Informative Inventory Report 2012
Sweden

Submitted under the Convention on Long-Range
Transboundary Air Pollution

SWEDISH ENVIRONMENTAL
PROTECTION AGENCY

Contents

1 EXECUTIVE SUMMARY

1.1 Background information on the air pollutant emission inventory

Sweden has carried out inventories on air pollutants since the 1980's to meet the obligations of the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution (UNECE CLRTAP). The inventory reports are submitted to the UNECE Secretariat and to the EEA annually.

This report constitutes Sweden's IIR 2012 (inventory data 2010) for anthropogenic emissions of air pollutants: NO_X, CO, NMVOC, SO_2, NH_3, TSP, PM_{10} and $PM_{2.5}$, heavy metals, dioxin and PAH. The report contains information on Sweden's inventories of air pollutants for all years from 1980 to 2010, including descriptions of methods, data sources, uncertainties, the quality assurance and quality control (QA/QC) activities carried out and a trend analysis. Data on estimated emissions, corresponding activity data, thermal values and emission factors are in the spreadsheet files provided in separate annexes to this report. NFR tables are used in reporting of the emission figures.

Emission estimates are mainly based on official Swedish statistics, e.g. energy statistics, agricultural statistics, environmental reports from industry and emission factors (nationally developed factors as well as internationally recommended ones).

Sweden uses the Guidelines for Estimating and Reporting Emission Data for reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the EMEP/EEA Air Pollutant Emission Inventory Guidebook as methodological guidance. Sweden also uses methodologies in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)[1] and methods that are in general in line with Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories IPCC-NGGIP (Good Practice Guidance)[2]. Some parts of the methodologies are taken directly from the IPCC Guidelines, the Good Practice Guidance and the EMEP/EEA Air Pollutant Emission Inventory Guidebook.[3].

[1] The IPCC Guidelines can be found at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm
[2] The Good Practice Guidance can be found at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/
[3] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

1.2 Overview of source category emission estimates and trends

The main sources of air pollutants have been divided into the following sectors: energy, industrial processes, solvent and product use, agriculture and waste. For the land use change and forestry sector no air pollutant emissions have been estimated. The sources of air pollutants are discussed in this report. Emission data are listed in the NFR tables.

Emissions of nitrogen oxides (NO_x) were about 161 ktonnes in 2010. The largest sources of emissions of nitrogen oxides are road traffic, mobile machinery, maritime transport and electricity and heat production. In areas where people congregate, road traffic is the most significant contributor to emissions of nitrogen oxides, but the introduction of catalytic converters in the late 1980's and the subsequent successively more stringent emission standards have contributed to a general reduction of nitrogen oxide levels in built-up areas. The increased use of district heating and the "NO_X charge" of the early 1990s have also resulted in a great reduction of emissions of nitrogen oxides from the energy sector.

The total emissions of volatile organic compounds (NMVOC) were about 197 ktonnes in 2010 and emissions have decreased by 45 % since 1990. The main contributors to NMVOC emissions are road traffic, wood combustion in the residential sector and solvents-containing products. Non-compulsory environmental standards for new installations of wood-burning boilers and reduced emissions from solvent-containing products have contributed to the decrease in emissions.

Emissions of sulphur dioxide (SO_2) have decreased substantially through the previous years and are estimated to almost 35 ktonnes in 2010, a decrease by a two-third compared with 1990. Sulphur dioxide emissions derive from the energy (including transport) and industrial sectors with 64 % and 35 %, respectively. Road traffic emissions of SO_2 have fallen by 99% since 1990 as a result of lower sulphur levels in motor fuels, and totalled 0.1 ktonnes in 2010.

Agriculture is the main source for ammonia emissions (NH_3) and contributing with about 85 % of the total emission in 2010. Manure management and fertilizers are the main sources of NH_3 emissions. About 9 % of NH_3 emissions come from the energy sector while the industrial processes and waste sectors stand for the rest of the emissions. In 2010, the total emissions of ammonia estimated to almost 52 ktonnes.

Emissions of carbon monoxide (CO) were about 639 ktonnes in 2010, More than 96 % of the emissions come from the energy sector in which road trafic stands for about one-third of the emissions. The emissions have decreased by 50 % since 1990.

Emissions of particles ($PM_{2.5}$) were almost 32 ktonnes in 2010. The largest source of emissions of particles is the energy sector (77 %), in which road traffic contributes with about 21 %. The industrial processes sector is the second largest source of $PM_{2.5}$ (18 %).

The energy sector, including the transport, is the major source of the heavy metal (Pb, Cd and Hg) emissions contributing with about 74 % in 2010. The industrial processes sector contributes with about 25 %. Lead (Pb) is the dominant heavy metal. The emissions of lead have substantially decreased from 355 tons in 1990 to about 13 tons in 2010. Public electricity and heat production together with stationary combustion plants contribute to about 77 % of cadmium (Cd) emissions. The emissions have decreased from 2.27 tons in 1990 to about 580 kg in 2010. The metal and pulp, and paper industries are responsible for this sharp reduction Emissions of mercury (Hg) to air have decreased by about two-third since 1990. The emission of Hg is estimated of about 550 kg in 2010. About half of the mercury emission comes from the energy sector. Industry, mostly from metals production, is also a considerable source for Hg emissions and the sector is responsible for about 26 %. Cremation is responsible for about 114 kg Hg or 20 % of the total emissions to air. The emission data are presented in the NFR-tables.

2 Introduction

Reporting of emission data to the Executive Body of the Convention on Long-range Trans-boundary Air Pollution (CLRTAP) is required in order to fulfil obligations regarding strategies and policies in compliance with the implementation of Protocols under the Convention. Parties should use the reporting procedures and are required to submit annual national emissions of SO_2, NO_X, NMVOC, CO and NH_3, particulate matter, various heavy metals and POPs using the Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution[4].

This report constitutes Sweden's Informative Inventory Report (IIR) due by February 15 2012. The report contains information on Sweden's inventories for all years from 1980 to 2010 including descriptions of methods, data sources, QA/QC activities carried out, and a trend analysis. The inventory accounts for anthropogenic emissions of SO_2, NO_X, NH_3, NMVOC, CO, TSP (Total Suspended Particulate matter), PM_{10} (particles of size <10 µm), $PM_{2.5}$ (< 2.5µm), Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PAH and dioxins.

Emission estimates are mainly based on official Swedish statistics, e.g. energy statistics, agricultural statistics, environmental reports from industry and emission factors (nationally developed factors as well as internationally recommended ones).

Sweden uses the Guidelines for Estimating and Reporting Emission Data[4] for reporting to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and to the Economic Commission for Europe (UNECE). Sweden also uses methodologies in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)[5] and, in general, in line with Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories IPCC-NGGIP (Good Practice Guidance)[6]. Some parts of the methodologies are taken directly from the IPCC Guidelines, the Good Practice Guidance and the EMEP/EEA Air Pollutant Emission Inventory Guidebook [7].

2.1 Institutional arrangements

The inventory system currently used in Sweden is presented in Figure 2.1. The Swedish Ministry of Environment has the overall responsibility and submits the inventory report to CLRTAP. The Swedish Environmental Protection Agency (Swedish EPA) co-ordinates the activities for developing the inventory report and are also responsible for the final quality control and quality assurance of the data before it is submitted.

A consortium called Swedish Environmental Emissions Data (SMED), composed of Statistics Sweden, the Swedish Meteorological and Hydrological Institute

[4] UNECE 2003, Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution. Air Pollution Studies No. 15.
[5] The IPCC Guidelines can be found at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm
[6] The Good Practice Guidance can be found at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/
[7] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

(SMHI), the IVL Swedish Environmental Research Institute Ltd. (IVL) and the Swedish University of Agricultural Sciences (SLU) collect data and calculate emissions for all sectors. SLU is however not involved in estimating emissions for reporting to CLRTAP.

