC, 1997). Soils may act as sources of or sinks for CO_2 depending on the conditions. Agricultural practices and lime application affect the amount of CO_2 released from agricultural soils.

7.3.2 Methodological issues

Methods

Cropland

CO_2 emissions from cropland remaining cropland are calculated by using methods described in IPCC (2003). Emission estimates of net changes in carbon stocks of from mineral and organic soils are included as well as CO_2 emissions from liming.

Mineral soils

Calculation of CO_2 emissions from mineral soils is based on changes in the carbon stocks resulting from changes in land use and management activities in the period of 20 years (IPCC 2003). 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. The reference carbon stock of each category is multiplied with the respective carbon stock change factor. Changes in carbon stocks of all categories are summed to gain the net carbon stock change. CO_2 emissions for each inventory year are calculated by multiplying the carbon stock change during a 20 year time period with -1 and the coefficient 44/12 and dividing this by 20.

Organic soils

Emissions from organic soils are calculated using the following equation (IPCC 2003):

$$\Delta C_{ccOrganic} = A * EF$$

$\Delta C_{ccOrganic}$ = Annual CO_2 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 CO_2 by multiplying with 44/12.

Liming

The emissions from liming have been calculated using the IPCC method (IPCC 2003) and data from the Finnish Liming Association. Limestone ($CaCO_3$), dolomite ($MgCa(CO_3)_2$) 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 is taken into account in the calculations. Carbon is converted to CO_2 by multiplying with 44/12.

Emission factors and other parameters

Mineral soils

Reference carbon stocks are based on soil analysis data from a soil survey (Mäkelä-Kurtto and Sippola 2002). 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_1.).

Table 7.3_1. Carbon stock change factors used in calculating CO_2 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

[a]Stock change factor for land use or land-use change type.
[b]Stock change factor for management regime
[c]Stock change factor for input of organic matter

Organic soils

For calculating CO_2 emissions from cropland on organic soils, national emission factors are used for organic soils under grass or other crops (Table 7.3_2).

Table 7.3_2. Emission factors used for calculating CO_2 emissions from cropland on organic soils.

Emission source	**EF (t C/ha/a)**	**Reference**
Grass	4.1	Maljanen et al. (in press)
Other crops	5.7	Maljanen et al. (in press)

Liming

IPCC default emission factors are used for calculating CO_2 emissions from agricultural lime application The emission factors are 0.12 from limestone and 0.13 for dolomite and 0.12 for briquette lime (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.

Activity data

Mineral soils

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 garden is not estimated and these areas are reported in the category Other land. The area of mineral cropland soils is the area remaining after the proportion of organic soils 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_3.). 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 loose 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 laboratory performing such analyses in Finland (Viljavuuspalvelu Oy). 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 is based on expert judgement (Mikkola et al. 2005) as well as the area of reduced tillage (Smith et al. 2004). 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_3. Distribution of areas of soil types, management and input on mineral cropland soils (kha).

	1970	1980	1990	2000	2005
Sandy soils	1454.37	1340.18	1283.12	1235.54	1262.44
Crops	1427.36	1282.38	1179.83	1133.22	1126.27
Full tillage	1427.36	1210.52	1036.19	894.96	813.41
Medium input	1427.36	1210.14	1033.08	835.00	754.85
High input	0.00	0.38	3.11	59.96	58.57
Reduced tillage	0.00	71.57	143.13	214.70	250.48
No-till	0.00	0.30	0.51	23.56	62.38
Fallow	27.01	57.80	103.28	102.32	136.17
High activity soils	480.42	542.49	622.29	650.17	698.35
Crops	471.50	519.09	572.20	596.33	623.03
Full tillage	471.50	490.00	502.53	470.95	449.96
Medium input	471.50	489.85	501.02	439.39	417.56
High input	0.00	0.15	1.51	31.55	32.40
Reduced tillage	0.00	28.97	69.42	112.98	138.56
No-till	0.00	0.12	0.25	12.40	34.51
Fallow	8.92	23.40	50.09	53.84	75.32

Organic soils

The development of the area estimate for organic soils for the years 1990-2003 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. Grass is estimated to be grown on 50 % of the organic soils, and the rest is mainly cereals.

Liming

The amount of lime sold annually has been used as activity data (Table 7.3_4). 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_4. The amount of lime sold annually for the agriculture and estimated to be applied to Finnish fields in 1990-2003 (1000 t/year) (Source: Finnish Liming Association).

Year	Limestone+briquette lime	Dolomite
1990	630.96	713.81
1991	432.95	505.18
1992	435.52	170.55
1993	706.92	287.60
1994	708.98	286.68
1995	610.12	245.92
1996	713.80	291.82
1997	739.33	297.68
1998	675.35	273.71
1999	677.29	274.47
2000	515.98	207.41
2001	623.51	252.82
2002	665.60	271.19
2003	439.12	177.09
2004	400.44	158.52
2005	420.70	167.10

7.3.3 Uncertainty and time series' consistency

Cropland

Uncertainty in the area of organic cropland was estimated at ±30% for 1990 and ±20% for 2003 based on expert judgement. The uncertainty estimate for the CO_2 emission factor for organic soils was ±90% according to 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 area estimates in the category Cropland are mainly based on the Yearbook of Farm Statistics published by the Information Center of the Ministry of Agriculture and Forestry each year and thus the time series can be considered consistent. However, there are subdivisions like the area 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 in of minor importance.

Liming

The uncertainty in activity data for liming is estimated at ±20% based on expert judgement. The uncertainty estimate for 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 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 amounts applied, it causes some additional uncertainty in this emission source category.

7.3.4 Source-specific QA/QC and verification

QA/QC plans for Cropland and CO_2 emissions from agricultural lime application include the QC measures based on 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.

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

No recalculation has been done.

7.3.6 Source-specific planned improvements

As CO_2 emissions from agricultural soils have been recognized as a key category, more focus should be put into developing the inventory of this source category. Currently there is not enough data from mineral soils in order to use process-based models for estimating carbon stock changes from cropland.

Areas converted to cropland will be included in the next inventory. The distribution of cultivated organic soils into different crop types should be checked and updated if necessary.

7.4 Grassland (CRF 5.C)

7.4.1 Source category description

The area of grassland comprises of grasslands and meadows more than five years old together with the abandoned agricultural area which can not yet be included in the forest category. Small roads and other small areas with tree cover inside cropland are also placed to the Grassland category. The ground for this is that these areas fit best into Grassland category by their characteristics.

Only CO_2 emissions from grasslands remaining grasslands are reported in this source category currently since no estimates of areas converted to grasslands are available.

The amount of CO_2 emitted from soils is the result of changes in the carbon stocks of the soils. Soil carbon balance is affected e.g. by the type and amount of organic matter input, disturbance, soil properties and climatic variables (IPCC, 1997). Soils may act as a source or sink of CO_2 depending on the conditions.

7.4.2 Methodological issues

Methods

Mineral soils

CO_2 emissions from grassland remaining grassland on mineral soils are calculated by using methods described in Chapter 3 of Good Practice Guidance for Land Use, Land-Use Change and Forestry (Equation 3.4.9B in IPCC 2003).

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 of the IPCC (IPCC 2003) are multiplied with the stock change factors. 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 methodology used corresponds to the Tier 1 level method of IPCC GPG LULUCF. There is no data currently available for higher tier methods. The carbon stock change factors used represent the average management of these soils which range from abandoned fields to pastures fertilized with manure. Division to different categories based on the intensity of management is not currently possible.

Organic soils

Emissions from organic soils are calculated using the following equation (IPCC 2003):

$\Delta C_{ccOrganic} = A * EF$

$\Delta C_{ccOrganic}$ = Annual CO_2 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 CO_2 by multiplying with 44/12.

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.

Emission factors and other parameters

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 fertilized with manure.

For organic soils the default emission factor of 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).

Activity data

The area estimate of grasslands was derived as described in chapter 7.2.2. Permanent grasslands and pastures are included in the source category, not grass cultivated as part of a crop rotation. The abandoned agricultural areas are included in this category before conversion to forests. The division to high activity and sandy soils is done according to the description in the section 7.3 Cropland. The percentage of organic soils is assumed to be the same as that on cropland soils.

Table 7.4_1. Distribution of areas of soil types on grassland soils (kha).

	1970	**1980**	**1990**	**2000**	**2005**
Sandy soils	334.65	431.79	364.70	275.58	294.04
High activity soils	110.55	174.78	175.93	145.01	162.84
Organic soils	147.11	157.66	104.86	67.16	63.55
Total	592.3	764.2	645.49	487.75	520.43

7.4.3 Uncertainty and time series' consistency

Uncertainty in the area of organic grassland was estimated at ±30% based on expert judgement. The uncertainty estimate for the CO_2 emission factor for organic soils is ±90% according to 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 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 considered to include also the area of grasslands during 1970-1989 there actually is no big difference in practice.

7.4.4 Source-specific QA/QC and verification

QA/QC plan for LULUCF category (Cropland, Grassland) includes the QC measures based on 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.

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

No recalculation has been done.

7.4.6 Source-specific planned improvements

The emissions from land converted to grassland will be added in the next inventory.

7.5 Wetland (CRF 5.D)

7.5.1 Source category description

In Category CRF 5.D.2.5 (Other Land converted to Wetlands) Finland reports CO_2 N_2O and CH_4 emissions from peat extraction fields. N_2O and CH_4 emissions from peat extraction are reported in Category CRF 5 (II) Non-CO_2 emissions from drainge of wetlands. However, description of method and activity data of all the three gases related to peat extraction fields are given in this chapter. These emissions comprise of the emissions arising 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 peat extraction have been rather stable during the whole time series from 1990-2005.

Emissions follow directly the changes in annual area under the peat production.

Table 7.5_1. Greenhouse gas emissions from the peat extraction in 1990-2005 (Gg CO_2 eq.)

Year	CO_2	CH_4	N_2O	Total
1990	585	6	8	599
1991	593	6	8	607
1992	618	6	8	633
1993	628	7	8	643
1994	648	7	9	663
1995	655	7	9	670
1996	668	7	9	683
1997	679	7	9	694
1998	677	7	9	693
1999	683	7	9	699
2000	678	7	9	693
2001	669	7	9	685
2002	692	7	9	708
2003	637	7	8	652
2004	609	6	8	623
2005	687	7	9	702

Key categories

CO_2 emissions from peat extraction were found to be a key category in 2005 based on level assessment.

7.5.2 Methodological issues

Methods

The emissions are calculated by multiplying area estimates with national emission factors. Annual activity (area) data is calculated from the data received from the Association of Finnish Peat Industry and the Finland's environmental administration (Regional Environmental Center of North Ostrobothnia). Emissions of stockpiles and ditches are included in the calculations.

Emission factors and other parameters

CO_2 emission factor describing the changes in soil organic matter due to oxidation of peat in the aerobic layer on the land during the peat extraction is from the Finnish research programme "Greenhouse Impacts of the Use of Peat and Peatlands in Finland" (2002 - 2005).

Carbon dioxide evolution from the soil follows to a large extent the dynamics of the soil surface layer temperature and soil moisture. Therefore, a statistical relationship of CO_2 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) CO_2 emission controlled by temperature and soil moisture regimes 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 CO_2 emissions for several static summertime water table values separately in order to find reasonable extreme values (close to minimum and maximum) for the emissions integrated over the year.

Emission factors for CO_2 were computed for 11 locations (weather stations) in Finland. The locations were pooled into climatic zones and the corresponding summertime CO_2 emissions averaged over the zone. Three zones were defined: North boreal, Middle boreal and South boreal. Separate CO_2 emission factors are provided for North boreal, Middle boreal and South boreal vegetation zones (water table 40 cm) (Table 7.5_2).

Greenhouse gas emission data in the current delivery was originally collected during the Silmu research programme 1991 and 1992. Most of the data were collected in the research programme "GHG-emissions from the use of peat and peatlands in Finland"

The data from measurements used in the estimation of the emission factors are still very sparse and will be improved when new data is available. The result of the research programme will be published in the end of the 2006 in Boreal Environmental Research.

Emission factors for stockpiles and ditches as well as emission factors for CH_4 and CH_4 are based on national measurements (Nykänen et al 1996) (corrected with IPCC 1995 GWP).

Table 7.5_2. Emission factors used in calculation of emissions from peat production sites (kg CO_2 eq /ha/year).

	Surface flux/North boreal	Surface flux/Middle boreal	Surface flux/South boreal	Stockpiles	Ditches
CO_2					
Peat production area	6020	7210	7350	1750	90
Abandoned (non- vegetated) area	4640	5040	5070		
CH_4	50	50	50	-	46
N_2O	120	120	120		0.5

Activity data

Industrial peat production area includes active and temporarily set-aside peat extraction fields and abandoned, non-vegetated emptied peat extraction areas (Table 7.5_3). Three percent of the Finnish peat production areas is situated in north boreal, 65% in middle boreal and 32% in south boreal vegetation zone (Source: VAPO, Association of Finnish Peat Industry).

The area data for the years 1990-2004 come 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 the small producers, which are not member of the Association of Finnish Peat Industry, thus the area data had to be complemented with the missing share of the small

producers. The share of small producers was estimated from the environmental license system of Finland's environmental administration, which cover all the peat producers in Finland. The share of small producers was estimated as 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 year 2005 has been obtained from the new inquiry, which take better in the account the information needs of the greenhouse gas inventory, Finland's environmental administration, and the Association of Finnish Peat Industry and covers all the peat producers in Finland. This inquiry is conducted by the Regional Environmental Center of North Ostrobothnia.

Table 7.5._3. Area of industrial peat production including abandoned, non-vegetated production areas in Finland in 1990-2005 (1000 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	70.2	2.5	72.6
1995	70.4	3.5	73.8
1996	71.0	4.7	75.8
1997	71.7	5.6	77.3
1998	71.6	5.6	77.2
1999	72.4	5.4	77.8
2000	72.1	4.8	76.9
2001	71.3	4.5	75.8
2002	74.0	4.1	78.1
2003	68.3	3.5	71.9
2004	65.0	3.8	68.9
2005	75.1	9.3	84.4

7.5.3 Uncertainty and time series' consistency

The uncertainty in fugitive emissions from fuels is very high due to uncertainties in emissions from peat production. The total uncertainty in fugitive emissions is estimated at -70 to +170% and that of solid fuels at -80 to +210%. Uncertainty associated with peat production area is estimated at ±15%. The uncertainty estimate covers possible errors or misunderstanding in responses to the survey.

CO_2 emission factor that is based on recent measurement data is taken at use for the first time for this inventory submission. But, the same uncertainties for CO_2 and CH_4 emission factors are used as in previous inventory submissions. The current uncertainty estimate (up to +200%) may overestimate uncertainties.

Area data for years 1990-2004 is based on one-time questionary and data for the earlier years is propably not as accurate as for the most recent years. However history data is best, what is available. Data for the 2005 is based on new questionary, which will be conducted annually. It takes into account all the peat producers, also small ones.

7.5.4 Source-specific QA/QC and verification

Normal statistical quality checking related to assessment of magnitude and trends has been carried out.

7.5.5 Source-specific recalculations

No recalculations were made.

7.5.6 Source-specific planned improvements

Emission factors will be revised, if necessary, when new national measurement data becomes available. The area data will be received from the next submission on from the improved inquiry of the Finland's environmental administration which covers all the peat producers in Finland and take into account the needs of greenhouse gas inventory.

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 comprises uplands, that do not fulfil the threshold values for Forest land (see 7.1 Overview of the sector). Area estimates base on the national forest inventory data (Table 7.6_1). The method applied to area estimation is same as for Forest land, and it is described in chapter 7.2.2 Methodological issues, Forest land area. The area time series for Settlements and for Other land are recalculated due to the new method applied for area estimation.

The emissions from land conversion to Settlements and Other land is 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.

Table 7.6_1. Areas of settlements and other land in 1990–2005 (1000 ha).

Year	Settlement	Other land
1990	1130	1212
1991	1156	1208
1992	1181	1205
1993	1207	1202
1994	1218	1200
1995	1230	1199
1996	1242	1197
1997	1254	1196
1998	1267	1194
1999	1273	1193
2000	1280	1191
2001	1287	1190
2002	1291	1188
2003	1299	1183
2004	1304	1178
2005	1293	1171

7.7 Non-CO_2 emissions

7.7.1 Direct N_2O emissions from fertilisation (CRF 5 (I))

7.7.1.1 Source category description

This source category cover the direct nitrous oxide emissions from forest fertilisation (CRF 5 (I)) (Figure 7.7_1) Forest fertilisation are distinguished between growth and forest vitality fertilisations. Nitrogen fertilisers are mainly used for increase growth. There are fertilisers only applied to forest and fertilisers, like salpetre and urea, both in agriculture and forestry use. The amount of these two fertilisers used in forestry is the expert judgement. The volume of fertilisation has halved since 1990.

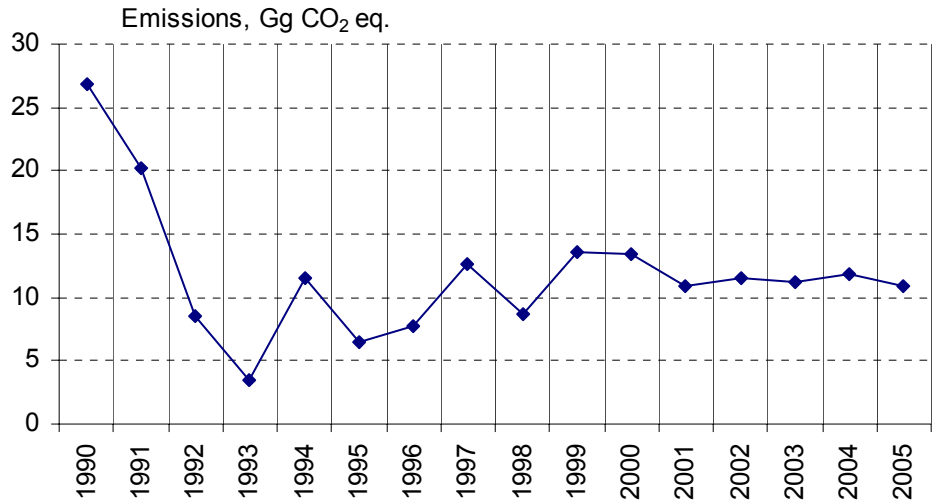


Figure 7.7_1. N_2O emissions from forest fertilisation (Gg CO_2 eq.).

7.7.1.2 Methodological issues

Methods

The IPCC default method (Tier 1) is used to estimate N_2O emissions from forest fertilisation (IPCC 2003). The 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, of which the amount of nitrogen is derived (Table 7.7_2.). The information is produced by Finnish company Kemira GrowHow Oyj. This company delivers almost 100 % of fertilisers applied to forest.

Table 7.7_2. The estimated amount of nitrogen (N) applied to forest in 1990–2005 (1000 kg/year) (Source: Kemira GrowHow Oyj).

Year	N (1000 kg/year)
1990	4404
1991	3324
1992	1408
1993	565
1994	1897
1995	1066
1996	1262
1997	2063
1998	1423
1999	2220
2000	2200
2001	1800
2002	1900
2003	1850
2004	1957
2005	1800

7.7.1.3 Uncertainty and time series' consistency

For the estimation of uncertainties, the same estimates for activity data (±10%) and emission factor (-90 to +380%) were used as in the Agriculture sector.

7.7.1.4 Source-specific QA/QC and verification

General Quality Control procedures (Tier 1)

- The conversion factors and units are checked through calculation system.
- Assumptions and expert judgements are reported.
- The data and calculation system is archived.
- Time series are calculated consistently.
- The estimates are compared to previous estimates.

7.7.1.5 Source-specific recalculations

No recalculations have been made.

7.7.1.6 Source-specific planned improvements

No improvement plan at the moment.

7.7.2 N_2O emissions from drainage of soils (CRF 5 (II))

In this submission Finland reports in the CRF table 5 (II) non-CO_2 emissions, that is N_2O and CH_4, from peat extraction areas. Source category description and methodological issues are given in the 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. At this point sufficient information is not available to prepare Finnish estimates.

7.7.3 N_2O emissions from disturbance associated to land use conversion to cropland (CRF 5 (III))

This source category is not so far included in reporting due to the lack of reliable area data. These emissions will be included to 2008 inventory submission.

7.7.4 Biomass burning (CRF 5 (V))

7.7.4.1 Source category description

This source category includes greenhouse gas emissions (CO_2, CH_4, N_2O, NO_x and CO) from biomass burning on forest land comprising wildfires and controlled burnings (Table 7.7_3). Restoration burnings carried out to increase biodiversity are excluded from this report. At the moment complete statistics on burned areas is not available. The area statistics on wildfires is compiled by the Ministry of Interior and it bases on information given by rescue authorities. On 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 categories, 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_3. Emissions from biomass burning (Gg).

Year	CO_2	CH_4	CO	N_2O	NOx
1990	48.04	1.52	13.32	0.01	0.38
1991	25.02	0.66	5.74	0.00	0.16
1992	122.00	1.30	11.40	0.01	0.32
1993	0.00	0.39	3.41	0.00	0.10
1994	91.80	1.02	8.91	0.01	0.25
1995	60.86	0.82	7.17	0.01	0.20
1996	54.73	0.60	5.27	0.00	0.15
1997	136.53	1.00	8.74	0.01	0.25
1998	11.18	0.29	2.51	0.00	0.07
1999	73.40	0.82	7.15	0.01	0.20
2000	44.06	0.39	3.45	0.00	0.10
2001	22.03	0.94	8.21	0.01	0.23
2002	69.51	1.08	9.43	0.01	0.27
2003	84.83	0.85	7.45	0.01	0.21
2004	41.34	0.27	2.35	0.00	0.07
2005	57.63	0.63	5.55	0.00	0.16

CO_2 emissions are reported only from wildfires. CO_2 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. The equation 3.2.9 was used to estimate annual losses of carbon and equation 3.2.19 to estimate non-CO_2 emissions from carbon released (IPCC 2003).

Wildfires

Mean volume of growing stock on forest land by tree species was estimated from NFI data (Table 7.7_4.). Volumes were converted to dry weight of biomass by stand-level biomass expansion factors (Lehtonen et al., 2004a).

Table 7.7_4. Mean volume (m^3 ha^{-1}) and biomass (tonnes d.m. ha^{-1}).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Scots pine																
Volume	39.4	39.4	40.4	41.1	42.2	42.5	42.5	43.5	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3
Biomass	22.7	22.7	23.3	23.7	24.3	24.5	24.5	25.0	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
Norway spruce																
Volume	31.7	31.7	32.1	31.8	31.3	31.3	31.3	30.9	30.8	30.9	30.9	30.9	30.9	30.9	30.9	30.9
Biomass	20.0	20.0	20.2	20.1	19.8	19.7	19.7	19.5	19.4	19.5	19.5	19.5	19.5	19.5	19.5	19.5
Broad-leaved trees																
Volume	15.3	15.3	15.8	16.5	16.8	17.0	17.0	17.3	17.5	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Biomass	11.3	11.3	11.6	12.1	12.3	12.5	12.5	12.8	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9

The biomass of under story was added in 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 an expert judgement[*] and it was assumed that 30 % of biomass would burn. The 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 includes also fires on treeless wetlands, but biomass burned is estimated applying mean volume of growing stock of forest land. The activity data came from statistic compiled on burned area and it is annually published in the Forest Statistical Year Book.

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 growing stock on these sites were estimated basing on NFI data of mature stands. Estimates were made separately for South and North Finland.

The volume of cutting residues was calculated multiplying mean volume by dry crown mass. Used crown mass (d.m. kg) per mean volume (m^3) after final cut of mature stand were (Hakkila 1991):

	South Finland	North Finland
Scots pine	82.1	107.4
Norway spruce	164.4	217.5
Broad-leaved trees	82.8	120.1

[*] Ilkka Vanha-Majamaa and Raisa Mäkipää, Finnish Forest Research Institute

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 the expert judgement* that 30 % of the bottom layer would burn and 50 % both of the field layer and the tree biomass. The default carbon fraction (50 %), emission ratios and N/C ratio were used.

The activity data came from statistic compiled on burned area and it is annually published in the Forest Statistical Year Book.

Emission factors and other parameters

Default emission factors from GPG LULUCF (IPCC 2003) were applied, namely 0.012 for CH_4, 0.007 for N_2O, 0.121 for NO_x and 0.06 for CO. For N/C ratio also IPCC default value of 0.01 was used.

Activity data

Time series of burned area base on the areas of prescribed burnings and wildfires published annually in the Finnish Statistical Year Book (Table 7.7_5). The source of wild fires is the Ministry of the Interior. Area of prescribed burnings bases on the information compiled from forestry organisations and companies who carries out prescribed burnings. Statistics is compiled by the Finnish Forest Research Institute.

Table 7.7_5. Burned forest area in 1990–2005 (ha).

Year	Wildfires	Controlled burning
1990	434	3754
1991	226	1445
1992	1081	2047
1993	0	963
1994	798	1668
1995	526	1395
1996	473	896
1997	1171	1183
1998	95	622
1999	623	1322
2000	374	472
2001	187	2286
2002	590	2010
2003	720	1343
2004	351	216
2005	489	1065

7.7.4.3 Uncertainty and time series' consistency

Uncertainty in activity data (area) for biomass burning is estimated at ±10% based on expert judgement. Uncertainties in emission factors (±70%) are based on IPCC Good Practice Guidance for LULUCF (IPCC, 2003).

* Ilkka Vanha-Majamaa and Raisa Mäkipää, Finnish Forest Research Institute

7.7.4.4 Source-specific QA/QC and verification

General QC procedures (Tier 1)

- the conversion factors and units are checked through calculation system
- assumptions and expert judgements are reported
- the adequacy of documentation for internal use is checked and to facilitating reviews
- the data and calculation system is archived
- recalculation methods are checked
- time series are calculated consistently
- the overlapping with other sources has been taken into consideration and it is reported
- the estimates are compared to previous estimates. Slight changes are detected due to recalculations

7.7.4.5 Source-specific recalculations

Calculation method of controlled burnings was corrected, in previous submission the burned forest biomasses of South and North Finland were counted twice.

7.7.4.6 Source-specific planned improvements

To complete the activity data, the restoration burnings will be added on the inventory when the data is available for whole country.

Appendix_7

National forest inventory

National Forest Inventory (NFI) is a sampling based forest inventory and it covers all land-use classes. Sampling design has been fitted to the variability of land-use classes and variation of the structure of the growing stock in the different parts of Finland. The first inventory was carried out in 1921–1924, and since the 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 carried out as line surveys, whereas in latter inventories sample plots are located in clusters.

Until the 10th inventory NFIs proceeded region by region (region of a Forestry Centre, Fig. 1), and the inventory cycle was 8–10 years. In NFI10 the cycle is five years and measurements are carried out in whole country every year, that is 20% of sample plots are measured every year (Fig. 1_App_7). In NFI9, the country was divided in six sampling regions, between areas the distance between clusters varies, as well as the number of sample plots in cluster and distance between sample plots (Fig. 2_App_7). South Finland comprises sampling regions 1, 2, and 3, and North Finland regions 4, 5, and 6. The distances between clusters and distance between sample plots in NFI9 and NFI10 are given in Table 1. The shape of clusters in NFI 9 are presented in Figure 3_App_7, and in NFI10 in Figure 4_App_7.

Inventory years of three previous NFIs are NFI7 1977–1984, NFI8 1986–1994 and NFI9 1996–2003.

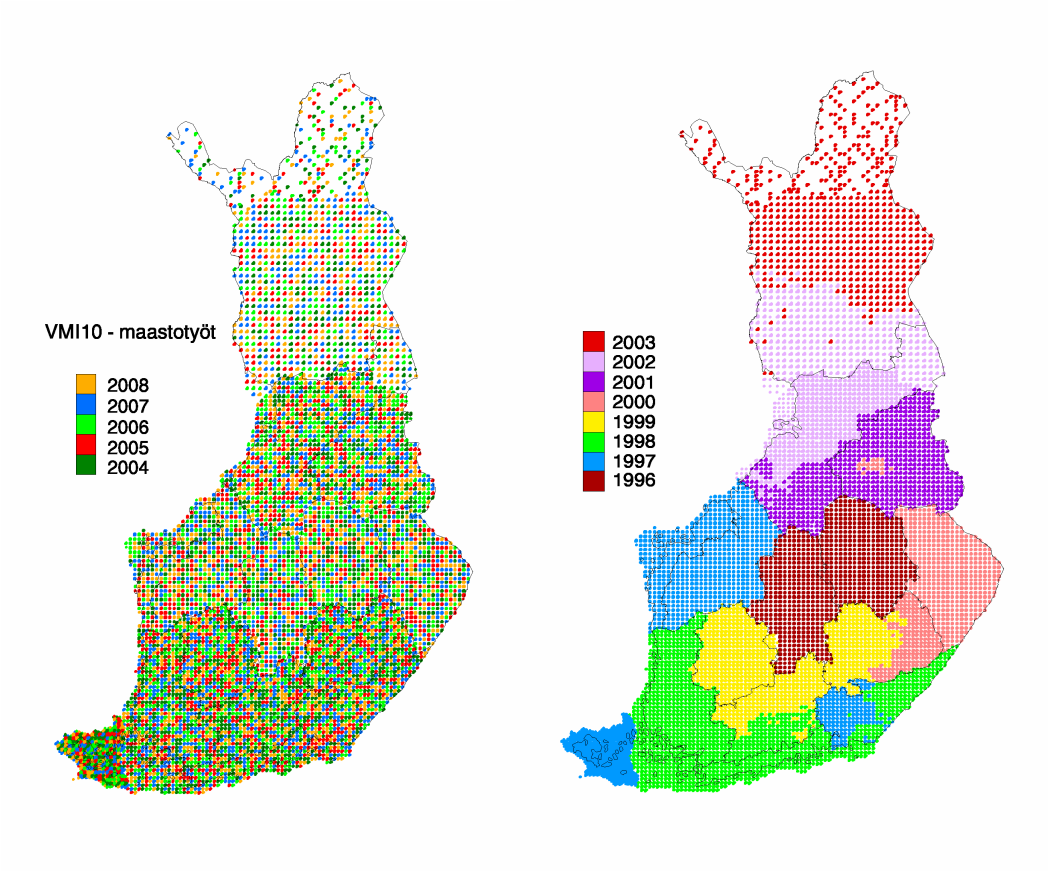


Figure 1_App_7. Field inventory years in NFI9 and NFI10.

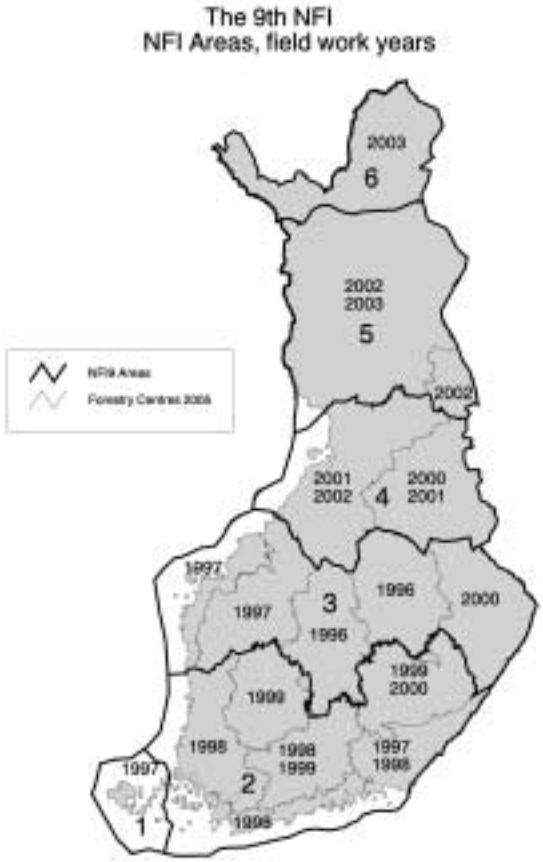


Figure 2_App_7. Six sampling regions of NFI9 with forestry centre boundaries & inventory years.

Table 1_App_7. Sampling regions and their parameters in 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 amount of temporary clusters.
2) Stratified sampling: sampled area was first divided into 6 strata according to the percentage of forests. Stratification was based on the forest maps produced by the multi-source NFI using satellite imagery and NFI8 data.

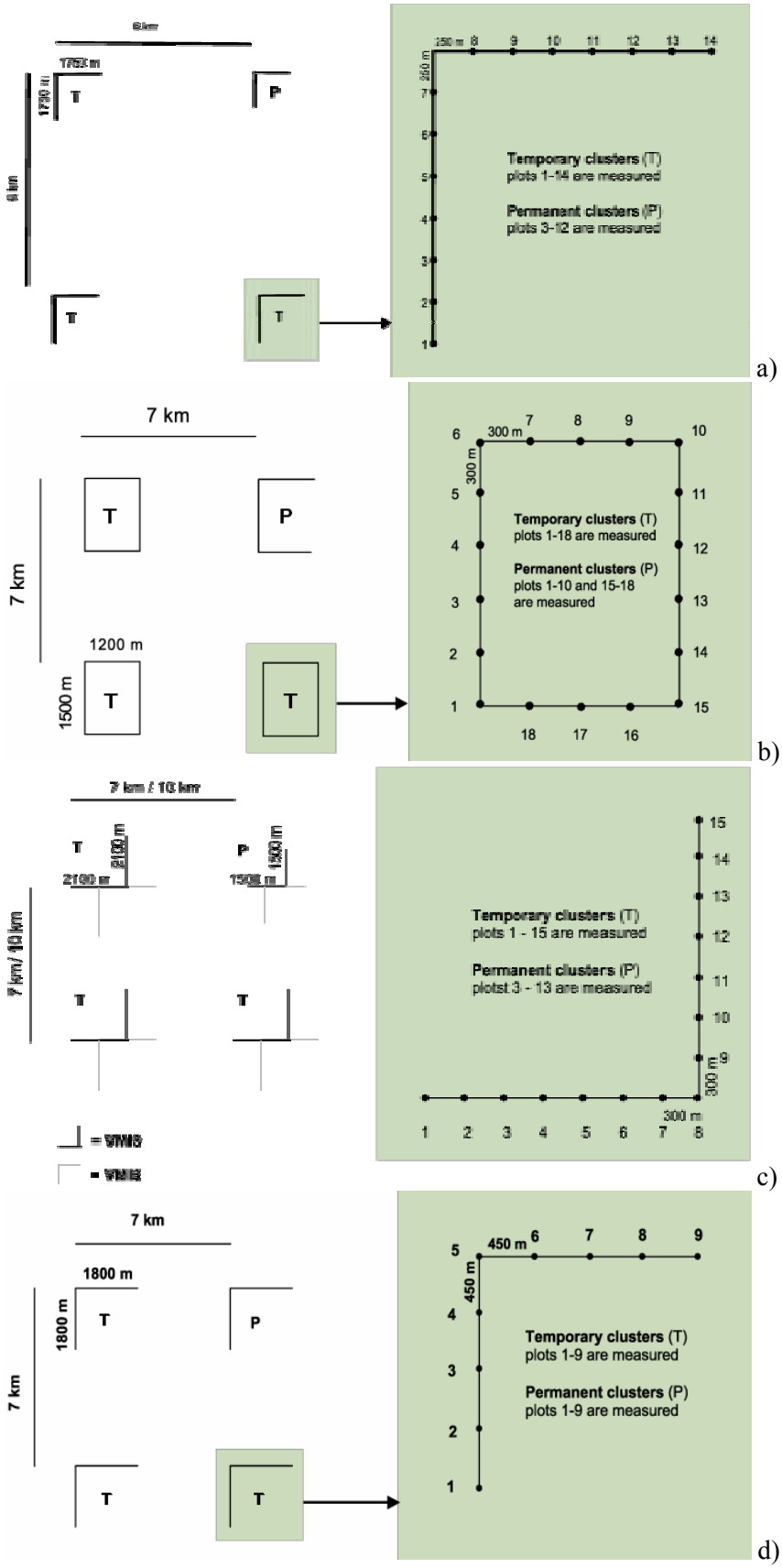
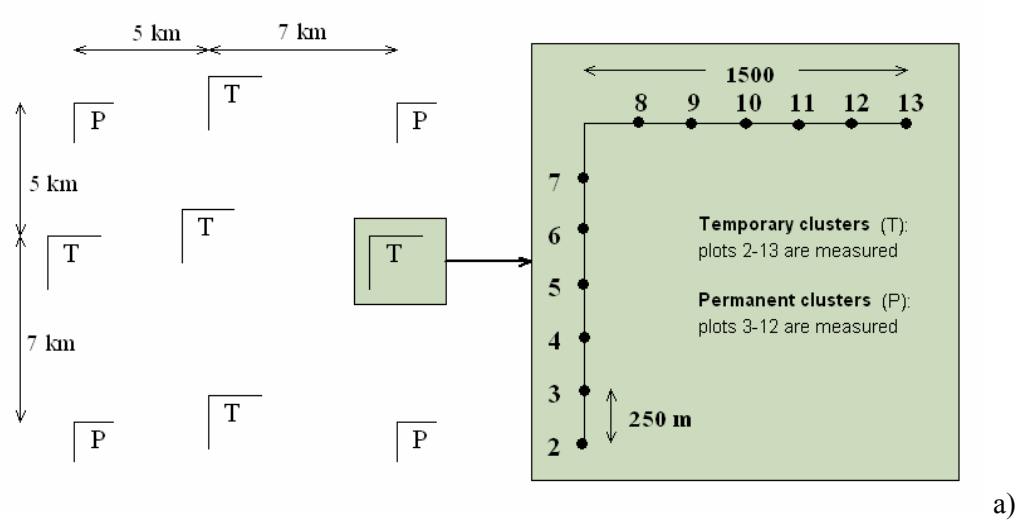
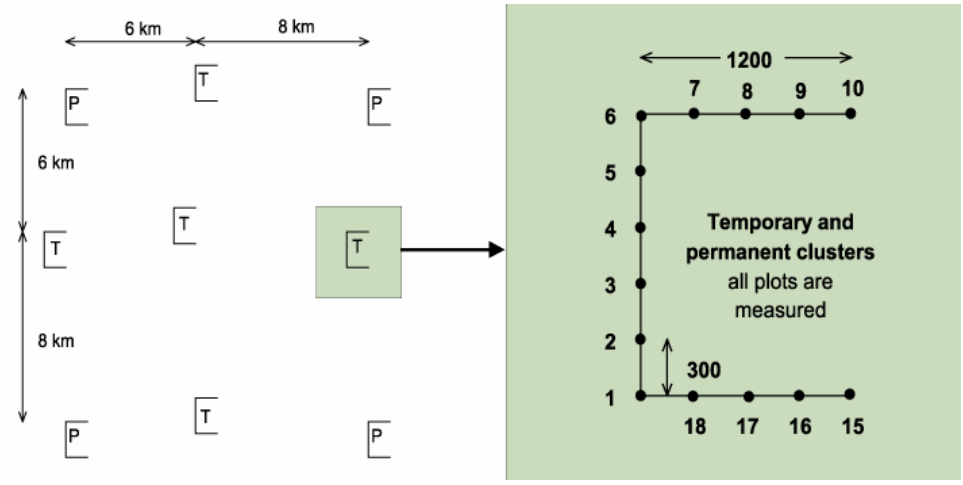