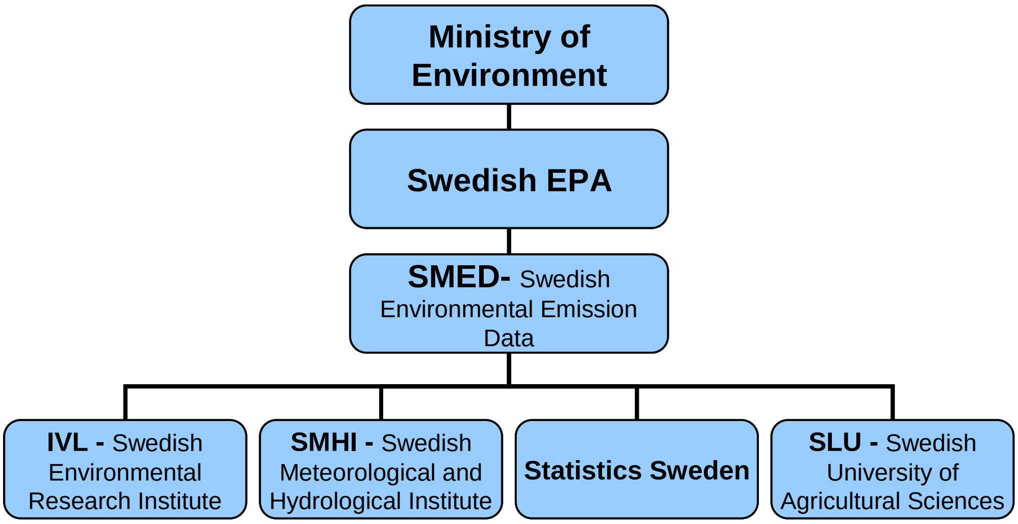

Figure 2.1. Current national inventory system.

A national system meeting the requirements laid down in article 5.1 of the Kyoto Protocol is developed and is fully used for the reporting activities taking place since 2006 (see Annex 5). The system also influences reporting under CLRTAP as the same procedures are applied where appropriate, and particularly regarding QA/QC-procedures.

2.2 The process of inventory preparation

2.2.1 Data collection and processing

The process of inventory preparation is carried out differently for the different sectors. Further descriptions of data collection are made for each sector in sections 3-7.

2.2.1.1 ENERGY

2.2.1.1.1 Stationary combustion

Activity data for the following subgroups is collected mainly from these sources:
Energy industries: Data from quarterly fuel statistics, a total survey conducted by Statistics Sweden at plant level and by fuel type.
Manufacturing industries: quarterly fuel statistics, a sample survey conducted by Statistics Sweden. All data is at plant level and by fuel type.

Other sectors: Data from official statistical reports prepared by Statistics Sweden at national level and by fuel type.

Activity data is multiplied by thermal values, mainly from Statistics Sweden and the Swedish Energy Agency, and emission factors provided by IVL and the Swedish EPA.

2.2.1.1.2 Mobile combustion

Data on fuel consumption at national level and by fuel type is collected[8] and used in combination with emissions data and fuel data from the Swedish Transport Agency, the Swedish Road Administration, the Swedish Rail Administration, the Civil Aviation Authority and the Swedish Military. Activity data is multiplied by thermal values, mainly provided by Statistics Sweden, and emission factors provided by among others IVL and the Swedish EPA.

2.2.1.2 INDUSTRIAL PROCESSES

The reported data for industrial processes is mainly based on information from environmental reports. According to Swedish environmental legislation, operators performing environmentally hazardous activities that require a permit by law are required to compile and send an annual environmental report to their supervisory authority. Only the operators that exceed the thresholds for the substances listed in Swedish environmental law governing environmental reports are obliged to compile the emission declaration. The County Administrative Boards audit the data from the operators' environmental reports.

Since the beginning of year 2007 environmental reports can be submitted electronically via the Swedish Portal for Environmental Reporting (SMP)[9].

In some cases, when there are a large number of smaller companies within a specific sector, and all the environmental reports are not available, a combination of information available from environmental reports and production statistics at national level is used to estimate national emissions. Emission factors used are usually derived nationally based on available information from some facilities in a specific sector, and applied to the national level. The use of default emission factors is limited.

[8] Data collected by Statistics Sweden
[9] Svenska Miljörapporteringsportalen. https://smp2.naturvardsverket.se/

2.2.1.3 SOLVENT AND OTHER PRODUCT USE

Estimated emissions from solvent and other product use are based on emission factors and national activity data obtained from the Products Register kept by the Swedish Chemicals Agency.

2.2.1.4 AGRICULTURE

Data on animal numbers, crop areas, yields, sales of manure, manure management and stable periods are taken from official statistical reports[10]. Some complementary information is collected from organisations and researchers, such as the Swedish Dairy Association, Swedish Poultry Meat Association, SLU and the Swedish Institute of Agricultural and Environmental Engineering (JTI) and the Swedish Board of Agriculture (SJV). The calculations concerning forestry are based on information from the Nation Board of Forestry (NBF).

2.2.1.5 WASTE

Emission estimates for the waste sector include waste-water handling, where estimates are based on model calculations. Emission estimates from incineration of hazardous waste (including cremation) are derived from environmental reports or from national statistics and emission factors. In this sector also various types of fires such as landfill fires, bonfires and open burning of garden waste are included. Calculations are based on emission factors and national estimates of activity.

2.2.2 Data storage

A system for handling emission data, entitled TPS, has been developed and was used for the first time in submission 2007. It supports data input from Microsoft Excel sheets, and provides different types of quality gateways. For instance the system makes it possible for multiple users such as the SMED consortium and the national independent reviewers to plot time series and make comparisons between different years and submissions. For all NFR codes time series from 1980 can be presented. The system also allows for different types of data output, e.g. to the NFR-tables.

[10] The reports are published by the Swedish Board of Agriculture and Statistics Sweden

2.3 Data sources and methodologies

Emission estimates are mainly based on activity data from national or official Swedish statistics, e.g. energy and agricultural statistics, environmental reports[11], as well as data on consumption obtained directly from the major producers and consumers, respectively.

Emission factors and thermal values used are either developed nationally or are internationally recommended default factors. Emission factors and thermal values for the energy sector are provided in Appendix 1.

The methodologies used for Sweden's emission inventory are to some extent taken directly from the IPCC Guidelines, the Good Practice Guidance and the EMEP/EEA Air Pollutant Emission Inventory Guidebook [12]. The methodologies are also in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)[13] and, in general, in line with IPCC's Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (Good Practice Guidance)[14].

2.4 Key source categories

Key source categories are sources that together contribute with either 95 % of the level or 95 % of the overall trend of reported emissions in Sweden. In this inventory, level and trend assessments are carried out for the following pollutants: As, Cd, CO, Cr, Cu, dioxins/furans, Hg, NH_3, Ni, NMVOC, NO_x, PAH 1-4, Pb, $PM_{2.5}$, PM_{10}, Se, SO_2, TSP and Zn. All sectors are covered except sector 5, LULUCF. The level assessment is performed for 2010, and the trend assessment for 2010, using 1990 as the base year for all pollutants. The analysis is done using both tier 1 and tier 2 methods.

The complete results of the key source category analysis are presented in Annex 6. In Annex 1 the methodology for the analysis is also described. Looking at the results for mercury and cadmium it is evident that metal production (NFR 2C1 and 2C5), is one of the major contributors to the trend for these two heavy metals. Furthermore, emissions of NO_X, CO, NMVOC and Pb from road transportation (NFR 1A3B) are in top in the trend assessment, showing strong decreasing trends. This sector is however in 2010 still a major contributor to the emissions of these pollutants.

Automobile road abrasion in the transport sector (NFR 1A3B) is the largest emitter of TSP and PM_{10} and the second largest of $PM_{2.5}$ in 2010.

Public Electricity and Heat Production (NFR 1A1A) is in top ten of both the level and trend assessments for most pollutants in 2010.

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[11] See Annex 7

[12] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

[13] The IPCC Guidelines can be found at: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

[14] The Good Practice Guidance can be found at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/

2.5 Information on QA/QC

2.5.1 Background

This section presents the general QA/QC plan for the Swedish air emission inventory[15]. The current system complies with the Tier 1 procedures outlined in the Good Practice Guidance (IPCC, 2000). A quality system as part of the National System has been developed and is fully in operation since January 2006.

2.5.2 Description of the QA/QC system

The Swedish EPA is responsible for the QA/QC plan for the inventory. The national emissions are compiled by SMED.

The QA/QC plan consists of quality procedures and checklists specified for each reporting NFR-code (or group of codes). The plan is updated annually and lists all quality control steps that must be undertaken during the inventory work (Tier 1 and where appropriate Tier 2). The QA/QC plan also includes descriptions of roles and responsibilities, descriptions of databases and models and documented procedures for uncertainty and key source analysis, as well as procedures for handling and responding to external reviews of the Swedish inventory. The QA/QC plan handles follow-up and improvement by procedures of non-conformity reporting and collection of improvement needs from all stages of the annual inventory cycle. This results in a planning document, which is used as a basis for planning and selecting further actions to continuously improve the inventory.

The QA/QC plan covers procedures to be performed on air emission inventory work, irrespective of convention. This means that reporting of greenhouse gases to UNFCCC and of air pollutants to CLRTAP are treated in the same way.