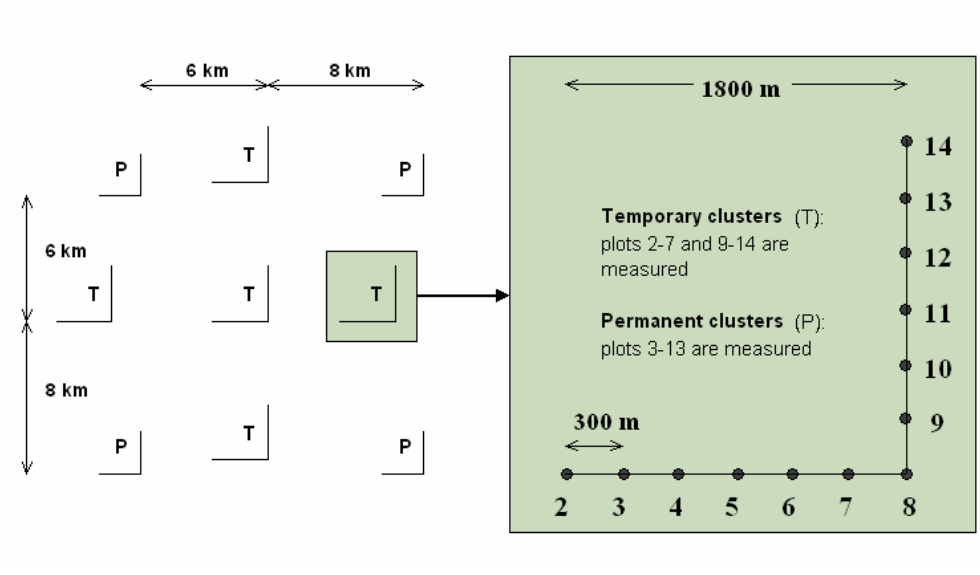
Figure 3_App_7. Sampling design of NFI9 in different sampling regions: a) region 2, in Åland, the design is same but the distances are 3 km x 3 km, b) region 3, c) region 4, in region 5, the design is same but the distances are 10 km x 10 km, d) region 6.



a)



b)



c)

Figure 4_App_7. Sampling design of NFI10 in different sampling regions: a) region 2, b) region 3, c) region 4, in region 5, the design is 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 e.g. forest site, growing stock, forest health and previous and proposed cuttings. Most important site description variables for 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. Also the conversions between land-use classes are

assessed, but the method to estimate converted areas is not yet available for this GHG inventory. 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 a minimum diameter a height of 1.3 meter is 0 cm. 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, NFI9, was:

- 70 955 field plots on forestry land
- over 150 characteristics measured or assessed
- 518 720 tallied trees.

The main task of NFI is to produce forest resource information, like 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.

Total area of Finland is classifies in ten land classes, of which eight are actual land categories. Land classes are:

Productive forest land where the mean annual increment of growing stock with bark over the rotation period is at least 1 m^3/ha
Poorly productive forest land where increment is less than 1 m^3/ha but at least 0.1 m^3/ha.
Un-productive land where the increment is less than 0.1 m^3/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 includes 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 consists of streems and rivers with the with of at least 5 m, ponds, lakes and reservoirs.
Salt water.

The area estimation bases 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:

$$A_S = \frac{N_S}{N} A, \qquad (1)$$

where A_S is the area estimate of the stratum s, N_S is the number of the 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).

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). Current volume over bark is thus a function

$$v_{ob,0} = f(\text{tree sp.}, d_{1.3}, d_{6.0}, h). \qquad (2)$$

Volumes are estimated for tally trees using a non-parametric regression method (Tomppo et al. 1997, Tomppo et al. 1998, Tomppo 2005).

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):

$$v_{ob,-5} = g(\text{tree sp.}, r, v_{ob,0}, g_{ub,0}, g_{ub,-5}, h), \quad (3)$$

where

$r = \frac{v_{ob,0}}{g_{ub,0}}$ 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. 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 Forest Resource Reports as follows; NFI7 by Kuusela and Salminen (1991), NFI8 by Tomppo et al. (2001), NFI10 by Korhonen et al. (2006). NFI9 results for South and North Finland are published in Finnish Statistical Year Book 2005.

Mathematical formulation of the YASSO model:

$$\frac{dx_{fwl}}{dt} = u_{fwl} - a_{fwl}x_{fwl} \ , \qquad (1)$$

$$\frac{dx_{cwl}}{dt} = u_{cwl} - a_{cwl}x_{cwl} \ , \qquad (2)$$

$$\frac{dx_{ext}}{dt} = u_{nwl}c_{nwl\_ext} - c_{fwl\_ext}a_{fwl}x_{fwl} + c_{cwl\_ext}a_{cwl}x_{cwl} - k_{ext}x_{ext} \ , \qquad (3)$$

$$\frac{dx_{cel}}{dt} = u_{nwl}c_{nwl\_cel} - c_{fwl\_cel}a_{fwl}x_{fwl} + c_{cwl\_cel}a_{cwl}x_{cwl} - k_{cel}x_{cel} \ , \qquad (4)$$

$$\frac{dx_{lig}}{dt} = u_{nwl}c_{nwl\_lig} - c_{fwl\_lig}a_{fwl}x_{fwl} + c_{cwl\_lig}a_{cwl}x_{cwl} + p_{ext}k_{ext}x_{ext} + p_{cel}k_{cel}x_{cel} - k_{cel}x_{cel} \ , \qquad (5)$$

$$\frac{dx_{hum1}}{dt} = p_{lig}k_{lig}x_{lig} - k_{hum1}x_{hum1} \ , \qquad (6)$$

$$\frac{dx_{hum2}}{dt} = p_{hum1}k_{hum1}x_{hum1} - k_{hum2}x_{hum2} \ , \qquad (7)$$

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 microbal 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).

8. WASTE (CRF 6)

8.1 Overview of sector

Description

In the Finnish inventory emissions from the Waste Sector cover CH_4 emissions from solid waste disposal sites including solid municipal, industrial, construction and demolition wastes and municipal (domestic and commercial) and industrial sludges. In addition, the Waste Sector includes CH_4 emissions from municipal (domestic and commercial) and industrial wastewater handling plants and uncollected domestic wastewaters. N_2O 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 CH_4 and N_2O emissions from composting are also estimated in the Finnish inventory.

Quantitative overview

Emissions from the waste sector were 2.4 Tg CO_2 equivalent in 2005. This was about 3.5% of the total greenhouse gas emissions in Finland. Solid waste disposal on land (landfills and dumps) causes relatively large CH_4 emissions in Finland while emissions from wastewater handling and from composting are smaller (Figure 8.1_1).

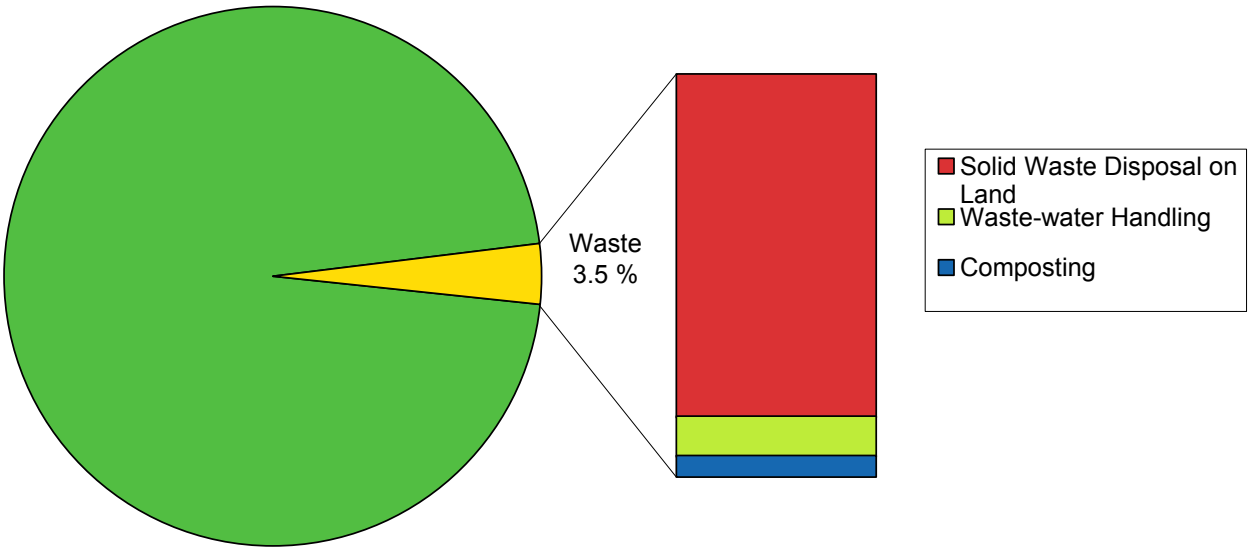


Figure 8.1_1 Greenhouse gas emissions from the Waste Sector in 2005 compared with the total greenhouse gas emissions in Finland.

CH_4 emissions from landfills are the most important greenhouse gas emissions in the waste sector. Since 1990 these emissions have decreased by more than 40%. (Figure 8.1_2). The decrease has been mainly due to the implementation of the new waste law in Finland in 1994. At the beginning of the 1990s, around 80% of the generated municipal waste was taken to solid waste disposal sites (landfills). After the implementation of the new waste law, 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.

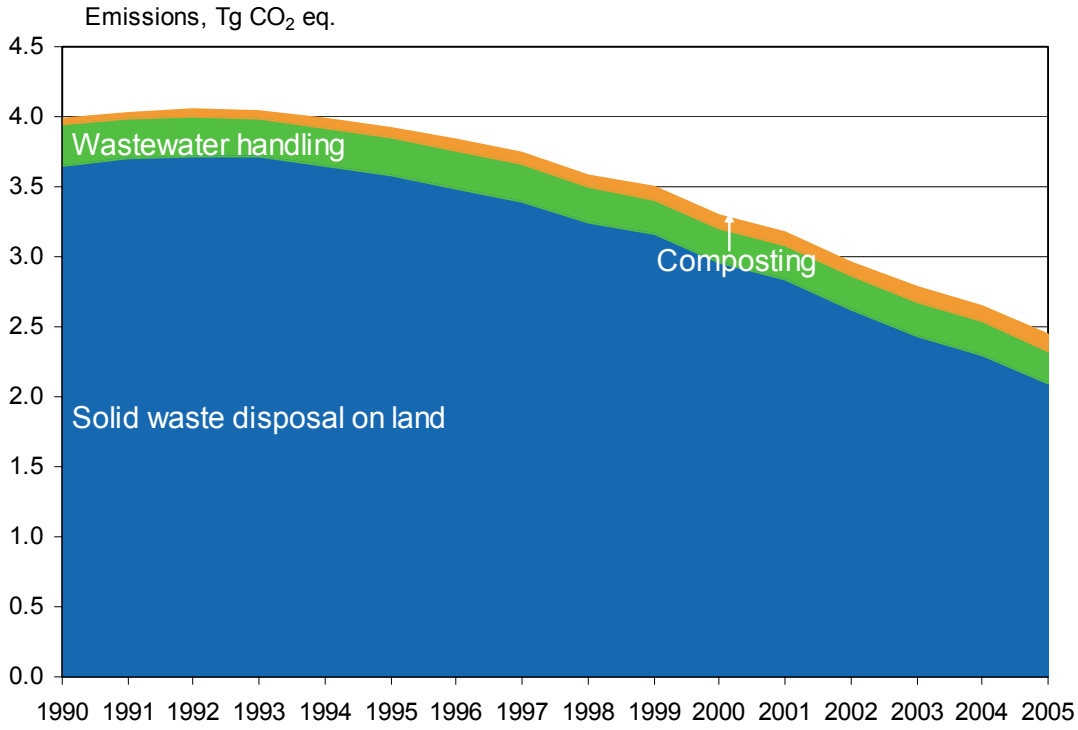


Figure 8.1_2 Trend in the Waste Sector's emissions in 1990-2005 (Tg CO_2 eq.).

The emission trend in the Waste Sector by subcategory and gas is presented in Table 8.1_1.

Key categories

Methane emissions from solid waste disposal on land have been identified with IPCC Tier 2 method as a key category by level in and trend in 2005. N_2O emissions from domestic and commercial wastewaters from densely populated areas and N_2O emissions from N input from industrial wastewater were also identified as a key category by level and trend. N_2O emissions from domestic and commercial wastewaters from sparsely populated areas were identified as a key category by level and methane emissions from compost production were identified as a key category by trend.

Table 8.1_1. Emissions in the Waste Sector during 1990-2005 (Tg CO_2 eq).

Source category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
6.A Solid waste disposal on land, CH_4	3.65	3.70	3.72	3.71	3.65	3.58	3.49	3.39	3.24	3.16	2.96	2.84	2.62	2.44	2.30	2.09
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
-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
-N_2O	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
	0.04	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
6.D Composting																
-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
-N_2O	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
Total	**3.99**	**4.03**	**4.05**	**4.05**	**3.98**	**3.92**	**3.83**	**3.74**	**3.58**	**3.49**	**3.29**	**3.18**	**2.96**	**2.79**	**2.65**	**2.45**

8.2 Solid Waste Disposal on Land (CRF 6.A)

8.2.1 Source category description

The emission source includes CH_4 emissions from solid waste disposal sites from disposal of solid municipal, industrial, construction and demolition wastes, and municipal (domestic) and industrial sludges. The trend in CH_4 emissions from solid waste disposal on land is presented by subcategory in Table 8.2_1.

8.2.2 Methodological issues

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 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 at the end of Chapter 8.

Emission factors and other parameters

The parameters used in the calculation are mainly IPCC default values. Some country-specific emission parameters (factors) are used (Table 8.2_2). The choices of the parameters are in full agreement with the information and data ranges given in the Good Practice Guidance (IPCC 2000).

Table 8.2_1. Emission from solid waste disposal on land in 1990–2005 by subcategory (Tg CO_2 eq.).

Source category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Municipal solid waste	2.24	2.26	2.26	2.25	2.19	2.15	2.10	2.04	1.96	1.93	1.81	1.75	1.62	1.52	1.45	1.31
Municipal sludge	0.15	0.15	0.15	0.15	0.15	0.13	0.12	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.03	0.02
Industrial sludge	0.53	0.55	0.55	0.55	0.54	0.54	0.53	0.52	0.49	0.46	0.42	0.39	0.35	0.31	0.27	0.23
Industrial solid waste	0.43	0.44	0.45	0.45	0.45	0.45	0.44	0.43	0.42	0.41	0.40	0.39	0.38	0.36	0.35	0.34
Constr. and demol. waste	0.31	0.31	0.32	0.32	0.31	0.31	0.30	0.30	0.28	0.28	0.26	0.26	0.24	0.22	0.21	0.19
Total	**3.65**	**3.70**	**3.72**	**3.71**	**3.65**	**3.58**	**3.49**	**3.39**	**3.24**	**3.16**	**2.96**	**2.84**	**2.62**	**2.44**	**2.30**	**2.09**

Table 8.2_2. Emission factors and parameters used in calculations (country-specific (CS) expert estimations or IPCC default values (D)).