2.5.3 Quality assurance

Experts at the Swedish EPA conduct an independent review of the inventory estimates, methodologies and emissions factors used. They also identify areas of improvement, which is part of the basis for improvements in coming submissions.

2.5.4 Quality control for NFR sector 1-4 and 6

In this inventory, general Tier 1 QC measures, according to Table 8.1 in IPCC Good Practice Guidance, have been carried out.

All QC measures carried out are documented in QC checklists for each NFR code or group of codes. After completion of the initial compilation of the inventory, a QC-team reviews all QC-checklists.

2.5.5 Quality control for the overall inventory

[15] Manual for SMED:s Quality System in the Swedish Air Emission Inventories

When the reporting tables and the IIR are completed, a quality co-ordinator performs a final quality control before delivery of the inventory to the Swedish EPA.

2.6 General uncertainty evaluation

The uncertainties in the Swedish emission inventory reported to the CLRTAP were for the first time evaluated in 2003[16], covering the emissions in 1990 and 2001. In order to prioritise efforts and resources in subsequent years, expert judgments mainly by the inventory staff together with IPCC references on uncertainties in activity data and emission factors have been the basis for the IPCC Tier 1 uncertainty evaluation.

In 2009, SMED performed a study to provide transparent uncertainty estimates of national emissions for the Swedish reporting to the CLRTAP of the 2010 submission in accordance with the Tier 1 methodology described in the EMEP/EEA Guidebook 2009 (Table 6-1).[17]

The results of the Swedish uncertainty analysis for 2010 are presented in Annex 6 together with the methodology. The summary tables (Tables 12 - 30) show for all pollutants; estimated emissions 1990 and 2010, the uncertainty for the trend 1990-2010 and the uncertainty in national emissions 2010 together with the estimated uncertainty for the emission factor and for the activity data. In Annex 6, Table 12 - 30, it can be seen that for several pollutants, a majority of the variance in national emissions derives from only one source contributor, e.g. 96% of the variance in total NO_X emissions stem from road transportation (1A3B). In general, the emission factors are more uncertain than the activity data.

Table 2.1 shows a summary of the uncertainty evaluation of the national inventory emissions 2010 and the trend uncertainties 1990-2010.

[16] Kindbom, 2004
[17] Gustafsson, 2009

Table 2.1. Summary of uncertainties in total inventory by pollutant 2010 and trend uncertainties 1990-2010, submission 2012.

Pollutant	Percentage uncertainty in total inventory 2010	Trend uncertainty 1990-2010
As	72%	12%
Cd	48%	10%
CO	25%	11%
Cr	28%	4%
Cu	68%	8%
DIOX	117%	203%
Hg	109%	6%
NH_3	34%	16%
Ni	32%	11%
NMVOC	15%	8%
NO_x	13%	3%
PAH 1-4	719%	180%
Pb	11%	0%
PM_{10}	16%	5%
$PM_{2.5}$	15%	5%
Se	19%	10%
SO_2	11%	2%
TSP	11%	4%
Zn	169%	46%

2.7 General assessment of the completeness

The inventory covers air pollutant emissions in Sweden. The general completeness for each sector is discussed below. Detailed information is presented in Annex 4.

2.7.1 Energy

Estimated emissions are considered to be complete for most sources. There might still be some incompleteness as regards in-house generated fuels in the chemical industry and in smaller companies.

Fugitive emissions, i.e. venting and flaring of liquid and gaseous fuels, are most likely not complete for smaller companies. However, all Swedish plants that flare gas and that are included in the European trading scheme for CO_2 in 2005-2009, are included. For smaller plants, data might be reported in NFR 1A instead of NFR 1B. Hence lack of data on emissions from flaring is considered to be insignificant.

2.7.2 Industrial Processes

For most sources, and particularly for the most important ones, the estimates are in accordance with the requirements concerning completeness as laid out in the Good Practice Guidance. However, some exceptions do exist. These are primarily in sub-sectors with a large number of smaller facilities with minor emissions.

2.7.3 Solvent and Other Product Use

The estimated emissions from solvent and product use are considered to be complete, since a new method was developed during 2005 in order to obtain all activity data concerning the sector from the Products register at the Swedish Chemicals Agency.

Incompleteness's in this sector primarily concerns other substances than NMVOC from product use. Emissions of particles are reported for some sources, but emissions of for instance metals have not been estimated.

2.7.4 Agriculture

All relevant agricultural emissions and sources are reported in the inventory. The majority of the country's horses do not belong to farms, but are included in the agricultural sector of the inventory.

All sales of fertilizers are included, even quantities used in other sectors.

2.7.5 Waste

Emissions from incineration of Municipal Solid Waste (MSW) are included in 1A1a, as MSW is used for energy production. In NFR 6 emissions from hazardous waste incineration, cremation, landfill fires and garden burning/bonfires are included. For hazardous waste incineration, emissions from one large plant are included, and there may be emissions from smaller plants that are not covered. The completeness for NH_3 emissions from the waste sector is currently unknown.

3 Description and interpretation of emission trends for NMVOC, NO_X, CO, SO_2 & NH_3

3.1.1 NMVOC

Emissions of non-methane volatile organic compounds (NMVOCs) totalled around 197 ktonnes in 2010, and emissions have decreased by 45 % in comparison with 1990. Road traffic and combustion of wood in households together dominate emissions, but machinery, some industrial activity and use of solvents are also significant for emissions. Road traffic leads to the greatest emissions in the area of transport, but road traffic has also shown the greatest reduction in emissions due to new exhaust emission requirements. Environmental requirements in the new installation of wood-fired boilers and reduced emissions from products containing solvents have also contributed to lower emissions.

NMVOC emissions from the energy sector (excl. transport) totalled 51 ktonnes in 2010, a decrease of 16 % in comparison with 1990. Most of the decrease occurred in the early 1990s and related to fugitive emissions from oil refineries.

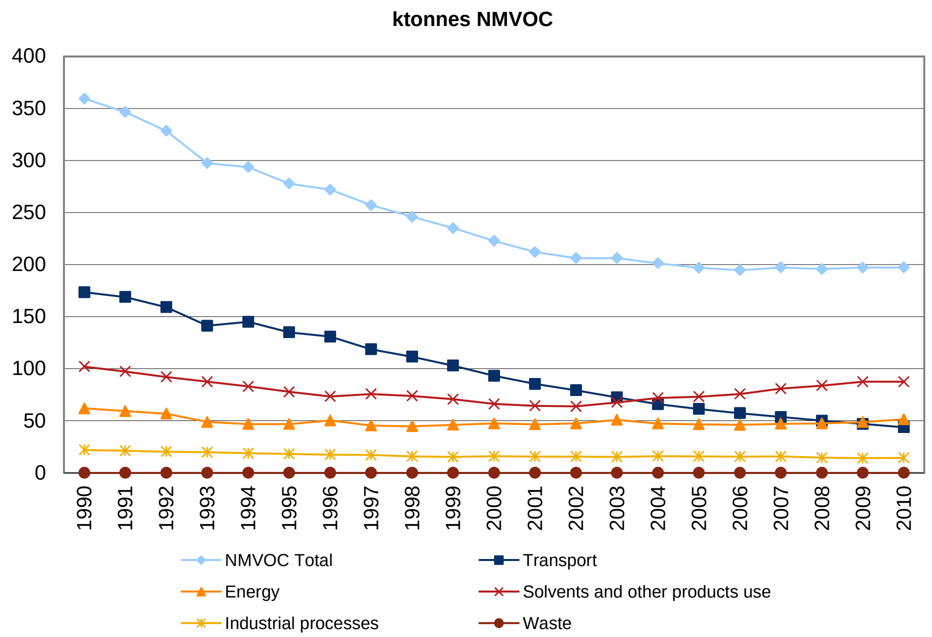


Figure 3.1 Total emissions of NMVOC and emissions from the different sectors.

3.2 NOx

Emissions of nitrogen oxides amounted to 161 ktonnes in 2010, a decrease of 40 % in comparison with 1990. Nitrogen oxides are formed in all combustion in the energy and transport sectors, and the largest emission sources are road traffic, machinery, navigation and production of electricity and heating. Emissions of nitrogen oxides from the energy sector, excluding transport, totalled 64 ktonnes in 2010, a decrease of 30 % compared with 1990. The largest sources of emissions are machinery in industry, agriculture and forestry and combustion in the production of electricity and heating and in industry.

About 27 % of emissions in the energy sector in 2010 came from electricity and district heating production. As a result of the NOx charges introduced in the early 1990s and the treatment measures they encouraged, emissions in terms of produced quantity of energy have decreased. Some variation in the absolute quantity of emissions is visible over the years, related to temperature and consequently the need for heating and to precipitation, which affects the need for combustion-based production of electricity. Emissions were therefore lower, for example, in 2000 than in 2003, which was a dry year.