Factor/parameter	Value	Type of emission factor
MCF (Methane correction factor)	1	D (from 2002 onwards)
DOC (Fraction of degradable organic carbon in municipal solid waste)	0.1975	D/CS (based on waste composition in 1990)
DOC_F (Fraction of DOC dissimilated)	0.50	CS
F (Fraction of methane in landfill gas)	0.5	D
OX (Oxidation factor)	0.1	CS
Methane generation rate constants; *k*1 = wastewater sludges, food waste in MSW *k*2 = wood waste in MSW and in construction and demolition waste, de-inking sludge, paper waste containing lignin in MSW *k*3 = industrial solid waste, other fractions of *MSW* than above, fibre and coating sludges	*k*1 = 0.2 *k*2 = 0.03 *k*3 = 0.05	D/CS Country-specific k1 and k2 are according to the rapid and slow rate constants in the Good Practice Guidance
MCF (Methane correction factor)	In 1990: 0.982 In 1991: 0.985 In 1992-1996: 0.988 In 1997-2001: 0.994 In 2002-2005: 1.0	D/CS; weighted mean value of the default values of 1 and of 0.4. Varies between the years

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, has 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 default values and national research data (Isännäinen 1994). For MSW IPCC default values of DOC fractions (wood 0.3, paper and textiles 0.4) are used except food and garden waste have the average value of 0.16 from the IPPC default values (0.17 and 0.15) resulting in the average DOC value of 0.1975 of solid municipal waste (Table 8.2_3). 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_3. The waste groups and the waste subgroups and the corresponding *DOC* values

Waste group and subgroups	***DOC***
Solid municipal waste	
Textile	0.1975
Paper	0.1975
Wood	0.1975
Grease	0.1975
Other	0.1975
Inert	0.1975
Plastic	0.1975
Mixed (other)	0.1975
Municipal sludge (from dry matter)	
Handling plants	0.50

Waste group and subgroups	*DOC*
Septic tanks	0.50
Sand separation (calculated with 0.50 and with the mass reduction to one fifth of the original)	0.10
Industrial sludge (from dry matter)	
Other industry (mainly wastewater sludges)	0.45
Pulp and paper	0.45
De-inking	0.30
Fibre and coating	0.10
Solid industrial waste	
Textile	0.40
Organic	0.16
Paper	0.40
Wood	0.30
De-inking reject	0.10
Oil	0.10
Green liquor sludge (from dry matter)	0.02
Other	0.10
Construction and demolition waste	
Plastic	0
Asphalt	0.02
Inert	0
Wood	0.3
Mixed (years 1990-1999)	0.069
Mixed (years 2000-2005)	0.097
Paper (packaging)	0.4
Textile (packaging)	0.4
Other (packaging)	0.1
Industrial inert waste	
Plastic	0
Other combustible	0
Other non-combustible	0
Ash	0
Other sludges (mainly from inorganic processes)	0
Other inert waste	
Mine	0
Soil	0

The waste composition of solid municipal waste is based on the situation in 1990 (Table 8.2_4). The share of slowly degradable paper and paperboard is based on the approximately estimated content of mechanical pulp (with lignin) and chemical pulp (no lignin) in the paper and paperboard products consumed in Finland.

Table 8.2_4. The waste composition of solid municipal waste.

Waste type	**Composition**
Paper and paperboard	26.7% of which 35% slowly degradable (k = 0.03) and 65% has k value of 0.05.
Food and garden waste	36.8% rapidly degradable (k = 0.2)
Plastics (inert)	5.6%
Glass (inert)	3.4%
Textiles	1.2% default k value (k = 0.05)
Wood	6.5% slowly degradable (k = 0.03)
Other – inert	12.6%
Other – organic	7.2% default k value (0.05)

Activity data

The activity data used in the calculation are taken from the VAHTI database. The VAHTI is the Compliance Monitoring Data System of Finland's environmental administration. The VAHTI database includes information on all landfills in Finland excluding Åland. 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 database 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. The disposal data (amount and composition) at the beginning of the 1990s for industrial, construction and demolition waste are based on surveys and research by Statistics Finland (Vahvelainen & Isaksson 1992; Isaksson 1993; Puolamaa et al. 1995), VTT Technical Research Centre of Finland (Perälä & Nippala 1998; Pipatti et al. 1996) and National Board of Waters and the Environment (Karhu 1993).

The amount of landfilled waste in 1990 – 2005 is presented in Table 8.2_5. The corresponding DOC tonnes are given in Table 8.2_6.

Estimated data on waste amounts before the year 1990 are based on the report of VTT (Tuhkanen 2002). Data on landfill gas recovery are obtained from the Finnish Biogas Plant Register (Kuittinen et al. 2005) and presented in Table 8.2_7 and in Appendix_8b (volume of collected gas by plant/site). The great increase in the amounts of recovered methane in 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. 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 Compliance Monitoring Data System.

Table 8.2_5. Landfilled waste in 1990 – 2005 (1000 t).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Municipal solid waste	2450	2291	2131	1906	1646	1689	1605	1521	1529	1477	1589	1532	1496	1470	1442	1471
Municipal sludge (d.m.)	47	48	48	47	46	25	21	8	6	5	7	8	7	6	7	6
Municipal sludge (wet m.)	498	504	510	505	501	298	212	93	76	67	72	84	66	63	63	53
Industrial sludge (d.m.)	337	318	299	285	268	260	248	229	183	147	119	135	75	44	31	50
Industrial sludge (wet m.)	1193	1129	1065	999	935	881	790	696	610	580	555	443	240	201	131	166
Industrial solid waste	2161	2120	2079	1989	1899	1808	1718	1628	1576	2461	2597	2812	2645	3135	4912	4828
Constr. and demol. waste	1262	1110	781	667	639	637	567	553	455	466	493	501	364	416	336	270

Table 8.2_6. Landfilled waste in 1990 – 2005 (1000 DOC t).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Municipal solid waste	484	452	421	376	325	334	317	300	302	292	314	303	295	290	285	290
Municipal sludge	24	24	24	24	23	12	10	4	3	3	3	4	3	3	3	3
Industrial sludge	110	104	98	95	92	91	88	83	67	54	41	47	22	13	6	15
Industrial solid waste	109	103	97	84	71	58	45	32	27	21	21	22	18	15	21	26
Constr. and demol. waste	93	79	57	48	45	43	39	39	32	29	39	38	27	25	24	18

Table 8.2_7. Landfill CH_4 recovery in 1990-2005 (Gg) and the number of operating CH_4 recovery plants.

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
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
Number	0	1	1	2	3	4	6	8	9	10	12	13	26	27	29	33

8.2.3 Uncertainty and consistency of time series

The uncertainty in solid waste disposal is assessed by replacing the parameters of the FOD model with probability density functions describing the uncertainty. As a result of simulation, uncertainty in the emission estimate of CH_4 from landfills contained an uncertainty of around ±40% in 2005. The correlation between uncertainties in emissions in 1990 and 2005 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 1900s was rather 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 some cases Finnish uncertainties are estimated lower than in the IPCC Good Practice Guidance due to advanced knowledge. For example, different DOC values are used for different types of waste based on measurements done in 1990. Therefore this uncertainty is estimated smaller than uncertainties in IPCC default DOC values.

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 (±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 are 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 law in Finland in 1994. At the beginning of the 1990s, around 80% of the generated municipal waste was taken to solid waste disposal sites (landfills). After the implementation of the new waste law, 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 database 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 Regional Environment Centres or from the companies that manage the landfills in question.

The activity data of the year 2005 are compared with the data of Statistics Finland.

Tier 2 QC for emission factors

Country-specific emission factors were cross-checked and compared with IPPC 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 Chapter 3.1).

8.2.5 Source-specific recalculations

Recalculations have been made in (CRF 6.A) for time-serie consistency and for more accurate activity data: the amount of municipal solid waste was corrected for one landfill in 2004. Also, one waste category (code 190203 in EWC 2002 and code 190202 in EWC 1997) was changed from inert to biodegradeable waste (industrial waste, other) which caused recalculations to years 2001-2004.

8.2.6 Source-specific planned improvements

The waste composition data for MSW after 1990 (the waste composition data for 1990 have been used also for the years 1991-2005 in this submission) will be reviewed for the 2008 submission.

8.3 Wastewater Handling (CRF 6.B)

8.3.1 Source category description

The emission sources cover municipal (domestic) and industrial wastewater handling plants and uncollected domestic wastewaters for CH_4 emissions.

N_2O emissions are generated from nitrogen input of fish farming as well as domestic and industrial wastewaters into waterways.

Emission trends from wastewater handling by subcategory and gas are presented in Table 8.3_1.

8.3.2 Methodological issues

Methods

A national methodology that corresponds to the methodology given in the Revised (1996) Guidelines is used in the estimation of the CH_4 emissions. The emissions from municipal wastewater treatment are based on the BOD_7 load (Biochemical Oxygen demand, 7-day test) of the wastewaters. The BOD_7 measurements are converted to the BOD_5 load (5-day test) by dividing them with factor 1.17 (Finnish Water and Waste Water Works Association 1995). The emissions from industrial wastewater treatment are based on the COD load (Chemical Oxygen demand).These DC (Degradable Organic Component) values of wastewaters with shared methane conversion factors have been used for both wastewater and sludge handling. The emissions from sludge disposal on land are, however, estimated and reported in the Solid waste disposal on land (landfills) subsector.

The equations used for calculating CH_4 emissions from domestic (not including uncollected domestic wastewater) and industrial wastewater treatment are described in the Appendix at the end of Chapter 8.

The emission estimates are uncertain as 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. The emission factors mainly illustrate exceptional operation conditions. For uncollected domestic wastewaters the Check method with the default parameters (IPCC Good Practice Guidance) has been used. 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 database. 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.

Table 8.3_1. Emissions from wastewater handling in 1990-2005 by subcategory (Tg CO_2 eq).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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**
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
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
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
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**	**0.106**	**0.102**
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
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	0.024	0.024
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
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
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**	**0.240**	**0.233**

The Revised (1996) Guidelines present a methodology to calculate the N_2O emissions from sewage in the Agriculture sector. The 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 database. For uncollected wastewaters the nitrogen load is based on population data.

The assessed N_2O 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.

N_2O emission estimations are consistent with the IPCC method for discharge of sewage nitrogen to waterways:

Emissions (Gg N_2O) = Nitrogen load into waterways (kg) * $EF_{N2O\ sewage}$*10^{-6}

Where

$EF_{N2O\ sewage}$ = Emission factor (kg N_2O/kg N), IPCC default = 0.01

Emission factors and other parameters

Emission factors for municipal (domestic) wastewaters are IPCC default factors for the maximum methane producing capacity B_o = 0.625 (= 2.5 * 0.25) kg CH_4/kg BOD and country-specific, based on expert knowledge, for the methane conversion factor *MCF* = 0.01.

For the industrial wastewaters the emission factor is the IPCC default for the maximum methane producing capacity B_o = 0.25 kg CH_4/kg COD and a country-specific emission factor based on expert knowledge for the methane conversion factor *MCF* = 0.005.

In the Check method and in the N_2O calculation the emissions factors are the IPCC default factors.

Activity data

Activity data is based on

- municipal (domestic and commercial) wastewater: Population (Check method); the BOD (BOD_7) values and N input values of wastewaters from the VAHTI database (years 1998-2005) and from the Water and Sewage Works Register (years 1990-1997).

- industrial wastewater: the COD values of wastewaters from the VAHTI database 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 (2005). Incoming COD loads are calculated from the measured outcoming COD values (VAHTI database) using partly estimated efficiencies of wastewater treatment plants and partly the efficiency values from the VAHTI database.

Both built-in queries in VAHTI operating system and own sampling routines from the VAHTI database 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 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.

The collected BOD and COD values and Nitrogen input values are presented in Table 8.3_2 and Table 8.3_3, respectively.

Table 8.3_2. BOD_5 and COD loads in 1990-2005 (1000 t).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Collected BOD_7 load (municipal wastewater)	121	118	107	109	110	113	110	112	112	118	118	118	125	127	125	130
Collected BOD_5 load (municipal wastewater)	103	101	92	93	94	97	94	96	96	101	101	101	108	109	107	112
Uncollected BOD_5 load (domestic wastewater)	23	22	22	23	22	22	22	22	21	20	19	19	19	19	19	18
COD load (industrial wastewater)	847	749	736	769	814	810	784	770	778	779	791	755	932	904	962	900

Table 8.3_3. N input from wastewater in 1990-2005 (1000 t).

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
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
N input from uncollected domestic wastewater	6.2	5.8	5.9	5.6	5.5	5.8	5.7	5.8	5.7	5.3	5.2	5.2	5.1	5.1	5.1	4.9
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
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

8.3.3 Uncertainty and consistency of time series

For the purposes of uncertainty estimation, emissions from wastewater management are divided into the following sub-groups: Industrial Wastewater (CH_4 and N_2O separately), Domestic and Commercial Wastewater from densely populated areas (CH_4 and N_2O separately), Domestic and Commercial Wastewater from sparsely populated areas (CH_4 and N_2O separately) and N input from Fish Farming (N_2O). The uncertainty in wastewater treatment was -50 to +140% in the 2005 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 (±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, CH_4 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 B_0 the IPCC default uncertainty (±30%) is used, and 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 (±15%) is larger than in densely populated areas, because the estimate is based on the population rather than on measured BOD. The emission factor uncertainty, however, is estimated rather 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 N_2O emission factor (-90% to +380%). The methane conversion factor (MCF) is the second most important factor in terms of uncertainty.

The 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 (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 N_2O 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 methane emissions in Industrial wastewater handling (1998-2004) for time-series consistency and for more accurate activity data. The incoming COD loads were re-estimated according to new information on efficiencies of wastewater treatment plants (the outcoming COD loads are the same). Also, recalculations have been made in uncollected wastewater handling (2002-2004) due to minor changes in population data.

8.3.6 Source-specific planned improvements

The activity data in VAHTI database is under checking which may cause recalculations in the future.

8.4 Waste Incineration (CRF 6.C)

Emissions of greenhouse gases CO_2, N_2O and CH_4 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 negligible small.

8.5 Composting (CRF 6.D)

8.5.1 Source category description

Emissions of greenhouse gases N_2O and CH_4 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). The trend in emissions is presented by subcategory in Table 8.5_1. The waste amounts with auxiliary matter (20-30 %) in composting are presented in Table 8.5_2, correspondingly.

8.5.2 Methodological issues

Methods

Emissions from composting have been calculated using an analogous method with 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

Emission factors

Emission factors in composting are presented in Table 8.5_1.

Table 8.5_1. Emission factors in composting (g CH_4/kg waste treated, g N_2O/kg waste treated).

	CH_4 emission factor	**N_2O 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 VAHTI database 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 years 1997, 2004 and 2005 are from VAHTI database and the intermediate years have been interpolated. In addition, composted solid biowaste in the years 1991-1996 has been interpolated using auxiliary information from the National Waste Plan until 2005 (Ministry of the Environment 1998).

Table 8.5_2. Emissions from composting in 1990-2005 by subcategory (Tg CO_2 eq).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Methane emissions (Total)	**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**
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
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
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
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
Nitroux oxide emissions (Total)	**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**
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
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
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
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
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**

Table 8.5_3. Composted waste with auxiliary matter in 1990–2005 by subcategory (1000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Municipal solid waste	60	66	72	77	83	102	122	141	154	167	180	190	199	209	218	233
Municipal sludge (d.m.)	60	72	83	90	97	110	123	120	123	125	128	131	133	136	138	159
Industrial sludge (d.m.)	13	12	12	12	12	12	12	7	10	13	15	18	21	23	26	32
Industrial solid waste	12	13	14	16	17	18	19	21	24	28	31	34	38	41	45	45

8.5.3 Uncertainty and consistency of time series

The VAHTI database has no treatment code solely for composting. This means manual work in estimating the activity data and the uncertainties (±30 %) in activity data are somewhat higher than in activity data on landfilled wastes.

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 previous submission.

8.5.6 Source-specific planned improvements

A treatment code for composting will be included in the VAHTI database and this is expected to improve the quality of the activity data in future inventories.

Appendix_8a

Equations used in calculation emissions from Waste sector (CRF 6)

Solid waste disposal on land (CRF 6.A)

The modified Equation 5.1 (IPCC 2000) is as follows:

CH_4 generated in year t (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)
$L_0(x) = MCF(t) * DOC(x) * DOCF * F * 16 / 12$ (Gg CH_4 / 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 CH_4 in landfill gas

16 / 12 = Conversion from C to CH_4

Emissions according to Equation 5.2 in GPG (2000) are calculated as follows:

CH_4 emitted in year t (Gg / yr) = [CH_4 generated in year $t - R(t)$]*$(1 - OX)$

where

$R(t)$ = Recovered CH_4 in inventory year t (Gg / yr)

OX = Oxidation factor (fraction)

Wastewater handling (CRF 6.B)

Equations used in calculating CH_4 emissions from domestic (not including uncollected domestic wastewater) and industrial wastewater treatment are as follows:

Emissions (Gg CH_4) = Organic load in wastewaters * B_0 * MCF / 1000000

where

B_0 = Maximum methane producing capacity (kg CH_4 / kg BOD or kg COD)

MCF = Methane conversion factor (fraction)

CH_4 emissions from uncollected domestic wastewater are estimated according to the Check method:

Emissions (Gg CH_4) = *P* * *D** *SBF* * *EF* * *FTA* * 365 / 1000000

where

P = Population with uncollected wastewaters (septic tanks)

D = Organic load kg BOD /person /day, default = 0.06 kg BOD /person /day

SBF = Fraction of BOD that readily settles, default = 0.5

EF = Emission factor (kg CH_4 / 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 2005

Name of a plant	**Volume of collected gas, 1000 m^3**
Vuosaari, Helsinki	1883
Seutula, Vantaa	2024
Kiertokapula, Hyvinkää	2300
Kiertokapula, Hämeenlinna	1900
Porvoo	1700
Espoo, Ämmässuo	63864
Espoo, Mankkaa	1765
Tampere	5800
Oulu	6760
Kerava	1100
Lappeenranta	708
Lohja	170
Joensuu	2727
Pori	2094
Simpele	460
Lahti	3938
Jyväskylä	2860
Nokia	1700
Kouvola	1019
Iisalmi	740
Järvenpää	500
Mikkeli	1200
Raisio	1600
Rovaniemi	740
Turku	1500
Uusikaupunki	300
Kajaani	550
Myllykoski Paper, Anjalankoski	700
Kuopio, Silmäsuo	1200
Kuopio, Heinälamminrinne	1900
Anjalankoski	700
Vaasa	1100
Imatra	900

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 implementing recalculations in Finland's greenhouse gas inventory arethe implementaion of 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. Reasoning and impact of the recalculations for the years 1990-2003 can also be found in the CRF tables 8(a)s1-8(a)s2 and 8(b) of the relevant years.

In the **Energy Sector** review and recalculation of the time series of **fuel combustion** activities (CRF 1A) have been continued. Most of the corrections were already done and reported in the 2006 submission, but some minor changes have been made in this submission. The point sources' data have been thoroughly checked for inconsistencies in activity data, technical data of the combustion processes, CRF categories, and fuel-specific CO_2 emission factors and oxidation factors. All identified shortages have been corrected, using data from different surveys and registers. Different fuel classifications used for earlier years have been harmonised to follow the latest revised classification; the same applies also to economic activity classification (NACE). At the same time, the improvement of the consistency of all non-point sources in the Energy Sector have been continued. In this submission, also the time series for SO_2, NO_2, NMVOC and CO have been recalculated.

A research and measurement study at VTT Technical Research Centre of Finland has evaluated the non-CO_2 (CH_4 and N_2O) emission factors used in the Finnish inventory. In 2005 VTT measured non-CO_2 emissions at several power plants in Finland. The power plants for the measurements 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 time periods to cover also start-ups, partial loads and other exceptional conditions. The results of the study were published in 2005 and 2006 (Tsupari et al. 2005; Tsupari et al. 2006). The final results of this study have been used in the recalculation of the time series. All emission factors used in the ILMARI system were checked and revised according to the VTT study (see Tables 3.2_6 and 3.2_7). The CRF tables and NIR have been updated accordingly.

Also the time series of indirect N_2O emissions from atmospheric deposition of nitrogen in NO_x has been recalculated due to recalculation of NO_x time series.

Two of the LIPASTO submodels, ILMI and TYKO were updated and the results were taken into the CRF tables, mostly in the transport subsectors.

Under **Industrial processes** (CRF 2) The time series 1990-2003 for NMVOC emissions has been checked and recalculated. Updated VAHTI data and reallocations resulted slight changes in NMVOC emissions in the Chemical industry, Other Production and Iron and Steel Industry sectors.

One cement plant informed that they had not taken into account the amount of organic carbon from raw materials in year 2004, the recalculated emissions decreased compared to previous estimates. One chemical plant and two tile producers corrected their amount of used limestone in 2004 and the recalculation increased the emissions.

In the Solvent and Other product use (CRF 3) NMVOC emissions have slightly increased during the time series 1990-2003 checking due to the reallocation and updated VAHTI data.

In the **Agriculture sector** (CRF 4) recalculations in source categories enteric fermentation, manure management and agricultural soils were done because of review of activity data, emission factors or other calculation parameters e.g. animal numbers and crop yield data was updated according to the latest statistics, weights of some cattle species were corrected on the basis of new data. Few changes were made on the distribution of

manure management system for cattle. Also, area of organic soils was corrected for the whole time series because previous value did not include organic grassland.

In the **LULUCF** sector (CRF 5) the emissions from controlled biomass burning (CRF 5.V) have been recalculated for the whole time seris due to an identified error in the calculation. The quantity of biomass burnt was previously incorrect.

In the **Waste sector** (CRF 6) recalculations have been made in CRF 6.A and CRF 6.B to improve the accuracy of activity data. The recalculations are the following in CRF 6.A: correction in the data of municipal solid waste from the VAHTI database and change in the classification of one waste type to biodegradeable industrial solid waste. In CRF 6.B there are improvements in calculation of total organic product of industrial wastewater treatment and in calculation of population having uncollected wastewater handling system).

Table 10.1_1. Recalculations made for the 2006 inventory submission by CRF category and their implications to the emission level in 1990 and 2004.

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 2004	in 1990	in 2004
1.A. Fuel combustion			58.01	-288.04	0.082	-0.355
1.Energy Industries		Update of time series consistency, activity data and emission factors; corrections of errors,	-278.73	-248.68	-0.392	-0.307
2. Manufacturing industries and construction			245.25	518.82	0.345	0.639
3. Transport		Update of TYKO model for non-road machinery and ILMI model for domestic aviation	8.99	57.27	0.013	0.071
4. Other sectors		The most important changes were the updates of the heating energy calculation system and TYKO submodel	-44.54	-669.21	-0.063	-0.825
5. Other			127.04	53.76	0.179	0.066
1.B Energy - Fugitive emissions						
2. Industrial Processes			-4.89	-6.42	-0.007	-0.008
A. Mineral products	Cement production., Limestone and dolomite use	In cement production one plant informed that they had forgot to reduce amount of organic carbon from raw materials. In Limestone and dolomite use few plants informed corrected amounts of used limestone.		-2.13		-0.003

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 2004	in 1990	in 2004
B. Chemical industry		Review of Vahti database (indirect CO_2 from NMVOC emissions)	-3.25		-0.005	
C. Metal production		Review of Vahti database (indirect CO_2 from NMVOC emissions)	0.72		0.001	
D. Other production		Indrect CO2 emissions from the Food and Drink processing are considered to be biological and therefore removed from emission data.	-2.36	-4.30	-0.003	-0.005
3. Solvents and Other product use	Indirect CO_2 emissions calculated from NMVOC emissions from solvents and other product use sector	Update of time series consistency, Review of the Vahti database	0.65		0.001	
4. Agriculture		Update of time series consistency, activity data and emission factors; corrections of errors	5.38	-20.16	0.008	-0.025
A. Enteric Fermentation		Some updating and corrections in weight data and animal nurmbers	-0.39	-2.75	-0.001	-0.003
B. Manure Management		Correction of N excretion for swine in 2004. Changes in the distribution of manure management systems as well as some minor changes in activity data	-1.93	-25.82	-0.003	-0.032

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 2004	in 1990	in 2004
D. Agricultural Soils		Updating of crop yield of sugar beet for 2004. Area of organic soils was corrected for the whole time series because area of grassland was previously accidentally excluded from the total area. Changes in the distribution of manure management systems.	7.70	8.40	0.011	0.010
5. Land use, Land Use Change and Forestry			-8.14	-0.51		
A. Forest land	biomass burning	Error in the calculation, the quantity of biomass burnt was corrected.	-8.14	-0.45		
D. Wetlands		Rounding error	0.00	-0.07		
6. Waste			15.60	15.60	0.022	0.019
A. Solid Waste Disposal on Land		Correction in activity data of municipal solid waste and change in classification of industrial solid waste	6.23	6.23	0.009	0.008
B. Waste-water Handling		Improvements in calculation of total organic product (efficiency in wastewater treatment). Improvements in calculation of population having uncollected wastewater handling system	9.37	9.37	0.013	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 2004	in 1990	in 2004
D. Other (composting)						

General improvements made to the inventory.

The quality management system forms an integrated part of the national system and the annual inventory process. The quality management system and its implementation during 2006 are described in Chapter 1.6.

Finland has established the national system required in the Kyoto Protocol (Article 5.1). The National Greenhouse Gas Inventory System in Finland has started on a permanent basis in the beginning of 2005. The system and the related agreements have been prepared in co-operation with the relevant organisations. The English description of the system has been updated to take in to account the implementation of the system during its first year. The description can be found on the web pages of Statistics Finland (www.stat.fi/greenhousegases).

10.2 Implications for emission levels

See chapter 10.1.

10.3 Implications for emission trends, including time series consistency

See chapter 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 review processes. More detailed information about planned improvements can be found under sectoral chapters.

Table 10.4_1. Sector-specific improvement needs of the Finland's national greenhouse gas inventory.

CRF category	Planned improvement	Tentative time schedule
CRF 1.A (Energy - fuel combustion)	The use of emission trading data in the following inventories.	Starting in 2007 Submission, more comprehensive approach in 2008 submission
CRF 1.A 3 (Transport)	Fuel shift in transport models (separation of gasoil for non-road use from heating gasoil)	2008 Submission
CRF 1.A 3a (Civil aviation)	Estimation of helicopters in ILMI model (preliminary study)	2008 Submission or later
Cross-sectoral (CRF 1.A - CRF 2)	Subtraction of captured share of transferred CO_2 in pulp and paper industry	2008 Submission
CRF 2 (Industrial processes)	CRF 2.F (F-gases). *As response to the review process* potential ways of verifying the level of F-gases emissions will be considered.	2006 Submission
CRF 3 (Solvent and other product use)	National speciation of NMVOC compounds will be developed. Also, the inventory of NMVOCs from products will be more accurate based on availability of data from the National Product Register	2007-2008
CRF 4 (Agriculture)	CRF 4.A (Enteric fermentation) Possible change in methodology for calculating methane emissions from enteric fermentation of cattle so that it would base on the feed consumption of cattle instead of estimating this indirectly from the data on animal weight, daily weight gain etc.	Not specified, not the first priority
CRF 4 (Agriculture)	CRF 4.B (Manure management) and CRF 4.D (Agricultural soils) The distribution of different manure management systems should be updated regularly. Little information about the distribution of different manure management systems exists in Finland. Data collecting methodology related to this issue should be improved.	Updated when new data available
CRF 5 (LULUCF)	Inclusion of N_2O emissions from disturbance	2008 submission

CRF category	Planned improvement	Tentative time schedule
	associated to land use conversion to cropland (CRF 5 (III))	to UNFCCC
CRF 5 (LULUCF)	Several improvement projects are ongoing in the LULUCF sector. An important subject is area transitions between land use categories. Finland will make an effort to report land use conversions in the submission 2008 to the UNFCCC.	2008 submission
CRF 5 (LULUCF)	The method for carbon stock changes in living biomass on Forest land will be renewed (CRF 5.A). New biomass models for Finland are introduced, and to apply them some modifications are needed. It also has been considering to replace the present default Method with the Stock change method.	2008 submission
CRF 5 (LULUCF)	Trees with height less than 1.3 meters will be added in the inventory when more information of the amount of them is available.	when more data is available
CRF 5 (LULUCF)	Implementation of new method currently under development to estimate carbon stock change in living biomass.	2008 or 2009 submission
CRF 6 (Waste)	CRF 6.A (Solid waste disposal on land) The waste composition data for MSW may be reviewed if better information is available	probably 2008 submission
CRF 6 (Waste)	CRF 6.D (Composting) The data from VAHTI database will substitute for the interpolated activity data in the years 1998-2003.	2008 submission

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ANNEX 1. Additional information on uncertainty reporting (Tier 2 and Tier 1)

Table A. Tier 2 uncertainty reporting according to Table 6.2 in IPCC (2000).

TABLE 6.2	TIER 2 UNCERTAINTY REPORTING											
A	B	C	D				E	F	G	H	I	J
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Gas	Base year emissions	Year t emissions	Uncertainty in base year emissions as % of emissions in the category		uncertainty introduced on national total in base year	Uncertainty in year t emissions as % of emissions in the category		uncertainty introduced on national total in year t	% change in emissions between year t and base year	range of likely % change between year t and base year	
		Gg CO2 equivalent	Gg CO2 equivalent	% below (2,5 percentile)	% above (97,5 percentile)	%	% below (2.5 percentile)	% above (97.5 percentile)	%	%	Lower % (2.5 percentile)	Upper % (97.5 percentile)
1.A. Fuel Combustion												
Liquid fuels	CO2	27 984	26 227	3	3	0.67	2.82	2.87	0.60	-6	-9	-4
Solid fuels	CO2	14 592	11 164	10	10	1.20	10.22	9.56	0.92	-23	-26	-21
Gaseous fuels	CO2	4 970	8 206	1	1	0.06	1	1	0.09	65	63	67
Other fuels	CO2	5 696	7 518	6	6	0.30	6	7	0.41	32	24	40
1.A.1 Energy Industries												
Liquid fuels	CH4	1	1	60	62	0.00	59	61	0.00	-8	-46	56
	N2O	25	24	60	61	0.01	58	61	0.01	-6	-42	48
Solid fuels	CH4	2	3	62	59	0.00	61	59	0.00	28	-21	107
	N2O	43	34	60	59	0.02	61	57	0.02	-22	-51	19
Gaseous fuels	CH4	1	6	59	59	0.00	61	61	0.00	438	247	715
	N2O	16	34	62	62	0.01	59	58	0.02	119	40	254
Biomass	CH4	2	8	60	68	0.00	59	67	0.00	424	212	804
	N2O	3	62	60	65	0.00	60	65	0.03	1 915	1 085	3 383
Other fuels	CH4	2	4	62	60	0.00	59	60	0.00	81	13	194
	N2O	35	62	57	60	0.02	59	60	0.03	79	12	189
1.A.2. Manufacturing Industries and Construction												
Liquid fuels	CH4	3	2	61	59	0.00	60	59	0.00	-8	-46	55
	N2O	38	31	62	60	0.02	62	60	0.02	-19	-48	25
Solid fuels	CH4	1	1	60	60	0.00	60	61	0.00	-61	-75	-40

	N2O	47	30	61	60	0.02	62	60	0.01	-37	-61	0
Gaseous fuels	CH4	1	1	62	59	0.00	60	60	0.00	-7	-41	45
	N2O	15	15	59	61	0.01	62	60	0.01	-3	-40	45
Biomass	CH4	7	9	61	65	0.00	60	62	0.00	36	-21	138
	N2O	56	75	61	62	0.03	60	63	0.04	34	-24	135
Other fuels	CH4	1	1	58	60	0.00	61	59	0.00	-18	-51	34
	N2O	17	15	58	61	0.01	61	61	0.01	-11	-46	46
1.A.3. Transport												
a. Civil Aviation	CH4	0.3	0.3	56	96	0.00	57	100	0.00	-11	-26	10
	N2O	5	4	71	156	0.01	70	152	0.01	-13	-35	15
b. Road Transportation												
Gasoline	CH4	78	32	51	50	0.03	49	50	0.01	-59	-65	-51
Cars with Catalytic Converters	N2O	32	477	94	361	0.09	94	348	1.33	1 387	659	2 939
Cars without Catalytic Converters	N2O	59	25	86	260	0.13	86	237	0.05	-57	-83	3
Diesel	CH4	12	6	48	52	0.00	50	50	0.00	-53	-60	-44
	N2O	68	89	100	158	0.09	96	157	0.11	30	-43	183
Natural gas	CH4											
	N2O											
c. Railways	CH4	0.2	0.1	61	109	0.00	60	113	0.00	-37	-54	-12
	N2O	2	1	71	142	0.00	71	144	0.00	-31	-52	-3
d. Navigation												
Residual Oil & Gas/Diesel Oil	CH4	0.4	0.5	58	99	0.00	57	100	0.00	20	-12	64
	N2O	3	3	70	145	0.00	70	158	0.00	16	-23	76
Gasoline	CH4	4	4	59	107	0.00	57	103	0.00	2	-36	64
	N2O	0.33	0.60	71	154	0.00	71	153	0.00	80	-23	345
e. Other Transportation												
Liquid fuels	CH4	5.0	6	54	61	0.00	54	62	0.00	30	-19	111
Gasoline	N2O	1	0.96	71	165	0.00	72	158	0.00	-21	-58	43
Diesel	N2O	4	4	71	156	0.01	71	157	0.01	5	-43	92
1.A.4. Other Sectors												
Liquid fuels	CH4	16	12	74	15	0.01	79	16	0.01	-22	-61	29
	N2O	56	40	74	15	0.03	75	16	0.02	-28	-64	34
Solid fuels	CH4	2.3	0.1	74	20	0.00	76	20	0.00	-96	-98	-93
	N2O	0.6	0.1	50	51	0.00	50	50	0.00	-79	-84	-72
Gaseous fuels	CH4	0.2	0.2	76	15	0.00	76	15	0.00	-4	-46	62
	N2O	1	1	50	51	0.00	51	51	0.00	99	52	158

Biomass	CH4	161	179	71	143	0.19	71	153	0.22	11	-36	98
	N2O	28	30	71	148	0.03	69	138	0.03	8	-33	78
Other fuels	CH4	1	1.13	53	58	0.00	52	60	0.00	-9	-43	46
	N2O	1	1	71	153	0.00	72	146	0.00	-9	-51	62
1.A.5. Other												
Liquid fuels	CH4	2	2	62	59	0.00	60	58	0.00	0	-31	50
	N2O	9	9	59	61	0.00	60	58	0.00	-1	-33	45
Gaseous fuels	CH4	0.1	0.3	67	81	0.00	62	67	0.00	419	181	1 028
	N2O	0	1	69	83	0.00	62	69	0.00	405	176	1 004
1.B. Fugitive Emissions from Fuels												
1.B.2. Oil and Natural Gas												
Flaring	CO2	123	77	60	60	0.06	21	141	0.09	-37	-58	167
Oil refining	CH4	8	9.42	91	90	0.01	89	92	0.01	23	-59	150
Gas transmission	CH4	4	21	49	49	0.00	3	3	0.00	490	296	1 064
Gas distribution	CH4	0	34	0	0	0.00	5	5	0.00			
2. Industrial Processes												
2.A.1 Cement Production	CO2	786	542	5	5	0.03	5	5	0.02	-31	-34	-28
2.A.2 Lime Production	CO2	383	455	4	4	0.01	4	4	0.01	19	14	24
2.A.3 Limestone and Dolomite Use	CO2	99	134	9	9	0.01	10	9	0.01	36	22	49
2.A.4 Soda Ash Use	CO2	18	19	5	7	0.00	5	7	0.00	4	-4	14
2.B.2 Nitric Acid Production	N2O	1 656	1 569	57	95	1.29	21	7	0.26	-5	-56	107
2.B.5 Other: Ethylene	CH4	4	6.86	21	20	0.00	20	21	0.00	74	46	107
2.B.5 Other: Hydrogen Production	CO2	60	116	9	13	0.01	9	13	0.01	93	67	124
2.C Iron and Steel production	CH4	5	9.39	20	20	0.00	20	20	0.00	84	56	114
2.C Iron and Steel production	CO2	1 859	2 394	7	9	0.14	10	10	0.20	29	8	32
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0.0126	789			0.00	11	26	0.17	6 261 805	5 557 633	7 907 151
2.F.2 Foam Blowing	HFCs		9	0	0	0.00	23	24	0.00			
2.F.4 Aerosols	HFCs		77	0	0	0.00	10	10	0.01			
2.F.7 Electrical Equipment	SF6	87	4	50	50	0.04	88	90	0.00	-96	-100	-88
2.F Other (grouped data)	HFCs, PFCs, SF6	8	17	49	51	0.00	39	38	0.01	113	11	352
3. Total Solvent and Other Product Use	N2O	62	47	35	38	0.02	36	38	0.01	-25	-53	20
4. Agriculture												
4.A. Enteric fermentation	CH4	1 918	1 577	21	33	0.52	10	17	0.21	-18	-39	7
4.B. Manure management	CH4	230	278	14	16	0.03	16	15	0.04	21	-4	49
4.B. Manure management	N2O	665	499	85	25	0.46	81	23	0.33	-25	-86	381