Emissions from machinery in industry account for 17 % of emissions of nitrogen oxides by the energy sector (excluding transport). These decreased by 39 % during the period 1990-2010. Machinery in agriculture and forestry taken together account for 16 % of the emissions in the energy sector. There has also been a decrease here in recent years.

Traffic is a large source of emissions of nitrogen oxides, and the emissions come largely from road traffic at 83 ktonnes, but the introduction of catalytic converters in cars and the subsequent successive tightening of exhaust emission requirements have contributed to a general decrease in concentrations of nitrogen oxides in urban areas. Road-traffic emissions of NOx decreased by 47 % between 1990 and 2010 and increased by 3 % between 2009 and 2010.

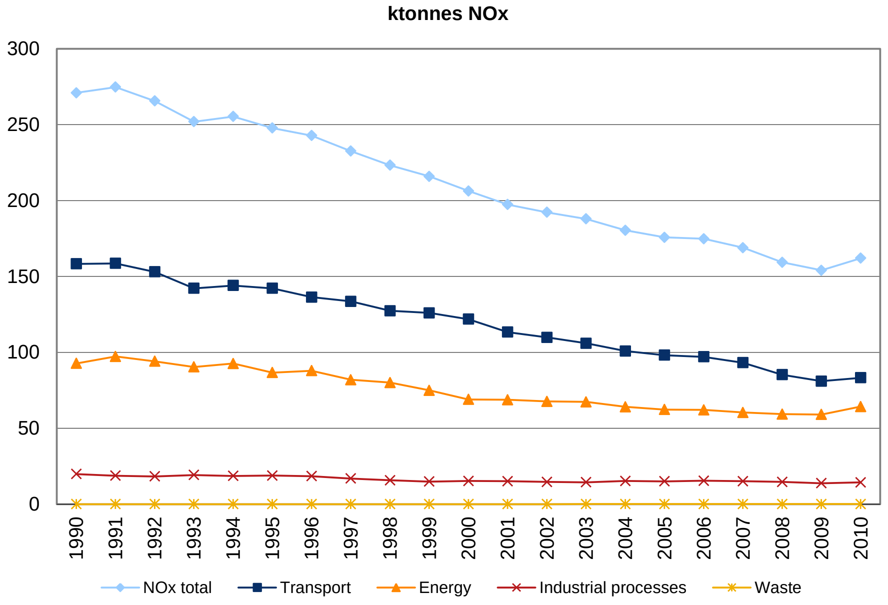


Figure 3.2 Total emissions of NO_X and emissions from the different sectors.

3.3 CO

Emissions of carbon monoxide have developed in the same way as NOx emissions. Emissions have decreased from 1280 ktonnes in 1990 to 640 ktonnes in 2010. About 40 % of emissions came from the transport sector and 43 % from the Other sectors.

Energy sector emissions of carbon monoxide increased from around 234 ktonnes in 1990 to around 359 tonnes in 2010. Around 78 % of emissions from the energy sector came from household energy use.

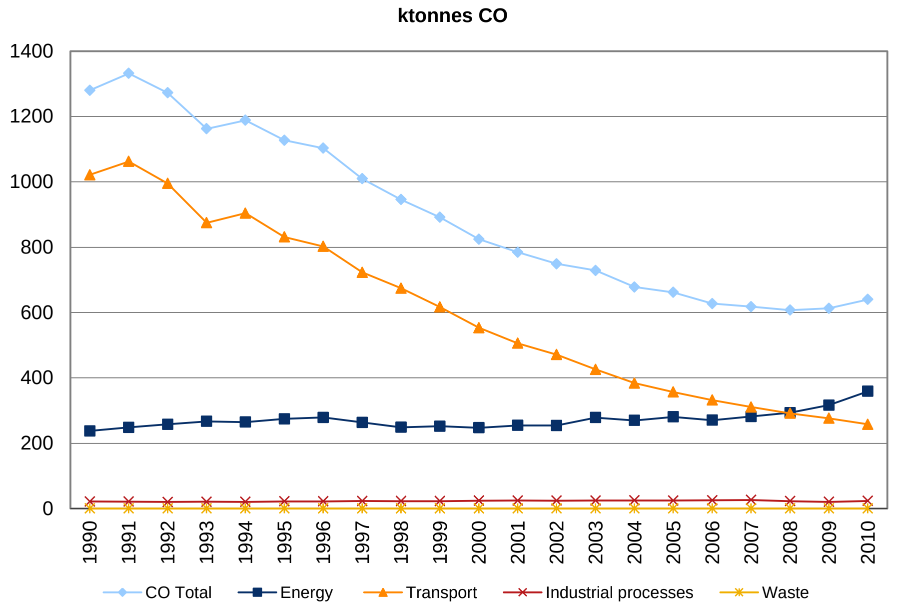


Figure 3.3 Emissions of CO, total and by sectors.

3.4 SO_2

Sulphur dioxide emissions come from the energy, transport and industry sectors and continued to decrease during the 1990s. In 2010, emissions totalled 35 ktonnes, which is a decrease of 67 % compared with 1990. The continued decrease is due to a change-over from fuels with high-sulphur levels to low-sulphur fuels, for both vehicles and heating.

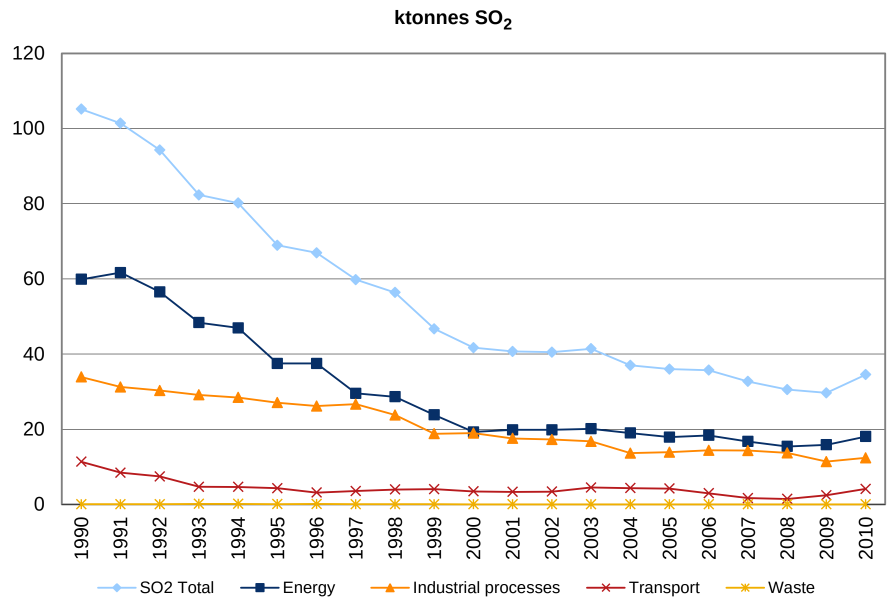


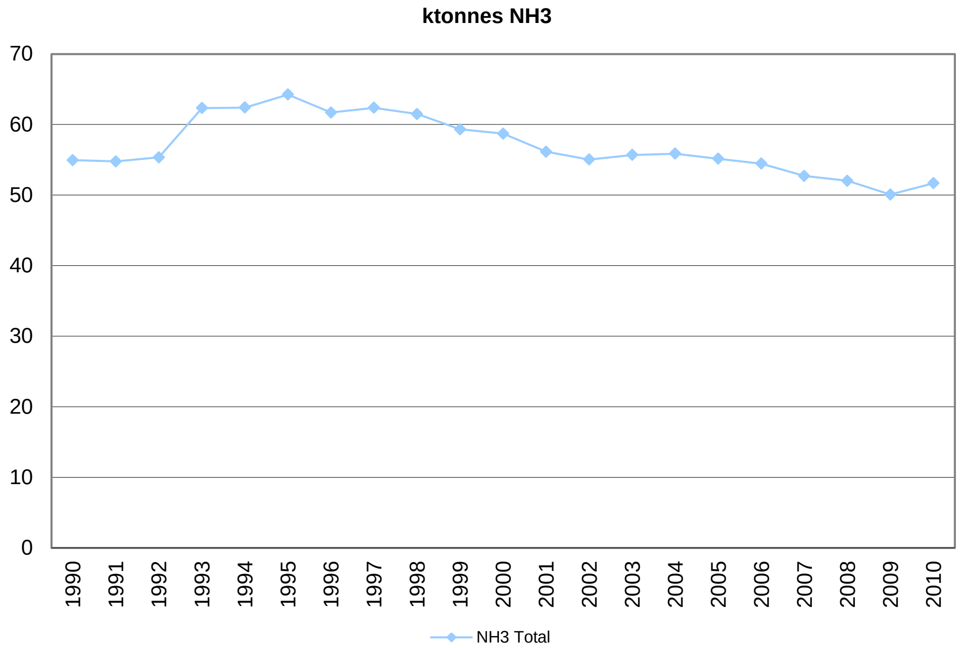
Figure 3.4 Total emissions of SO_2 and emissions from the different sectors.