4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3 360	2 488	76	228	6.27	53	138	2.76	-26	-83	291
4.D. Agricultural soils: indirect emissions	N2O	932	737	68	276	2.11	62	236	1.40	-21	-86	346
5. LULUCF												
5.A.1. Forest Land remaining Forest Land												
carbon stock change in living biomass	CO2	-28 566	-37 184	62	61	14.60	38	38	11.39	30	-19	181
net carbon stock change in soils: mineral	CO2	-6 772	-5 905	136	139	7.71	156	158	7.48	-13	-779	779
net carbon stock change in soils: organic	CO2	7 531	5 436	130	129	8.04	183	178	7.99	-28	-557	646
5.A2. Land converted to Forest Land												
5.B1. Cropland Remaining Cropland												
net carbon stock change in soils: mineral	CO2	214	-1 569	101	97	0.18	102	100	1.29	-833	-6 352	1 355
net carbon stock change in soils: organic	CO2	6 584	4 916	91	104	5.59	90	91	3.61	-25	-96	150
5.B.2. Land Converted to Cropland												
5.C1. Grassland Remaining Grassland												
net carbon stock change in soils: mineral	CO2	-1 744	2 274	98	100	1.43	101	97	1.84	-230	-1 375	62
net carbon stock change in soils: organic	CO2	1 230	16	93	102	1.02	91	105	0.01	-99	-100	-96
5.C.2. Land Converted to Grassland	CO2	0	0									
5.D.1. Wetlands Remaining Wetlands												
5.D2. Land Converted to Wetlands												
Peat production areas	CO2	585	728	82	205	0.99	80	205	1.20	24	-44	162
Peat production areas	CH4	6	7.21	80	203	0.01	80	204	0.01	16	-47	161
Carbon stock change in living biomass per area	CO2	0	0									
5 (I) Direct N2O Emissions from N Fertilization	N2O	17	7	94	355	0.05	94	387	0.02	-59	-93	171
5 (II) N2O Emissions from Drainage of Soils												
5 (III) N2O Emissions from Disturbance Associated with Land-use Conversion	N2O	0	0									
5 (IV) Carbon Emissions from	CO2	168.510	72	25	22	0.04	26	23	0.01	-57	-69	-41

Agricultural Lime Application												
5 (V) Biomass Burning												
Forest Land	CO2	13	16	70	71	0.01	72	72	0.01	20	-50	176
	CH4	9	4	72	74	0.01	69	69	0.00	-60	-82	-11
	N2O	1	0	70	73	0.00	71	72	0.00	-60	-84	-6
6. Waste												
6.A. Solid Waste Disposal on Land	CH4	3 653	2 092	42	41	1.27	43	42	0.73	-43	-64	-10
6.B.1 Industrial Wastewater	CH4	22	24	62	117	0.02	61	108	0.02	6	-52	131
6.B.2 Domestic and Commercial Wastewater												
sparsely populated areas	CH4	118	92	34	26	0.03	35	27	0.03	-22	-46	12
densely populated areas	CH4	14	15	60	110	0.01	60	109	0.01	9	-49	134
sparsely populated areas	N2O	30	24	94	388	0.10	95	346	0.07	-21	-88	402
densely populated areas	N2O	75	55	94	381	0.23	95	347	0.15	-26	-89	368
6.B.3. N input from Fish Farming	N2O	8	3	94	376	0.03	94	358	0.01	-59	-94	171
6.B.3. N input from industrial wastewater	N2O	30	19	94	372	0.09	94	356	0.06	-35	-90	320
6.D Other Compost production	CH4	22	63	63	123	0.02	64	90	0.05	194	-23	773
6.D Other Compost production	N2O	20	61	63	110	0.02	67	94	0.05	200	-20	821
7.Other - non-energy use of fuels	N2O											
Total		**49 645**	**37 642**	50	50		60	50		-24	-60	40

Table B. Tier 1 Uncertainty reporting according to Table 6.1 in 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	Base Year emissions, 1990	Current Year emissions, 2003	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty	Combined uc as part of total national emissions in 2003	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																
Liquid Fuels	CO2	27 984	26 227	2 %	2 %	3 %	2.03 %	0.1207	0.5130	0.24 %	1.45 %	1.47 %	R	R	E1	
Solid fuels	CO2	14 592	11 164	2 %	10 %	10 %	3.09 %	0.0141	0.2184	0.14 %	0.49 %	0.51 %	R	R	E1	
Gaseous fuels	CO2	4 970	8 206	1 %	1 %	1 %	0.32 %	0.0909	0.1605	0.09 %	0.23 %	0.24 %	R	R	E1	
Other fuels	CO2	5 696	7 518	4 %	5 %	7 %	1.36 %	0.0673	0.1471	0.34 %	0.89 %	0.96 %	M	R	E1	M4
1.A.1 Energy Industries																
Liquid fuels	CH4	1	1	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	25	24	2 %	60 %	60 %	0.04 %	0.0001	0.0005	0.01 %	0.00 %	0.01 %	R/M	R	E1	M2
Solid fuels	CH4	2	3	2 %	60 %	60 %	0.00 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	43	34	2 %	60 %	60 %	0.06 %	0.0001	0.0007	0.00 %	0.00 %	0.00 %	R	R	E1	
Gaseous fuels	CH4	1	6	1 %	60 %	60 %	0.01 %	0.0001	0.0001	0.01 %	0.00 %	0.01 %	R/M	R	E1	M2
	N2O	16	34	1 %	60 %	60 %	0.06 %	0.0005	0.0007	0.03 %	0.00 %	0.03 %	R	R	E1	
Biomass	CH4	2	8	20 %	60 %	63 %	0.01 %	0.0001	0.0002	0.01 %	0.00 %	0.01 %	R	R	E1	
	N2O	3	62	20 %	60 %	63 %	0.11 %	0.0012	0.0012	0.07 %	0.03 %	0.08 %	R	R	E1	
Other fuels	CH4	2	4	5 %	60 %	60 %	0.01 %	0.0001	0.0001	0.00 %	0.00 %	0.00 %	R	R	E1	
	N2O	35	62	5 %	60 %	60 %	0.10 %	0.0007	0.0012	0.04 %	0.01 %	0.04 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction																
Liquid fuels	CH4	3	2	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	38	31	2 %	60 %	60 %	0.05 %	0.0001	0.0006	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
Solid fuels	CH4	1	1	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	47	30	2 %	60 %	60 %	0.05 %	-0.0001	0.0006	0.00 %	0.00 %	0.00 %	R	R	E1	
Gaseous fuels	CH4	1	1	1 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
	N2O	15	15	1 %	60 %	60 %	0.02 %	0.0001	0.0003	0.00 %	0.00 %	0.00 %	R	R	E1	
Biomass	CH4	7	9	15 %	60 %	62 %	0.02 %	0.0001	0.0002	0.01 %	0.00 %	0.01 %	R	R	E1	
	N2O	56	75	15 %	60 %	62 %	0.13 %	0.0007	0.0015	0.04 %	0.03 %	0.05 %	R	R	E1	
Other fuels	CH4	1	1	5 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	

	N2O	17	15	5 %	60 %	60 %	0.02 %	0.0001	0.0003	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.3. Transport																
a. Civil Aviation	CH4	0.3	0.3	5 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	D	R		L4
	N2O	5	4	5 %	150 %	150 %	0.02 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
b. Road Transportation																
Gasoline	CH4	78	32	1 %	50 %	50 %	0.04 %	-0.0005	0.0006	-0.02 %	0.00 %	0.02 %	M	R		L5
Cars with Catalytic Converters	N2O	32	477	1 %	378 %	378 %	4.93 %	0.0089	0.0093	3.36 %	0.01 %	3.36 %	M	R		L6,L7,L8 ,L9,L10, L19,L20, L21,L22, L23
Cars without Catalytic Converters	N2O	59	25	1 %	259 %	259 %	0.18 %	-0.0003	0.0005	-0.09 %	0.00 %	0.09 %	M	R		L6, L9, L10, L19, L21
Diesel	CH4	12	6	1 %	50 %	50 %	0.01 %	-0.0001	0.0001	0.00 %	0.00 %	0.00 %	M	R		L5
	N2O	68	89	1 %	158 %	158 %	0.38 %	0.0008	0.0017	0.12 %	0.00 %	0.12 %	M	R		L6, L8, L11, L21
Natural gas	CH4	0	0	1 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	M	R		L5
	N2O	0	0.0000	1 %	150 %	150 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
c. Railways	CH4	0.2	0.146	5 %	110 %	110 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	M	R		M3
	N2O	2	1	5 %	150 %	150 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
d. Navigation																
Residual Oil & Gas/Diesel Oil	CH4	0.4	1	10 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	D	R		L4
	N2O	3	3	10 %	150 %	150 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
Gasoline	CH4	4.1	4	20 %	100 %	102 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
	N2O	0.3	0.6	20 %	150 %	151 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
e. Other Transportation																
Gasoline&Diesel	CH4	5.0	6	30 %	50 %	58 %	0.01 %	0.0001	0.0001	0.00 %	0.01 %	0.01 %	R	R		
Gasoline	N2O	1	1	30 %	150 %	153 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
Diesel	N2O	4	4	30 %	150 %	153 %	0.02 %	0.0000	0.0001	0.00 %	0.00 %	0.01 %	R	R		
1.A.4. Other Sectors																
Liquid fuels	CH4	16	12	3 %	75 %	75 %	0.03 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	56	40	3 %	75 %	75 %	0.08 %	0.0000	0.0008	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
Solid fuels	CH4	2.3	0.1	10 %	75 %	76 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	0.6	0.1	10 %	50 %	51 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
Gaseous fuels	CH4	0.2	0.2	5 %	75 %	75 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	1	1	5 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
Biomass	CH4	161	179	15 %	150 %	151 %	0.74 %	0.0012	0.0035	0.19 %	0.07 %	0.20 %	R	R	E1	
	N2O	28	30	15 %	150 %	151 %	0.12 %	0.0002	0.0006	0.03 %	0.01 %	0.03 %	R	R	E1	

Other fuels	CH4	1	1	25 %	50 %	56 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
	N2O	1	1	25 %	150 %	152 %	0.01 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.5. Other																
Liquid fuels	CH4	2	2	7 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	9	9	7 %	60 %	60 %	0.01 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
Gaseous fuels	CH4	0.1	0.3	13 %	60 %	61 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
	N2O	0	1	13 %	60 %	61 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.B. Fugitive Emissions from Fuels																
1.B.1 Solid Fuels																
1.B.2. Oil and Natural Gas																
Flaring	CO2	123	77	50 %	0 %	50 %	0.11 %	-0.0002	0.0015	0.00 %	0.11 %	0.11 %	R	R	E9	
Oil refining	CH4	8	9	2 %	90 %	90 %	0.02 %	0.0001	0.0002	0.01 %	0.00 %	0.01 %	R	R	E9	
Gas transmission	CH4	4	21	3 %	0 %	3 %	0.00 %	0.0004	0.0004	0.00 %	0.00 %	0.00 %	R	R	E9	
Gas distribution	CH4	0	34	5 %	0 %	5 %	0.00 %	0.0007	0.0007	0.00 %	0.00 %	0.00 %	R	R	E9	
2. Industrial Processes																
2.A.1 Cement Production	CO2	786	542	2 %	5 %	5 %	0.08 %	-0.0004	0.0106	0.00 %	0.03 %	0.03 %	R	R	E9	
2.A.2 Lime Production	CO2	383	455	2 %	3 %	4 %	0.04 %	0.0035	0.0089	0.01 %	0.03 %	0.03 %	R	R	E9	
2.A.3 Limestone and Dolomite Use	CO2	99	134	7 %	9 %	11 %	0.04 %	0.0012	0.0026	0.01 %	0.03 %	0.03 %	R	R	E9	
2.A.4 Soda Ash Use	CO2	18	19	7 %	2 %	7 %	0.00 %	0.0001	0.0004	0.00 %	0.00 %	0.00 %	R	R	E9	
2.B.2 Nitric Acid Production	N2O	1 656	1 569	5 %	100 %	100 %	4.29 %	0.0075	0.0307	0.75 %	0.22 %	0.78 %	R/M	R		M1
2.B.5 Other: Ethylene	CH4	4	7	5 %	20 %	21 %	0.00 %	0.0001	0.0001	0.00 %	0.00 %	0.00 %				
2.B.5 Other: Hydrogen Production	CO2	60	116	12 %	5 %	13 %	0.04 %	0.0014	0.0023	0.01 %	0.04 %	0.04 %	R	R	E9	
2.C Iron and Steel production	CH4	5	9	3 %	20 %	20 %	0.01 %	0.0001	0.0002	0.00 %	0.00 %	0.00 %	R	R	E1	
2.C Iron and Steel production	CO2	1 859	2 394	0 %	10 %	10 %	0.65 %	0.0208	0.0468	0.21 %	0.00 %	0.21 %			E10	
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs	0	789	26 %	0 %	26 %	0.56 %	0.0154	0.0154	0.00 %	0.57 %	0.57 %	R	R	E8	
2.F.2 Foam Blowing	HFCs	0	9	24 %	0 %	24 %	0.01 %	0.0002	0.0002	0.00 %	0.01 %	0.01 %	R	R	E8	
2.F.4 Aerosols	HFCs	0	77	10 %	0 %	10 %	0.02 %	0.0015	0.0015	0.00 %	0.02 %	0.02 %	R	R	E8	
2.F.7 Electrical Equipment	SF6	87	4	88 %	0 %	88 %	0.01 %	-0.0011	0.0001	0.00 %	0.01 %	0.01 %	R	R	E8	
2.F Other (grouped data)	HFCs, PFCs, SF6	8	17	38 %	0 %	38 %	0.02 %	0.0002	0.0003	0.00 %	0.02 %	0.02 %	R	R	E8	
3. Total Solvent and Other Product Use	N2O	62	47	30 %	20 %	36 %	0.05 %	0.0000	0.0009	0.00 %	0.04 %	0.04 %	R	R	E1	

4. Agriculture																
4.A.Enteric fermentation	CH4	1 918	1 577	0 %	17 %	17 %	0.72 %	0.0040	0.0308	0.07 %	0.00 %	0.07 %	D/R	R		L4, L13
4.B.Manure management	CH4	230	278	0 %	16 %	16 %	0.12 %	0.0022	0.0054	0.03 %	0.00 %	0.03 %	R	R		
4.B.Manure management	N2O	665	499	0 %	81 %	81 %	1.11 %	0.0005	0.0098	0.04 %	0.00 %	0.04 %	R	R		L12, L14, L15, L16, L17, L4
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3 360	2 488	0 %	138 %	138 %	9.41 %	0.0016	0.0487	0.23 %	0.00 %	0.23 %	R/M	R		L1
4.D.Agricultural soils: indirect emissions	N2O	932	737	0 %	236 %	236 %	4.76 %	0.0014	0.0144	0.32 %	0.00 %	0.32 %	R/M	R		L1
5. LULUCF																
5.A.1. Forest Land remaining Forest Land																
carbon stock change in living biomass	CO2	-28 566	-37 184	0 %	37 %	37 %	-37.61 %	-0.3294	-0.7274	-12.19 %	0.00 %	12.19 %				
Net carbon stock change on mineral soils	CO2	-6 772	-5 905	0 %	100 %	100 %	-16.14 %	-0.0207	-0.1155	-2.07 %	0.00 %	2.07 %				
Net carbon stock change on organic soils per area	CO2	7 531	5 436	0 %	250 %	250 %	37.15 %	0.0009	0.1063	0.23 %	0.00 %	0.23 %				
5.B.1. Cropland Remaining Cropland																
net carbon stock change in soils: mineral	CO2	214	-1 569	0 %	100 %	100 %	-4.29 %	-0.0337	-0.0307	-3.37 %	0.00 %	3.37 %	R		E7	
net carbon stock change in soils: organic	CO2	6 584	4 916	20 %	90 %	92 %	12.39 %	0.0040	0.0962	0.36 %	2.72 %	2.74 %	D	R	E4	L24
5.C1. Grassland Remaining Grassland																
net carbon stock change in soils: mineral	CO2	-1 744	2 274	0 %	100 %	100 %	6.22 %	0.0689	0.0445	6.89 %	0.00 %	6.89 %	R		E7	
net carbon stock change in soils: organic	CO2	1 230	16	30 %	90 %	95 %	0.04 %	-0.0169	0.0003	-1.52 %	0.01 %	1.52 %	D	R	E4	L24
5.C2. Land Converted to Grassland	CO2															
5.D1. Wetlands Remaining Wetlands																
Net carbon stock change on soils per peat mining area	CO2															
Net carbon stock change per area in soils per area of drained wetlands	CO2															
carbon stock change in living biomass	CO2															
5.D2. Land Converted to Wetlands																

Peat production areas	CO2	585	728	15 %	208 %	208 %	4.14 %	0.0060	0.0142	1.25 %	0.30 %	1.29 %	R	R	E6	L3
Peat production areas	CH4	6	7	0 %	208 %	0 %	0.00 %	0.0001	0.0001	0.01 %	0.00 %	0.01 %	R	R	E6	L3
Net carbon stock change per area in soils per area of drained wetlands	CO2															
Carbon stock change in living biomass per area	CO2															
5 (I) Direct N2O Emissions from N Fertilization	N2O	17.1	7.0	10 %	380 %	380 %	0.07 %	-0.0001	0.0001	-0.04 %	0.00 %	0.04 %	R/M	R		L1
5 (II) N2O Emissions from Drainage of Soils																
Forest Land	N2O															
Wetlands	N2O															
5 (III) N2O Emissions from Disturbance Associated with Land-use Conversion	N2O															
5 (IV) Carbon Emissions from Agricultural Lime Application	CO2	169	72	20 %	20 %	28 %	0.06 %	-0.0009	0.0014	-0.02 %	0.04 %	0.04 %	R	R	E5	
5 (V) Biomass Burning																
Forest Land	CO2	13	16	10 %	70 %	71 %	0.03 %	0.0001	0.0003	0.01 %	0.00 %	0.01 %	D	R		L24
	CH4	9	4	10 %	70 %	71 %	0.01 %	-0.0001	0.0001	0.00 %	0.00 %	0.00 %	D	R		L24
	N2O	1	0	10 %	70 %	71 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	D	R		L24
6. Waste																
6.A. Solid Waste disposal on Land	CH4	3 653	2 092	0 %	43 %	43 %	2.46 %	-0.0102	0.0409	-0.44 %	0.00 %	0.44 %	R/D		E2	L4
6.B.1 Industrial Wastewater	CH4	22	24	10 %	104 %	105 %	0.07 %	0.0002	0.0005	0.02 %	0.01 %	0.02 %	R/D	R	E2	L4
6.B.2 Domestic and Commercial Wastewater																
sparcely populated areas	CH4	118	92	15 %	32 %	35 %	0.09 %	0.0002	0.0018	0.00 %	0.04 %	0.04 %	R	R	E3	
densely populated areas	CH4	14	15	5 %	104 %	105 %	0.04 %	0.0001	0.0003	0.01 %	0.00 %	0.01 %	R	R	E2	L4
sparcely populated areas	N2O	30	24	10 %	380 %	380 %	0.25 %	0.0000	0.0005	0.02 %	0.01 %	0.02 %	R	R	E2	L2
densely populated areas	N2O	75	55	5 %	380 %	380 %	0.58 %	0.0000	0.0011	0.01 %	0.01 %	0.02 %	R	R	E2	L2
6.B.3. N input from Fish Farming	N2O	8	3	10 %	380 %	380 %	0.04 %	0.0000	0.0001	-0.02 %	0.00 %	0.02 %	R	R	E2	L2
6.B.3. N input from inustrial wastewater	N2O	30	19	5 %	380 %	380 %	0.20 %	0.0000	0.0004	-0.02 %	0.00 %	0.02 %	R	R	E2	L2
7.Other - non-energy use of fuels	N2O	0	0	50 %	5 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
Total		**51 121**	**36 580**				**58.8%**					**15.5%**				

Table C. Source category analysis for base year (1990) according to Tier 2 method without LULUCF.