Energy sector emissions of sulphur dioxide (excl. transport) continued to decrease during the 1990s and in 2010 emissions totalled 18 ktonnes, a decrease of 70 % compared with 1990. The continued decrease is due to a shift from fuels with higher sulphur levels to low-sulphur fuels, both for industry and for production of electricity and district heating. The sulphur tax introduced in 1991 has been significant in this shift. Other factors which contribute to reduced emissions include the consideration of industries under the Environmental Code. Emissions increased between 2009 and 2010 by 18 % from electricity and district-heating and by 16% from manufacturing industry as a result of increased combustion.

Road traffic emissions of SO_2 have fallen by 99 % since 1990 as a result of lower sulphur levels in motor fuels, and totalled 0.1 ktonnes in 2010. Sulphur emissions from domestic navigation have decreased by 23 % since 1990 and are now 3.9 ktonnes due to a switch to oils with lower sulphur content.

3.5 NH_3

The total emission of ammonia to air in 2010 is estimated of about 51.7 ktonnes. The emissions have decreased by about 20 % compared to 1995, when 64.2 ktonnes were emitted. For methodological reasons, data for 1990-1995 are not comparable to later estimates, and the annual emissions reported from that period are likely to be underestimated.



Figur 3.1 Total emissions of NH_3.

Agriculture is the dominant source of ammonia in Sweden and contributed by about 44 ktonnes, or 85 % of the total emission in 2010. The rest of the emissions about 8 ktonnes NH_3 or 15% come from the energy, industrial processes and waste sectors. During the period 1995-2010 emissions of NH_3 from agriculture have decreased by about 12 ktonnes, or 23 %. This decrease is mainly due to a decline in the livestock population size, especially dairy cows and pigs. Furthermore, many farms have changed from solid to liquid manure handlings systems. New legislation concerning storage and spreading of animal manure, introduced during the period 1995-1998, in combination with strengthened advisory programmes for farmers, have also contributed to reduced emissions of NH_3.

4 Energy (NFR sector 1)

4.1 Overview

Energy consumption per capita is high in Sweden compared to other OECD countries. This is because of the availability of natural resources such as forests and hydropower, which led to the early and rapid expansion of energy-intensive industries. Sweden's geographical position, with low mean annual temperatures and low population density, also explains the high demand of energy for heating.

4.2 Source category description

4.2.1 Public electricity and heat production, NFR 1A1a

Since 1980 the Swedish energy system has changed substantially. The dependence on fossil fuels (oil and coal), both for heating purposes and in industry, has decreased. During the period 1980-1990, the production of electricity from nuclear power plants increased from 26 TWh to 68 TWh. Another factor behind the decrease in fossil fuel use is the increased use of district heating. Use of biofuel (wood chips, bark) and incineration of municipal waste is common in district heating plants. The use of heat pumps both in district heating plants and in residential houses has increased since 1985. In the manufacturing industry the combustion of oil products has decreased from 1980 and has to a large extent been replaced by biofuels.

Swedish production of electricity is characterized by large proportions of hydropower and nuclear energy. Only a small share of electricity production is based on fuels used in conventional power plants. Public electricity and heat use vary between years, mainly due to variations in ambient wintertime temperatures. In addition, production of electricity based on fuels depends to a large extent on the actual weather conditions. Years with dry weather and cold winters have a significant effect on the use of fuel in electricity production since less electricity can be produced by means of hydropower and more electricity is needed for heating. The largest emissions from electricity production were thus in 1996, due to very dry and cold weather. In Sweden, electricity and district heating are used to a large extent to heat homes and commercial premises. Increased use of district heating since 1990 to heat homes and commercial/industrial premises has led to increased energy efficiency and thus lower emissions. Electricity is an important energy source in the manufacturing industry, which is dominated by the pulp and paper industry and the steel industry.

Production of district heating is currently to a large extent based on biomass and waste. There has been a change from fossil fuels towards biomass since 1990. In 2010, about 55% of all fuels used for district heating were biomass while waste accounted for 18 %. In 1990, 15% of fuels used were biomass and 15 % was waste.[18] During the same period, there has been a large increase in the use of district heating from 90 PJ (1990) to 202 PJ (2010).[19]

The number and distribution of Swedish power stations in 2008 are presented in Table 4.1[20].

Changes since 1990 in number of plants and their installed effect have been minor in the electricity sector, but the number of plants that only produce district heating has increased.

Table 4.1. Number and distribution of Swedish energy stations in 2008.

Type of plant	Number of plants	Production GWh	Production TJ
Total power stations	2211	149 651	**538 744**
Power generation not based on fuels	2024	71 098	255 953
- Wind	1138	1 996	7 186
- Water	886	69 102	248 767
Power generation based on fuels	187	78 553	282 791
- Nuclear power	3	63 889	230 000
- Power and heat production	184	14 664	52 790
- Manufacturing industries, ISIC 10-37	45		
- Energy plants, ISIC 40	117		
- Others	22		

The trend in fuel consumption in this sector varies depending on the production of waterpower and climate variables. The greatest changes in fuel consumption are for biomass fuels, where the consumption has increased significantly due to, for instance, increased district heating. There was a significant increase in the use of natural gas in 2009 due to an increase in the number of gas fuelled facilities. In 2010, the production and use of district heating increased significantly compared to 2009 due to the cold weather with unusually low temperatures in the beginning and the end of the year.

4.2.2 Refineries, NFR 1A1B

Refineries process crude oil into a variety of hydrocarbon products such as gasoline and kerosene. During the refining process, dissolved gases are separated, some of which may be leaked or vented during processing. There are five refineries in Sweden. Three of these produce fuel products such as gasoline, diesel and heating oils. The other two mainly produce bitumen products and naphthenic special oils. One facility has a catalytic cracker; two facilities have hydrogen production plants and four of the facilities have sulphur recovery plants. The fuel consumption in this sector is mainly based on refinery gas, which is a by-product in the refining process. The use has increased due to higher demand of refined products.

[18] All numbers are according to data used in the inventory this submission.
[19] Statistics Sweden EN 11 SM 1102
[20] Statistics Sweden EN11SM 0901 2010. Data for later years are not available.

4.2.3 Manufacture of solid fuels and other energy industries, NFR 1A1C

Most emissions in this sector arise from two plants belonging to one company, producing coke to be used in blast furnaces for production of iron. The plants are integrated into the iron and steel production industry. Other fuel combustion in manufacturing of solid fuels and all fossil fuel combustion in manufacturing of nuclear power are also included in NFR 1A1c. The levels of fuel combustion and emissions in this category are closely correlated to iron and steel production, which explains the low emissions in 2009 when the demand of iron and steel on the global market was low due to the financial crisis.

4.2.4 Manufacturing Industries and Construction, NFR 1A2

A limited number of industries account for the majority of industrial energy use, i.e. the pulp and paper industry, iron and steel works and the chemical industry together account for about 70% of the energy used. Despite rising industrial production, oil consumption has fallen sharply since 1970. This has been possible due to increased use of electricity and improved energy efficiency.

In 2010 there were 41 paper mill plants, 165 sawmills (production capacity >10 000 m^3/year) and 41 pulp industry plants in Sweden. In total, they were producing 11.4 million tonnes of paper, 17.0 million m^3 of sawn timber and 11.9 million tonnes of pulp.[21] Since 1990, production has had an increasing trend, but not in the latest few years. There is no apparent trend in total fuel consumption since 1990, but in recent years, the share of energy from biomass fuels has increased.

In Sweden, there are three primary steel works that base their production on iron ore pellets producing either steel or iron powder. There are also 10 secondary steel plants producing steel based on scrap metal. The Swedish iron and steel works produced in total 4.8 million tonnes of steel in 2010, which is 73% more than the production in 2009.[22] The trend of the fuel combustion is increasing slightly since 1990 due to higher production of iron and steel products. In 2009 this trend was broken due to decreasing demand of iron and steel. In 2010, production and fuel consumption recovered to more “normal” levels.

The chemical industry produces a number of different products such as chemicals, plastics, solvents, petrochemical products etc. In total, around 60 plants are included. Ten of these plants use roughly about 90 % of the energy according to the activity data used for emission calculations for this sector.

4.2.5 Transport, NFR 1A3

The Swedish road network comprises of around 137,000 km of public highways, and road traffic is the dominating mode for both transport of goods and people.[23] .

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[21] The Swedish Forest Industries Federation
[22] The Swedish Steel Producers´ Association
[23] Ministry of the Environment, 2001.

Car travel is also the third most common way of travelling abroad, after air and sea travel. Road transport is as well the single largest source category contributing to the total national greenhouse gas emissions in Sweden for all years. Road transport includes several vehicle categories: Passenger cars, Light duty vehicles, Heavy duty vehicles, Mopeds & Motorcycles, Gasoline evaporation, Automobile tyre and brake wear and Automobile road abrasion.

Swedish citizens travelled in average 13 180 km by car and year in 2009. This is an increase by 1.4 % in 10 years. [24] For buses there has been an increase by 11.8 % and for trucks there has been a decrease by 1.5 %.

4.2 Average km driven by different kind of vehicles, regarding year 2009

	Passenger cars	HDV (excl. buses)	Buses	Motorcycles
2009	1 318	1 950	5 772	257
1999	1 300	1 980	5 164	

Energy use in the transport sector is mainly confined to various oil products such as gasoline, diesel and aviation fuel. Gasoline is the most common fuel used for road transports in 2010, but since 2002 emissions of CO_2 from gasoline have steadily been reduced mainly due to the increased number of diesel powered passenger cars and the introduction of biofuels. Energy use in this sector has been rising since 1970, as a consequence of the overall growth in transport and, hence, emissions have also increased. Since 1990, the number of gasoline passenger cars and light-duty trucks equipped with catalytic converters has increased[25], resulting in decreasing emissions of e.g. NMVOC and NO_X by 79 and 80 percent respectively between 1990 and 2010.

4.2.6 Other sectors, NFR 1A4

NFR 1A4 includes emissions from combustion in the commercial sector, institutions, households, agriculture, forestry and fishing. The largest users of energy are dwellings and premises. In Sweden, the heated area in this sector is 606 million m^2, of which households have a heated area of 451 million m^2 and premises have a heated area of 155 million m^2.[26]

The most common ways of heating these areas are by district heating and electricity. For premises, the area heated with district heating only has increased from 43 % in 1990 to 71 % in 2010, while the area heated with oil only has decreased from 22 % in 1990 to 2 % in 2008. For multi-dwellings, the area heated with district heating only increased from 67 % in 1990 to 85 % in 2010. The area heated with oil only in multi-dwellings has decreased from 15 % in 1990 to 1 % in 2007 and later. For one- and two-dwellings there was a minor increase, from 7 to 9%, in the

[24] http://www.trafa.se/Statistik/Vagtrafik/Korstrackor/Korstrackor-baserade-pa-matarstallningsuppgifter/
[25] Ministry of the Environment, 2001.
[26] The Swedish Energy Agency, 2011

area heated with district heating only between 1990 and 2007. In 2008, however, a significant increase can be observed as 12% of the area was heated with district heating only in that year, and this proportion has been roughly the same since then (11 % in 2009 and 2010). The area heated with oil only in one- and two-dwellings has decreased from 13 % in 1990 to 1 % in 2010.[27]

Changes in use of liquid and gaseous fuels in agriculture, fishing and forestry have been small since 1990. Due to availability of better data for the period 2003 and later years, there is since submission 2009 a shift in the time series for biomass. Consumption of solid fuels within this sector has decreased substantially since 1990.

In 2010, heating of premises and dwellings accounted for 43 % of fuel consumption in the Other sector, off-road vehicles and working machinery accounted for 46 % and agriculture (excluding off-road vehicles and working machinery) and fisheries for 11 %.

4.2.7 Other, NFR 1A5

NFR 1A5 includes emissions from military transports. The emissions have decreased over the years since 1990 due to a decrease in activity.

4.2.8 Fugitive emissions, NFR 1B

During all stages from extraction of fossil fuels to final use, escape or release of gaseous fuels, volatile components or absorbed gases may occur. These fugitive emissions are intentional or unintentional escapes and releases of gases from extraction point to final oxidation. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not support a productive activity (e.g. flaring).

Fugitive emissions in Sweden include flaring of fuels in the iron and steel industry, refineries and the pulp and paper industry, transmission losses of gas works gas, storage and handling of oil in refineries, depots and gasoline distribution. NFR 1B also includes fugitive emissions from coke production as well as emissions from storage and handling of solid fuels and emissions from hydrogen production (applicable since 2005).

4.2.9 Memo Items International bunkers, NFR 1A3ai and 1A3d i

This sector includes emissions from refuelling in Sweden used for international navigation and international aviation. All gases are covered.

According to IPCC guidelines international bunkers are not included in national totals. To evaluate Swedish emissions, international bunkers are of course important, especially as international bunkering of fuel is substantially greater than the fuel use for domestic navigation and aviation. Emissions have increased significantly since 1990 due to, among other things, increased travelling and increased transportation of goods. See also section 2.3.10.

[27] Ibid

In 2008 the consumption of residual fuel oil decreased and through an investigation of the reason it became clear that one company through restructuring had not reported what was believed to be full consumption. So in submission 2010 this was corrected by using 2007 values. However, new data for 2009 showed the same level of consumption as the year before and the same company still report lower values of residual oil. For submission 2011 this value has not been altered, but for submission 2012 the consumption of residual oil has again risen to the levels before the reconstruction.

The distribution of marine distillate fuels and residual fuel oils over domestic and international navigation (bunkers) entail additional uncertainties. The current distribution is provided by the respondents of the survey on supply and delivery of petroleum products, but these are suspected to lack full information on the end-use of all the fuels provided. Hence, the distribution between domestic and international use might vary considerably for some years. As a result, fuel consumption by national and international navigation has been looked into in a recent study by SMED[28]. Fuel data in the Monthly fuel, gas and inventory statistics, which is used as activity data for estimating emissions from national navigation and international maritime bunkers, has been analysed and been found to be of good quality. As a consequence of that VAT is applied on national fuel consumption, but not on international bunkers, all respondents to the survey are able to separate these fuel amounts with high accuracy. Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines.

The fuel consumption 2010 for national navigation has increased noticeably since 2009. The data has been verified and is correct according to reported amounts of fuel deliveries. Note that the amount of fuel used by national navigation is relatively small compared to the total amount of fuel for navigation, including international navigation (bunkers).

4.3 Methodological issues

Emissions from fuel combustion in Sweden are, if not specifically otherwise stated, determined as the product of fuel consumption, thermal value and emission factors (EF) as shown in Equation 4-1:

Equation 4-1:

$$\text{Emissions}_{\text{fuels}} \text{ (unit)} = \sum \text{Fuel consumption (unit)} * \text{thermal value}_{\text{fuels}} * \text{EF}_{\text{fuels}}$$

Different Tiers are used for different sub-sectors as discussed in sections below.

Please note that some fuel types are used in industrial processes rather than for energy purposes. This is the case for black liquor in the paper- and pulp industry and for coal and coke in the metal industry. Emissions from these fuels are thus accounted for under NFR 2 and methods used are described in section 5.

[28] Eklund et al. 2011. Emissions from navigation and fishing including international bunkers

Several recalculations have been carried out in the energy sector, which is described for each code below and in section 4.6.

Due to problems with data files on energy consumption in energy industries and manufacturing industries 1980-1989, it has not been possible to recalculate emissions as has been done for different sectors later years (described below). Because of this, time series 1980-89 and 1990-2009 are not directly comparable. The differences are greatest for NFR 1A1b, 1A1c, 1A2a and 1A2c.

4.3.1 Public Electricity and Heat Production, NFR 1A1a

A combined Tier 2 and 3 method is used.

Activity data for emissions in NFR 1A1a are taken from quarterly fuel statistics. For this sector, the quarterly fuel statistics is sent to all companies registered as ISIC 40 according to databases used by Statistics Sweden and the response rate is almost 100%. This gives very good data to the inventory, accurate, complete and consistent and with very low uncertainties.

Since submission 2010, no emissions from the integrated iron and steel industry are allocated to NFR 1A1a. However, emissions from steelwork gases sold to and combusted by ISIC 40 facilities are still allocated to NFR 1A1a. This is related to the revision of process emissions from the iron and steel industry discussed in section 4.3.4.

In submission 2012, minor emissions from combustion of natural gas in gas works were reallocated from NFR 1A5 to 1A1a.

4.3.2 Petroleum refining, NFR 1A1b

The Tier 2 method is used.