Table 7.A1

Tier 2 Analysis - Level Assessment for Base Year

A	B	C	E	F
IPCC Source Categories	**Direct Greenhouse Gas**	**Base Year Estimate**	**Level Assessment**	**Cumulative Total of Column E**
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3360	0.41	0.41
4.D. Agricultural soils: indirect emissions	N2O	932	0.13	0.53
2.B.2 Nitric Acid Production	N2O	1656	0.09	0.62
6.A. Solid Waste Disposal on Land	CH4	3653	0.08	0.70
1.A. Fuel Combustion: Solid fuels	CO2	14592	0.07	0.77
1.A. Fuel Combustion: Liquid fuels	CO2	27984	0.04	0.81
4.A. Enteric fermentation	CH4	1918	0.03	0.84
4.B. Manure management	N2O	665	0.03	0.87
1.A. Fuel Combustion: Other fuels	CO2	5696	0.02	0.89
6.B.2 Domestic and Commercial Wastewater: densely populated areas	N2O	75	0.01	0.90
1.A.4. Other Sectors: Biomass	CH4	161	0.01	0.91

Table D. Source category analysis for inventory year 2005 according to Tier 2 method without LULUCF.

Table 7.A1					
Tier 2 Analysis - Level Assessment for Year t					
A	**B**	**C**	**D**	**E**	**F**
IPCC Source Categories	**Direct Greenhouse Gas**	**Base Year Estimate**	**Current Year Estimate**	**Level Assessment**	**Cumulative Total of Column E**
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3360	2488	0.27	0.27
4.D. Agricultural soils: indirect emissions	N2O	932	737	0.15	0.42
1.A.3. Transport: b. Road Transportation Cars with Catalytic Converters	N2O	32	477	0.11	0.53
1.A. Fuel Combustion: Solid fuels	CO2	14592	11164	0.08	0.61
6.A. Solid Waste Disposal on Land	CH4	3653	2092	0.07	0.68
1.A. Fuel Combustion: Liquid fuels	CO2	27984	26227	0.05	0.73
1.A. Fuel Combustion: Other fuels	CO2	5696	7518	0.04	0.77
4.B. Manure management	N2O	665	499	0.03	0.80
2.B.2 Nitric Acid Production	N2O	1656	1569	0.02	0.82
1.A.4. Other Sectors: Biomass	CH4	161	179	0.02	0.84
2.C Iron and Steel production	CO2	1859	2394	0.02	0.85

4.A. Enteric fermentation	CH4	1918	1577	0.02	0.87
6.B.2 Domestic and Commercial Wastewater: densely populated areas	N2O	75	55	0.02	0.89
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0	789	0.01	0.90

Table E. Source category analysis for base year (1990) according to Tier 2 method with LULUCF.

Table 7.A1				
Tier 2 Analysis - Level Assessment for Base Year				
A	**B**	**C**	**E**	**F**
IPCC Source Categories	**Direct Greenhouse Gas**	**Base Year Estimate**	**Level Assessment**	**Cumulative Total of Column E**
5.A.1. Forest Land remaining Forest Land: carbon stock change in living biomass	CO2	-28566	0.26	0.26
5.A.1. Forest Land remaining Forest Land: net carbon stock change in soils: organic	CO2	7531	0.14	0.41
5.A.1. Forest Land remaining Forest Land: net carbon stock change in soils: mineral	CO2	-6772	0.14	0.55
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3360	0.11	0.66
5.B1. Cropland Remaining Cropland: net carbon stock change in soils: organic	CO2	6584	0.10	0.76
4.D. Agricultural soils: indirect emissions	N2O	932	0.04	0.80
5.C1. Grassland Remaining Grassland: net carbon stock change in soils: mineral	CO2	-1744	0.03	0.82
2.B.2 Nitric Acid Production	N2O	1656	0.02	0.85
6.A. Solid Waste Disposal on Land	CH4	3653	0.02	0.87
1.A. Fuel Combustion: Solid fuels	CO2	14592	0.02	0.89
5.C1. Grassland Remaining Grassland: net carbon stock change in soils: organic	CO2	1230	0.02	0.91

Table F. Source category analysis for inventory year 2005 according to Tier 2 method with LULUCF.

Table 7.A1					
Tier 2 Analysis - Level Assessment for Year t					
A	**B**	**C**	**D**	**E**	**F**
IPCC Source Categories	**Direct Greenhouse Gas**	**Base Year Estimate**	**Current Year Estimate**	**Level Assessment**	**Cumulative Total of Column E**
5.A.1. Forest Land remaining Forest Land: carbon stock change in living biomass	CO2	-28566	-37184	0.25	0.25
5.A.1. Forest Land remaining Forest Land: net carbon stock change in soils: organic	CO2	7531	5436	0.18	0.42
5.A.1. Forest Land remaining Forest Land: net carbon stock change in soils: mineral	CO2	-6772	-5905	0.16	0.59
5.B1. Cropland Remaining Cropland: net carbon stock change in soils: organic	CO2	6584	4916	0.08	0.67
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3360	2488	0.06	0.73
5.C1. Grassland Remaining Grassland: net carbon stock change in soils: mineral	CO2	-1744	2274	0.04	0.77
4.D. Agricultural soils: indirect emissions	N2O	932	737	0.03	0.80
1.A.3. Transport: b. Road Transportation Cars with Catalytic Converters	N2O	32	477	0.03	0.83
5.B1. Cropland Remaining Cropland: net carbon stock change in soils: mineral	CO2	214	-1569	0.03	0.86
5.D2. Land Converted to Wetlands: Peat production areas	CO2	585	728	0.03	0.88
1.A. Fuel Combustion: Solid fuels	CO2	14592	11164	0.02	0.90
6.A. Solid Waste Disposal on Land	CH4	3653	2092	0.02	0.92

Table G. Source category analysis - Trend assessment according to Tier 2 method without LULUCF.

Table 7.A2					
Tier 2 Analysis - Trend Assessment					
A	**B**	**C**	**D**	**E**	**F**
IPCC Source Categories	**Direct Greenhouse Gas**	**Base Year Estimate**	**Current Year Estimate**	**Trend Assessment**	**Cumulative Total of Column E**
1.A.3. Transport: b. Road Transportation Cars with Catalytic Converters	N2O	32	477	0.26	0.26
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3360	2488	0.22	0.48
6.A. Solid Waste Disposal on Land	CH4	3653	2092	0.12	0.60
4.D. Agricultural soils: indirect emissions	N2O	932	737	0.09	0.69
1.A. Fuel Combustion: Solid fuels	CO2	14592	11164	0.06	0.75
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0	789	0.04	0.78
1.A. Fuel Combustion: Other fuels	CO2	5696	7518	0.02	0.81
4.B. Manure management	N2O	665	499	0.02	0.83
1.A.3. Transport: b. Road Transportation Cars without Catalytic Converters	N2O	59	25	0.01	0.84
2.F.7 Electrical Equipment	SF6	87	4	0.01	0.86
6.B.2 Domestic and Commercial Wastewater: densely populated areas	N2O	75	55	0.01	0.87
1.B.2. Oil and Natural Gas: Flaring	CO2	123	77	0.01	0.88
2.C Iron and Steel production	CO2	1859	2394	0.01	0.89
1.A. Fuel Combustion: Gaseous fuels	CO2	4970	8206	<0.01	0.90

Table H. Source category analysis - Trend assessment according to Tier 2 method with LULUCF.

Table 7.A2					
Tier 2 Analysis - Trend Assessment					
A	**B**	**C**	**D**	**E**	**F**
IPCC Source Categories	**Direct Greenhouse Gas**	**Base Year Estimate**	**Current Year Estimate**	**Trend Assessment**	**Cumulative Total of Column E**
5.A.1. Forest Land remaining Forest Land: carbon stock change in living biomass	CO2	-28566	-37184	0.33	0.33
5.C1. Grassland Remaining Grassland: net carbon stock change in soils: mineral	CO2	-1744	2274	0.20	0.53
5.B1. Cropland Remaining Cropland: net carbon stock change in soils: mineral	CO2	214	-1569	0.10	0.62
1.A.3. Transport: b. Road Transportation Cars with Catalytic Converters	N2O	32	477	0.09	0.71
5.A.1. Forest Land remaining Forest Land: net carbon stock change in soils: mineral	CO2	-6772	-5905	0.07	0.78
5.C1. Grassland Remaining Grassland: net carbon stock change in soils: organic	CO2	1230	16	0.05	0.83
5.D2. Land Converted to Wetlands: Peat production areas	CO2	585	728	0.03	0.86
5.A.1. Forest Land remaining Forest Land: net carbon stock change in soils: organic	CO2	7531	5436	0.03	0.89
6.A. Solid Waste Disposal on Land	CH4	3653	2092	0.02	0.90
1.A. Fuel Combustion: Other fuels	CO2	5696	7518	0.01	0.92
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0	789	0.01	0.93

ANNEX 2. Description of the Compliance Monitoring Data System VAHTI

The VAHTI compliance data system functions as a tool for the 13 Regional Environment Centres in their work on processing and monitoring permits. The data system contains information on the environmental permits of clients and on their wastes generated, discharges into water, emission to air. In the future, the system will also include information on noise emissions. This baseline data is 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.

Currently, there are 800 active users of the system which is an effective tool in the everyday work of the environmental administration. The user interface makes it possible to add new customers, change or add customer data, retrieve reports from database and write inspection reports. The system also includes mapping functions and a calendar to remind the inspector of time limits.

VAHTI is a customer information system (Figures 1 and 2).

The operators must have an environmental permit from the authority containing, for example, the following information:

- identification details
- contact persons
- respective authorities
- environmental permit conditions
- environment insurance information
- loading points (stacks and sewers)
- information on emission control equipment and/or wastewater treatment plants
- information on boilers and fuels used
- information on landfills
- information on emissions to air, water and wastes and related analysis
- information on energy and other production
- information on raw materials and water consumption

Figure 1. Structure of the VAHTI Data System

The operators of installations (such as energy producers, industrial installations, fish farmers, peat producers, waste management and wastewater treatment plants) that have an environmental permit report information of their annual emissions and wastes to the Regional Environment Centres according to the monitoring obligations determined in their environmental permits. After checking and approving the data the supervising authorities record the data into the database (VAHTI) from where it is available for emission inventory purposes (see Chapter 2).

The coverage of the Finnish Environment legislation is much wider than the European Union's IPPC directive. The VAHTI Data System includes information of about 31000 clients of which about 28 000 in operation and about 3000 out of operation. There are only about 600 installations that are under the European Union's IPPC directive. In 2003, 3825 facilities sent their emission reports to the authorities. The number of facilities that reported information on emissions to air, water or on wastes is presented in Table 1 below.

Table 1. Facilities reporting information to the VAHTI Data System in 2003**.**

Activity	Water	Air	Waste
Energy production and industrial installations	361	791	731
Municipalities	517	1	381
Fish farms	251	-	7
Others	59	114	612
Total	1188	906	1731

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, include orders on what the operator (i.e. person or legal person in charge of a facility) must report to the authorities. The annual reporting obligation of an installation concerns emissions for which the installation has an emission limit value (ELV) in the environmental permit. The monitoring system for these substances is stipulated together with the ELV for these compounds. Of those emissions reported to the UNFCCC, ELVs are usually given for emissions of sulphur (as SO_2) and nitrogen oxides (as NO_2), but not for carbon dioxide, methane or nitrous oxide. However, the operators may report also these compounds based on the reporting obligations to the integrated emission registers such as the European Polluting Emissions Register (EPER) and the future European Pollutant Release and Transfer Register (E-PRTR)[3]. The EPER and PRTR reporting substance lists include also 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 are not possible to split between the CRF reporting categories.

In addition to emission data the operators also report on the types, characteristics and consumption of fuels though this data may not be as complete as emission data. Also, waste amounts (with classification data) to solid waste disposal sites, and wastewater handling data are reported to the VAHTI Data System.

The operators must report emissions of carbon dioxide and fuel data to the Energy Market Authority that keeps the Emission Trading Register. The Energy Market Authority shall decide soon how the reporting must be carried out by the operators.

Quality checking carried out by the supervising authority

When receiving the emission report from the operator the supervising authority checks whether the data is 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 on hard copies or electronically by email or through the Internet (Figure 2). The larger industrial installations have recently developed reporting systems which are based on direct information flow from the plant information systems to the supervising authority. The emission data is always checked by the supervising authority before recording into the VAHTI data system as described in Chapter 1.3. When the operator chooses to send the data over the

[3] According to the Finnish Environmental Protection Act paragraph 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.

internet using a centralized data collection system[4] the data will automatically be checked for completeness and only the completed data will be sent to the authorities for check of the substance.

Figure 2. Reporting options for the operators

Further information on the VAHTI Data System is available from Mr Markku Hietamäki, Ministry of the Environment (email: firstname.surname@ymparisto.fi).

[4] The centralized 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 also s e.g. the tax authority, customs, statistics)

ANNEX 3. Discussion of the default CO_2 emission factor for coal and its applicability to the Finnish inventory

Problem statement

The current Finnish inventory uses the default emission factor 94.6 g CO_2/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 IPCC Guidelines (IPCC 1995) and 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).

The Table 3.3 gives a range of variation equal to ± 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 appear in Table B–1 of OECD/IEA (1991, p. 154). Given the information reported in that table, the factor seems to be a weighted average reflecting the market shares of hard and brown coals in North America in 1987. In that same table, the factor given for Europe is 3.1% higher, equal to 26.6 g C/MJ (97.5 g CO_2/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 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 1987 markets in North America are similar to 1990s, or 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 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 expect also the emission factor to show annual variation. We model this variation by weighing emission factors calculated for each type of coal x_i by their share of total imports s_i in any given year t, thus yielding an average annual emission factor for that year

$$\bar{x}_t = s_{1,t} x_1 + s_{2,t} x_2 + \cdots + s_{n,t} x_n,$$

where it is understood that constant properties of 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. This data is available for 1990–2003, except for 1996 when the table was not prepared.

Data on properties of fuel combusted in Finland was obtained from Taipale (1996). This study reports results from measurements carried out mainly during 1990s. 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 net calorific value and water content. Measurements of carbon content were more scarce ranging from few to tens of measurements, depending on the country of origin. For 13 countries or regions, the net calorific value and water content was not available. The carbon content was not available for 16 countries or regions. In all, the data consists 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 missing data. Although the proportion of imports with missing fuel property data was not greater than 1–17%, depending on 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 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 was 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 t/2 = 500 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 individual year's emission factors, and also that the years are clearly different from each other.

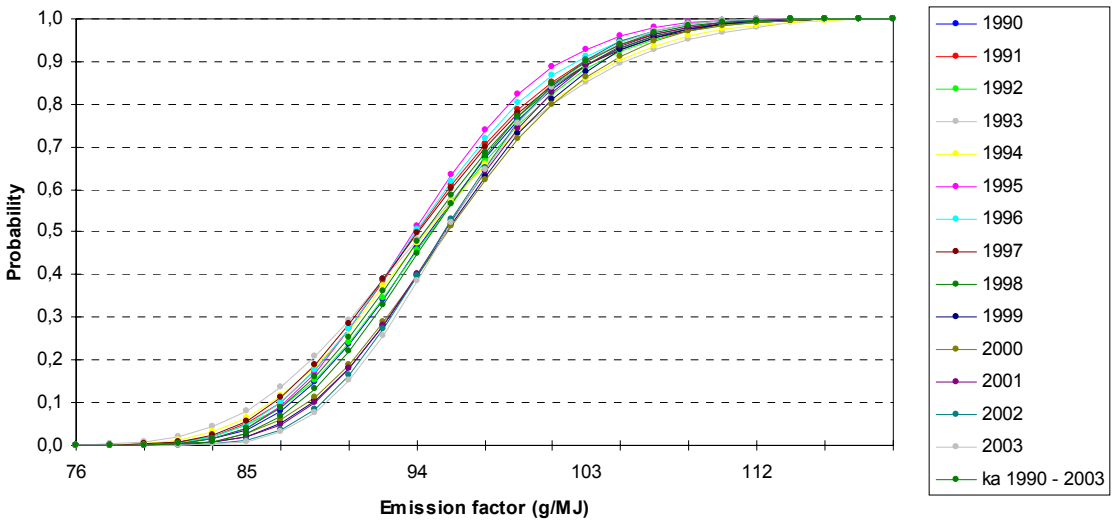

Figure 1. Uncertainty and year-to-year variability in average coal emission factor.

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 was not available, was calculated simply as the average of year 1995 and 1997 emission factors.

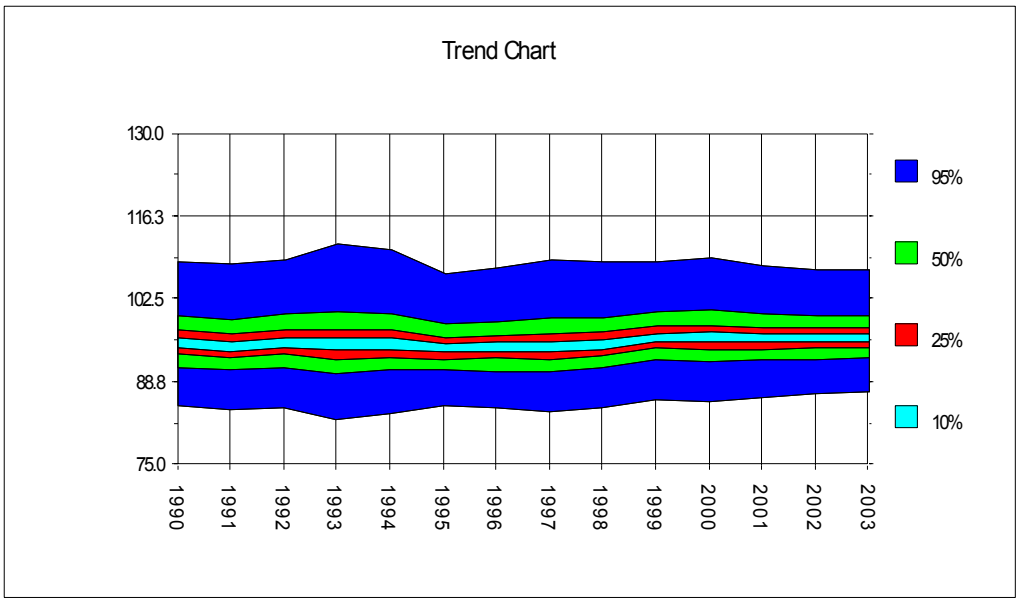

Figure 2. Uncertainty in coal emission factor over time.

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 that the ± 3% given in 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). Distribution in Fig. 3 suggests an uncertainty around 12–13%. It is much larger than the current uncertainty used for solid fuels in the inventory, which are 3–5%.

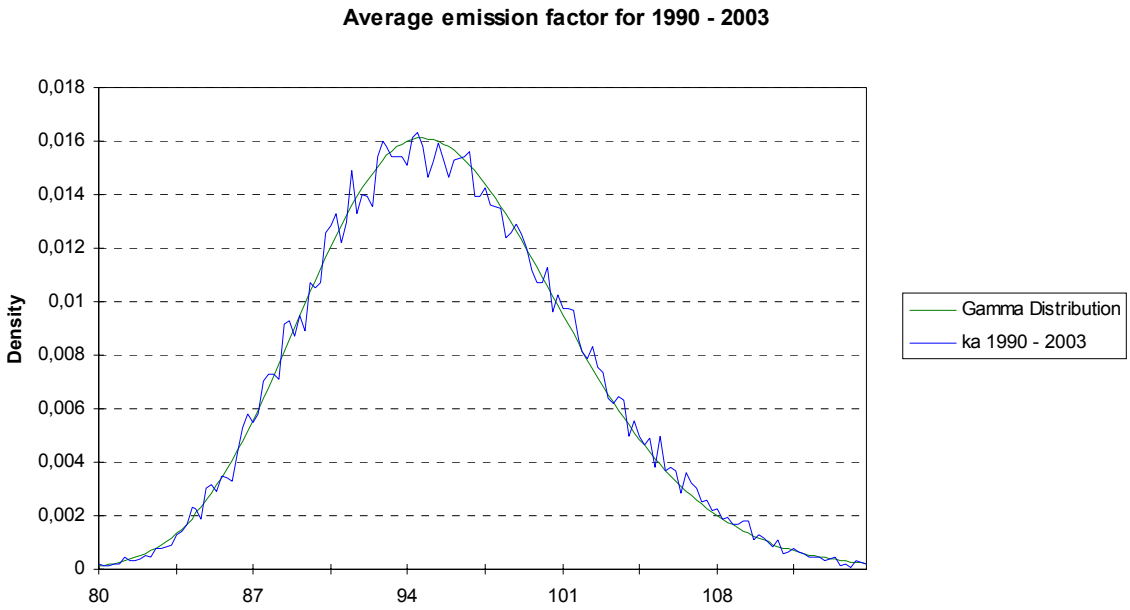

Figure 3. An average coal emission factor for years 1990–2003.

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.

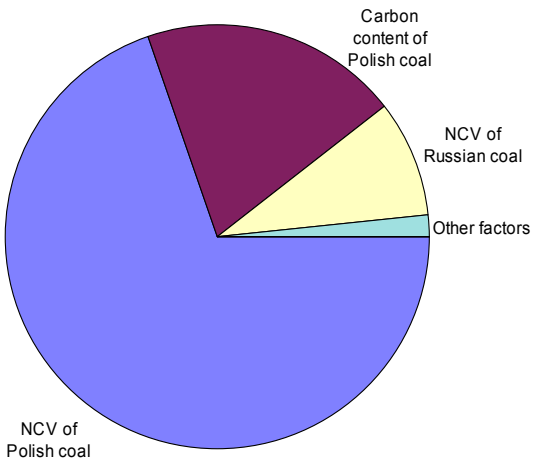

Figure 4. Variance decomposition of the average emission factor for 1990–2003.

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/√n.

ANNEX 4. Tier 1 Reference calculation based on National Energy Balances.

Energy Balance Sheet 2005, ktoe											
	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Wood and recycled fuels	Electricity	District heat & heat pumps	**Total**
	1	2	3	4	5	6	7	8	9	10	11
Indigenous production	–	–	–	–	5 825	1 184	2 138	5 559	–	157	**14 862**
Recycled oil	–	–	23	–	–	–	–	–	–	–	**23**
Imports	3 357	10 594	5 096	3 607	–	–	–	1 585	1 541	–	**25 781**
Exports	-2	–	-5 090	–	–	–	-14	-78	-80	–	**-5 264**
International marine bunkers	–	–	-503	–	–	–	–	–	–	–	**-503**
Stock Changes	-150	269	-830	–	–	–	-481	–	–	–	**-1 191**
Total Primary Energy Supply	**3 206**	**10 864**	**-1 303**	**3 607**	**5 825**	**1 184**	**1 643**	**7 065**	**1 461**	**157**	**33 708**
Statistical Difference	–	141	-116	8	–	–	–	–	–	–	**32**
Electricity generation	-655	–	-35	-59	-5 825	-1 184	-287	-351	3 564	–	**-4 831**
Combined district heat and power	-1 093	–	-40	-1 611	–	–	-725	-593	1 296	2 173	**-592**
Cogeneration electricity in industry	-41	–	-31	-319	–	–	-93	-779	970	–	**-294**
District heat production	-71	–	-177	-286	–	–	-89	-265	–	792	**-97**
Oil refinery	–	-11 004	10 867	–	–	–	–	–	–	–	**-137**
Coal transformation	-652	–	–	–	–	–	–	–	–	–	**-652**
Transmission and distributions losses	–	–	–	–	–	–	–	–	-256	-259	**-515**

TFC (total final consumption)	**694**	**–**	**9 166**	**1 340**	**–**	**–**	**448**	**5 077**	**7 036**	**2 862**	**26 622**
Industry	690	–	1 678	1 194	–	–	422	3 923	3 796	401	**12 104**
Transport	–	–	4 739	21	–	–	–	–	56	–	**4 815**
Residential	0	–	637	28	–	–	11	970	1 607	1 584	**4 837**
Agriculture	4	–	650	13	–	–	13	120	75	11	**885**
Commerce and public services	–	–	296	33	–	–	2	64	1 339	867	**2 600**
Other consumption	–	–	568	–	–	–	–	–	163	–	**730**
Non-energy use	–	–	599	53	–	–	–	–	–	–	**651**

Energy Balance Sheet 2005, TJ												
	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Wood and recycled fuels	Electricity	District heat & heat pumps	**Total**	
	1	2	3	4	5	6	7	8	9	10	11	
Indigenous production	–	–	–	–	243 887	49 561	89 512	232 739	–	6 560	**622 259**	
Recycled oil	–	–	977	–	–	–	–	–	–	–	**977**	
Imports	140 567	443 565	213 370	151 020	–	–	–	66 340	64 519	–	**1 079 381**	
Exports	-70	–	-213 093	–	–	–	-596	-3 270	-3 359	–	**-220 389**	
International marine bunkers	–	–	-21 075	–	–	–	–	–	–	–	**-21 075**	
Stock Changes	-6 283	11 270	-34 730	–	–	–	-20 131	–	–	–	**-49 874**	
Total Primary Energy Supply	**134 214**	**454 835**	**-54 551**	**151 020**	**243 887**	**49 561**	**68 784**	**295 809**	**61 160**	**6 560**	**1 411 279**	
Statistical Difference	–	5 886	-4 865	324	–	–	–	–	–	–	**1 345**	
Electricity generation	-27 408	–	-1 455	-2 457	-243 887	-49 561	-12 020	-14 701	149 219	–	**-202 270**	
Combined district heat and power	-45 740	–	-1 668	-67 436	–	–	-30 369	-24 823	54 261	90 979	**-24 796**	
Cogeneration electricity in industry	-1 735	–	-1 308	-13 346	–	–	-3 910	-32 630	40 628	–	**-12 302**	
District heat production	-2 978	–	-7 401	-11 985	–	–	-3 731	-11 090	–	33 138	**-4 047**	
Oil refinery	–	-460 721	454 996	–	–	–	–	–	–	–	**-5 726**	
Coal transformation	-27 306	–	–	–	–	–	–	–	–	–	**-27 306**	
Transmission and distributions losses	–	–	–	–	–	–	–	–	-10 702	-10 853	**-21 555**	
TFC (total final consumption)	**29 046**	**–**	**383 748**	**56 120**	**–**	**–**	**18 754**	**212 566**	**294 565**	**119 824**	**1 114 623**	
Industry	28 880	–	56 781	50 000	–	–	17 674	164 251	158 940	16 774	**506 752**	
Transport	–	–	198 405	864	–	–	–	–	2 332	–	**201 601**	
Residential	13	–	26 684	1 150	–	–	470	40 620	67 277	66 318	**202 531**	

Agriculture	153	–	27 226	540	–	–	530	5 015	3 139	452	**37 055**	
Commerce and public services	–	–	12 380	1 370	–	–	80	2 680	56 074	36 280	**108 864**	
Other consumption	–	–	23 762	–	–	–	–	–	6 804	–	**30 566**	
Non-energy use	–	–	25 058	2 196	–	–	–	–	–	–	**27 254**	
Blast furnane oil (subtracted from TFC industry)			13 451									
									Total		**CRF2005/EU_v2**	
Comparison to CRF categories:									excluding	including	sector totals	difference
Data from energy balance	Coal		Oil products	Natural gas			Peat	Wood+recycl.	biomass	biomass	excl. biomass	CRF/EB
Transformation (CRF 1A1)	77 861		17 558	95 224			50 030	83 243	**240 673**	323 916	**277 783**	15.4 %
Industry (CRF 1A2)	28 880		56 781	50 000			17 674	164 251	**153 336**	317 587	**133 797**	-12.7 %
Transport (CRF 1A3)	–		198 405	864			–	–	**199 269**	199 269	**184 017**	-7.7 %
Commerce and public services (CRF 1A4a)	–		12 380	1 370			80	2 680	**13 830**	16 510	**14 454**	4.5 %
Residential (CRF 1A4b)	13		26 684	1 150			470	40 620	**28 317**	68 937	**27 933**	-1.4 %
Agriculture (CRF 1A4c)	153		27 226	540			530	5 015	**28 449**	33 464	**25 895**	-9.0 %
Other (CRF 1A5)	–		23 762	–			–	–	**23 762**	23 762	**22 476**	-5.4 %
Totals by fuel	**106 908**		**362 797**	**149 148**			**68 784**	**295 809**	**687 637**	983 446	**686 355**	-0.2 %
Aviation bunkers correction			**-17 626**									
Totals	**106 908**		**345 171**	**149 148**			**68 784**	**295 809**	**670 011**	**965 820**		
	Solid fuels		Liquid fuels	Gaseous fuels			Other	Biomass				
CRF totals by fuel	**104 338**		**356 432**	**149 810**			**75 774**	**279 667**	**686 355**	**966 021**		
difference CRF/EB	-2.4 %		3.3 %	0.4 %			10.2 %	-5.5 %	2.4 %	0.0 %		

Energy Balance Sheet 2005, Gg CO2												
	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Wood and recycled fuels	Electricity	District heat & heat pumps	**Total (fossil & peat)**	**Total (incl. biomass)**
	1	2	3	4	5	6	7	8	9	10	11	
Indigenous production	–	–	–	–	0	0	9 367	25 253	–	0	**9 367**	**34 620**
Recycled oil	–	–	72	–	–	–	–	–	–	–	**72**	**72**
Imports	14 918	32 244	15 710	8 271	–	–	–	7 198	0	–	**71 143**	**78 341**
Exports	-7	–	-15 690	–	–	–	-62	–	0	–	**-15 760**	**-15 760**
International marine bunkers	–	–	-1 552	–	–	–	–	–	–	–	**-1 552**	**-1 552**
Stock Changes	-667	819	-2 557	–	–	–	-2 107	–	–	–	**-4 511**	**-4 511**
Total Primary Energy Supply	**14 244**	**33 063**	**-4 017**	**8 271**	**0**	**0**	**7 198**	**32 451**	**0**	**0**	**58 759**	**91 210**
Statistical Difference	–	–	-358	18	–	–	–	–	–	–	**-340**	**-340**
Electricity generation	2 909	–	107	135	0	0	1 258	1 595	0	–	**4 408**	**6 003**
Combined district heat and power	4 854	–	123	3 693	–	–	3 178	2 693	0	0	**11 848**	**14 541**
Cogeneration electricity in industry	184	–	96	731	–	–	409	3 540	0	–	**1 421**	**4 961**
District heat production	316	–	545	656	–	–	390	1 203	–	0	**1 908**	**3 111**
Oil refinery	–	33 491	-33 501	–	–	–	–	–	–	–	**-10**	**-10**
Coal transformation	2 898	–	–	–	–	–	–	–	–	–	**2 898**	**2 898**
Transmission and distributions losses	–	–	–	–	–	–	–	–	0	0	**0**	**0**
TFC (total final energy)	**3 066**	**–**	**25 420**	**2 953**	**–**	**–**	**1 962**	**23 064**	**0**	**0**	**33 402**	**56 466**
Industry	3 065	–	4 181	2 738	–	–	1 849	17 822	0	0	**11 834**	**29 655**
Transport	–	–	14 609	47	–	–	–	–	–	–	**14 656**	**14 656**
Residential	1	–	1 965	63	–	–	49	4 407	0	0	**2 078**	**6 486**
Agriculture	–	–	2 005	30	–	–	55	544	0	0	**2 090**	**2 634**
Commerce and public services	–	–	912	75	–	–	8	291	0	0	**995**	**1 286**

Other consumption	–	–	1 750	–	–	–	–	–	0	–	**1 750**	**1 750**
Non-energy use	–	–	1 845	120	–	–	–	–	–	–	**1 965**	**1 965**
Total CO2 emissions	11 330		26 281	8 168			7 198	32 096			52 977	87 971
(excluding non-energy use)												
CO2 emission factor g/MJ	107.2	73.1	74.0	55.04	0.0	0.0	105.7	109.6	0.0	0.0		
oxidation factor	0.99	0.995	0.995	0.995	0.00	0.00	0.99	0.99	0.00	0.00		
Comparison to CRF categories:									**Total**		**CRF2005/EU_v2**	
									excluding	including	sector totals	difference
Data from energy balance									biomass	biomass	excl. biomass	CRF/EB
Transformation (CRF 1A1)	8 263		861	5 215			5 235	9 032	**19 575**	28 607	**21 672**	10.7 %
Industry (CRF 1A2)	3 065		4 181	2 738			1 849	17 822	**11 834**	29 655	**11 407**	-3.6 %
Transport (CRF 1A3)	–		14 609	47			–	–	**14 656**	14 656	**13 492**	-7.9 %
Commerce and public services (CRF 1A4a)	–		912	75			8	291	**995**	1 286	**1 043**	4.8 %
Residential (CRF 1A4b)	1		1 965	63			49	4 407	**2 078**	6 486	**2 050**	-1.3 %
Agriculture (CRF 1A4c)	–		2 005	30			55	544	**2 090**	2 634	**1 928**	-7.7 %
Other (CRF 1A5)	–		1 750	–			–	–	**1 750**	1 750	**1 546**	-11.6 %
Totals by fuel	**11 330**		**26 281**	**8 168**			**7 198**	**32 096**	**52 977**	85 073	**53 139**	0.3 %
Aviation bunkers correction			**-1 290**									
Totals	**11 330**		**24 991**	**8 168**			**7 198**	**32 096**	**51 686**	**83 783**		
CRF totals by fuel	**11 168**		**26 245**	**8 207**			**7 518**	**30 121**	**53 139**	**83 260**		
difference CRF/EB	-1.4 %		5.0 %	0.5 %			4.5 %	-6.2 %	2.8 %	-0.6 %		