The statistics for NFR 1A1b are based on a total of seven plants with the Swedish Standard Industrial Classification 232, petroleum refining. Five of these companies are real refineries which use more than 99% of the energy within the sector and thereby give rise to most of the emissions. The other two plants are oil companies, mainly involved in production of lubricating grease, which means that they are dealing with products from refineries, and therefore should be reported under refineries according to the IPCC guide-lines.

For 1980-1989, activity data is taken from the industrial statistics and quarterly statistics. Activity data for the five refineries has been collected directly from each company for 1990-1999, since the industrial energy statistics and quarterly fuel statistics did not account for all fuels produced within refineries for these years. Data on the corresponding energy content of all fuels has also been collected and individual thermal values have been calculated for each operator and fuel. For 2000-2002, industrial energy statistics could be used for all refineries except one in 2000 and 2001, for which data was collected directly from the company in 2000 and from the environmental report in 2001. For 2003, industrial energy statistics could be used for all refineries except two, for which data was collected directly from the companies, since data was not yet available in the industrial energy statistics. For 2004, quarterly fuel statistics was used for one plant, the industrial energy statistics for three plants and the environmental report for one plant. As a result of a specific SMED study during 2006[29], data from the EU Emission Trading System (ETS) are used for four refinery plants for 2005 and later years. For the fifth plant data from environmental reports were used. In 2008 and later years, the quality of ETS data is considered to be very high for all the five refineries, and thus this is the primary source of activity data for this sector. The use of so many different sources for this sector could of course lead to consistency problems. Data used in the inventory in earlier years has been analyzed and no (significant) signs of inconsistency have been found. In recent years, environmental reports are used for verification.

The fuel consumption in this sector is mainly based on liquid fuels and the use has increased due to higher demand of refined products.

It has been noted that combustion of LPG has increased starting in 2003. In submission 2009, activity data was carefully studied to verify this increase. As a result of this, activity data for one company was revised for the years 2002-2006. It was found that reported amounts of LPG were not correct in data from Statistics Sweden. These data were replaced with data from the company's environmental report.

4.3.3 Manufacture of solid fuels and other energy industries, NFR 1A1c

The Tier 2 method is used.
Emissions from fuel combustion in the manufacturing of solid fuels are reported under NFR 1A1c, in line with IPCC Guidelines. This includes emissions from combustion in coke ovens in the iron and steel industry and emissions from fuel combustion in nuclear power plants. The methodology for estimating emissions from the iron and steel industry has been thoroughly revised in submission 2010. The new methodology is described in section 5.4.2.

For 1980-1989, activity data is taken from the industrial statistics and quarterly statistics. Activity data for fuel combustion in nuclear power plants is collected from industrial energy statistics for 1990 - 1996 and 2000 - 2002 and from quarterly fuel statistics for 1997 - 1999 and from 2003 onwards. For more details on the surveys see Annex 2. Activity data on combustion of coke oven gas and blast furnace gas in coke ovens is discussed in connection with other emissions from the iron- and steel industry in section 4.3.4.1.

Since 1990, solid fuel consumption has increased slightly due to higher production of coke caused by higher demand of primary iron and steel. In 2009, however, solid fuel consumption decreased considerably due to lower production of coke, caused by a lower demand of primary iron and steel. Consumption of liquid fuels has decreased since 2006 and the consumption of biomass is small and fairly constant.

The significant increase in consumption of liquid fuels between 2005 and 2006 is an effect of variations in the statistical sampling between years together with

[29] Backman & Gustafsson, 2006

relatively high uncertainties in the enumeration factors for fuel consumption. The increase is, however, very small compared to the use of solid fuels in NFR 1A1c.

The methodology change for the iron and steel industry in submission 2010 resulted in a reallocation of emissions from NFR 1A1c to NFR 2C1.

4.3.4 Iron and steel, NFR 1A2a

The Tier 2 method is used. Emissions from companies with less than 10 employees are allocated to NFR 1A2f and for these the Tier 1 method is used, since data on plant level is not available. During 2009, a new methodology was applied for the two largest primary iron and steel works, and this approach has been used since submission 2010. This is described in chapter 5.4.2.1.

Emissions reported from primary steel works and other iron and steel works are reported in both NFR 1A1c, 1A2a, 1B1b, 1B1c and 2C1 since some emissions arise from fuel combustion and some from reducing agents in the process. The text in this section is hence closely connected to the text in the section NFR 2C1 (iron and steel production). Fuel combustion has increased slightly since 1990 due to higher production of iron and steel products. However, there was a significant decrease in solid fuel consumption in 2009 due to lower production of coke, caused by a lower demand of primary iron and steel.

4.3.4.1 PRIMARY IRON AND STEEL WORKS

In Sweden, there are two plants for integrated primary iron and steel production, i.e. basing their production on iron ore pellets. The integrated iron and steel production consists of material flows between coke oven, blast furnace and steelworks, and in one plant, rolling mill (see Figure 5.1 in section 5.4.2.1.1.2). Emissions from fuel combustion (oils, LPG and recovered energy gases, i.e. coke oven gas and blast furnace gas) used in the rolling mills and for in-house power and heat production are allocated to this sub-sector in accordance with the IPCC Guidelines.

4.3.4.2 SECONDARY IRON AND STEEL WORKS

Except for the primary iron ore based iron and steel works, this sector include emissions from for instance electric arc furnaces plants, iron ore pellet plants and iron powder plants. Emissions from fuel combustion for energy purposes at these facilities are estimated with Tier 2 methodology, i.e. activity data on plant level and national emission factors are used. Activity data is collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003 onwards, further described in Annex 2.

4.3.5 Non-Ferrous Metals, NFR 1A2b

The Tier 2 method is used. Emissions from companies with less than 10 employees are allocated to NFR 1A2f and for these the Tier 1 method is used, since data on plant level is not available.

Activity data is taken from industrial energy statistics for 1990-1996 and 2000-2002 and from quarterly fuel statistics for 1997-1999 and 2003-2009. For more details on these surveys see Annex 2. Fuel consumption shows a decreasing trend since 1990. In 1999 there is a large jump in the time series due to increased consumed amounts of natural gas. This has been identified as a possible reporting error for one facility, but original raw data from 1999 is no longer available and hence revision is not possible.

4.3.6 Chemicals, NFR 1A2c

The Tier 2 method is used. Emissions from companies with less than 10 employees are allocated to NFR 1A2f and for these the Tier 1 method is used, since data on plant level is not available.

Generally, plants classified as ISIC 24 in the energy statistics are included in this sector. In submission 2011, it was decided to include one major plastic manufacturing plant classified as ISIC 24 some years and ISIC 25 other years in NFR 1A2c, in order to improve time series consistency in NFR 1A2c and 1A2f.

Activity data is, with exceptions mentioned below, collected from industrial energy statistics for 1990-1996 and 2000-2002 and from quarterly fuel statistics for 1997-1999 and 2003-2009. For more details on these surveys see Annex 2.

The fuel consumption is increasing since 1990, especially for liquid fuels, mainly due to increased use in the base plastic industry.

In submission 2009, after careful studies of different data sources regarding activity data of consumption of other petroleum fuels in this sector, it was found that the fuel used is a by product of the process in one facility, a gas that consists mainly of methane. Since no specific emission factors for methane and methane based gas mixtures are available, emission factors for natural gas are used as these fuels are considered to have similar properties, but of course fuel consumption and emissions are still reported under liquid fuels. As natural gas contains around 90 molar% methane, the emission factors are considered to be accurate also for methane-rich gas mixtures of liquid origin.

In a development project in 2010[30], the activity data time series 1990-2008 for all fuel types and all facilities within the chemical industry were thoroughly reviewed. Reported emissions and activity data in NFR 1 and 2 were analysed on facility level and verified against environmental reports, and when necessary the facilities were contacted for explanations or complementary data. Most of the data reported in submission 2010 was concluded to be correct, and only a few revisions had to be made in submission 2011. A few erroneous activity data records were detected and revised. The errors include double-counting, input data errors and miscoding, e.g. biogenic ethanol that had been coded as natural gas or hydrogen coded as other petroleum fuels.

The project also resulted in revisions of a couple of emission factors. Emission factors for hydrogen, which were previously set equal to those of “other petroleum fuels” for all substances containing nitrogen, i.e. including NH_3, were corrected and set to zero for all substances except for NO_x.

[30] Gustafsson, Nyström & Gerner, 2010

The revision that had the largest impact on the emissions is the conclusion drawn that some (not all) of the natural gas consumption previously reported in NFR 1A2c 2004 and onwards is actually used as feedstock and not for energy production, and hence no emissions from this activity should be reported in NFR 1A2c.

4.3.7 Pulp, Paper and Print, NFR 1A2d

The Tier 2 method is used. Emissions from companies with less than 10 employees are allocated to NFR 1A2f and for these the Tier 1 method is used, since data on plant level is not available. Emissions from processes in the Pulp, paper and print industry are also reported under NFR 2D1 according to IPCC Guidelines. See chapter 4.5.

Activity data is, if not otherwise stated, collected from industrial energy statistics for 1990-1996 and 2000-2002, and from quarterly fuel statistics for 1997-1999 and 2003-2009. For more details on these surveys see Annex 2.

There is no apparent trend in fuel consumption since 1990.

During 2009, an investigation of emissions of NO_x, SO_2 and particulate matter from the pulp and paper industry was performed. A comparison between the total emissions from the facilities calculated with national emission factors and the corresponding emissions reported in the environmental reports of the corresponding facilities showed that the use of national emission factors leads to an overestimation of the emissions. In the environmental reports, however, emissions are not reported per fuel type, and hence it was not possible to develop revised emission factors per fuel. Instead, emissions of NO_x, SO_2 and particulate matter from fuel combustion in pulp and paper production facilities are enumerated with the same mean factors for all fuels:

$$EM_{NOX} = 0.736*EF_{NOX}* AD$$

$$EM_{SO2} = 0.565*EF_{SO2}*AD$$

$$EM_{TSP/PM10/PM2.5}=0.686* EF_{TSP/PM10/PM2.5}*AD;$$

where EM= emission, EF= national emission factor, and AD= activity data in TJ. The availability of environmental reports for the years before 2000 is very limited, why the correction factors quoted above are used only for the years 2000 and later. The investigation, and hence the correction factors, applies to the pulp and paper industry only, and not to the printing works.

Emissions from combustion of sulphur lyes are presently not reported in 1A2d as this activity has been considered as an industrial process. This might, however, be revised in future submissions.

4.3.8 Food Processing, Beverages and Tobacco, NFR 1A2e

The Tier 2 method is used. Emissions from companies with less than 10 employees are allocated to NFR 1A2f and for these the Tier 1 method is used since data on plant level is not available.

Activity data is collected from industrial energy statistics for 1990-1996 and 2000-2002 and from quarterly fuel statistics for 1997-1999 and 2003-2009. For more details on these surveys see Annex 2.

The fuel consumption varies between years. A slight decrease can be observed since 1990.

As a side effect of the quality control of the chemical industry in 2010, the reported consumption of other petroleum fuels in the food and drink industry was investigated, and comparisons with the annual industrial energy survey were made. It turned out that this fuel was miscoded as it was actually landfill gas, i.e. biomass. This was corrected in submission 2011.

4.3.9 Other, NFR 1A2f

For emissions from stationary combustion, the Tier 2 method is used with the following exception:

For the construction industry and for companies with less than 10 employees the Tier 1 method is used, since current data does not allow the Tier 2 method to be used.

Emissions from mobile combustion refer to off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions was revised in submission 2009 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

Emissions from stationary combustion in mining and quarrying and in the manufacturing of various products such as textiles, wearing apparel, leather, wood and wood products, rubber and plastics products, other non-metallic mineral products, fabricated metal products and manufacturing of different types of machinery, are calculated with activity data from the industrial energy statistics for 1990-1996 and 2000-2002, and from the quarterly fuel statistics for 1997-1999 and 2003 and later. For more details on these surveys see Annex 2.

Emissions from all companies with less than 10 employees are estimated and reported under NFR 1A2f. Activity data are collected from the annual energy balances produced by Statistics Sweden[31]. The last emission year is estimated as a projection of the second last year by the trend from the quarterly energy balances, as the annual energy balances for the last emission year are not ready in time for the emission calculations. Emissions are minor and with current data not possible to separate on different industry sectors.

Emissions from stationary combustion in the construction industry are calculated with activity data from Statistics Sweden[32] in the same way as for small companies described above.

The fuel consumption varies between years, but has totally decreased slightly since 1990, especially the consumption of liquid and biomass fuels.

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[31] Statistics Sweden, EN20SM 1990-2008. See also Annex 2.
[32] Statistics Sweden, EN20SM 1990-2008. See also Annex 2.

Since 2002, for one glassworks plant, it is no longer possible to separate combustion emissions of SO_2 from process emissions. The reason is that the facility has restructured its environmental report, and only reports emissions of SO_2 on an aggregate level. The median value for the share of process-related SO_2 emissions of the total SO_2 emissions is 2 % for the years 1990 - 2001. The emission data reported in the plants environmental report are considered to be more accurate than emissions calculated from fuel combustion with standard emission factors, and thus for practical reasons, all data that is available from environmental reports from this plant, namely SO_2 and NO_X, are reported in NFR 2A7 and all other emissions are reported in NFR 1A2F.

For 2008 and later, activity data for the three plants within the cement production industry is taken from the EU ETS system.

4.3.10 Civil Aviation, NFR 1A3a ii (i-ii)

Sweden uses the Tier 2a for all gases.

Emissions from aviation in agricultural and forestry sectors are currently reported together with domestic aviation. Emissions from military use of aviation fuels are reported under Other – mobile sources (NFR 1A5b).

Emissions from aviation are calculated using statistics on supply and delivery of petroleum products (see Annex 2), and information from the Swedish Civil Aviation Authority (SCAA) on fuel use and emissions estimates related to the governmental airports in Sweden.

Presently data are provided for a total of 41 airports with regular and/or charted air traffic. The national government administers 19 of these airports, while the remaining 22 are private and/or administered by local government.[33] The traffic routed through governmental airports account for about 90 % of the total fuel consumption within the civil aviation sector. The SCAA publishes information on aviation emissions from these airports in annual environmental reports. Complementary emission calculations are carried out to reach full national coverage including non-governmental airports. SCAA include the traffic from a number of non-governmental airports in their estimates from 2005 and almost all Swedish airports from 2006, the methodology for calculating national emissions is however the same for all years.

During 2007, the Swedish Transport Agency responded to the governmental call to reduce response burden on statistical compilations. As a result, private aviation as well as educational training flights and military are no longer covered in the calculations of emissions. The emissions mostly affected were CO, HC and N_2O.

However, the fuel consumption and emission data were already underestimated, since the model used base estimations on a flight route that is too short. The model estimates the fuel consumption based on the shortest distance between airports, which often is incorrect. The model also discounts extra fuel consumption due to “holding”, e.g. when the airplane has to circulate above the airport before landing.

[33] Swedish Civil Aviation Authority.

As the fuel consumption estimation is adjusted to correlate with the statistics of the national fuel deliveries of jet kerosene and aviation gasoline for reporting to the UNFCCC, all emissions are consequently adjusted to correlate with these statistics. So the missing data from the private aviation as well as educational training flights is as a result adjusted to correlate with the supply in Sweden and is therefore included.

The emissions of NMVOC have decreased noticeably in the last years. The reason is that a specific type of airplane (MD-80/82), which is a major contributor to these emissions, is being phased out.

The fuel consumption and emissions published by the SCAA are calculated by the Swedish Defence Research Agency (FOI). FOI uses statistics on the number of flights between city pairs (domestic and international), type of aircraft, amount of fuel needed for different flights and emissions per fuel on specific flights based on data on aircraft performance during different phases of the flight and the distance between destinations.

To estimate fuel consumption and emissions from domestic landing and takeoff (LTO) FOI uses two models – HARP (HAsselrot´s Reviewed Pollutions) and PIANO (Project Interactive Analysis and Optimization). HARP is used for estimating national Times in Mode (TIM) and PIANO is used for calculating the fuel consumption and emissions. Due to the fact that the Swedish airports generally are smaller than international airports in other countries, taxi times are much shorter for domestic flights and climb-out and take-off times are often shorter as well. Hence traffic from Swedish airports needs less fuel and give rise to less emissions compared to the International Civil Aviation Organization (ICAO) standards that the IPCC guidelines follow.[34] For international flights, ICAO standard taxi time has been used for the part of the LTO cycle occurring on international airports.[35]

The results from the emissions calculations are aggregated into four groups: domestic landing and takeoff (LTO), domestic cruise, international LTO and international cruise. This is in line with the IPCC guidelines and data of good quality exists from 1995 and onwards.

Emissions of CO_2 are based on fuel delivery statistics, national thermal values from Statistics Sweden and emission factors from the Swedish EPA. Quotas for distributing of CO_2 emissions on domestic and international LTO and cruise are based on information on CO_2 emissions from the SCAA. This information is not available for 1990-1994 and is therefore estimated as described by Figure 4.1.

[34] Gustafsson, 2005.
[35] Näs, 2005.

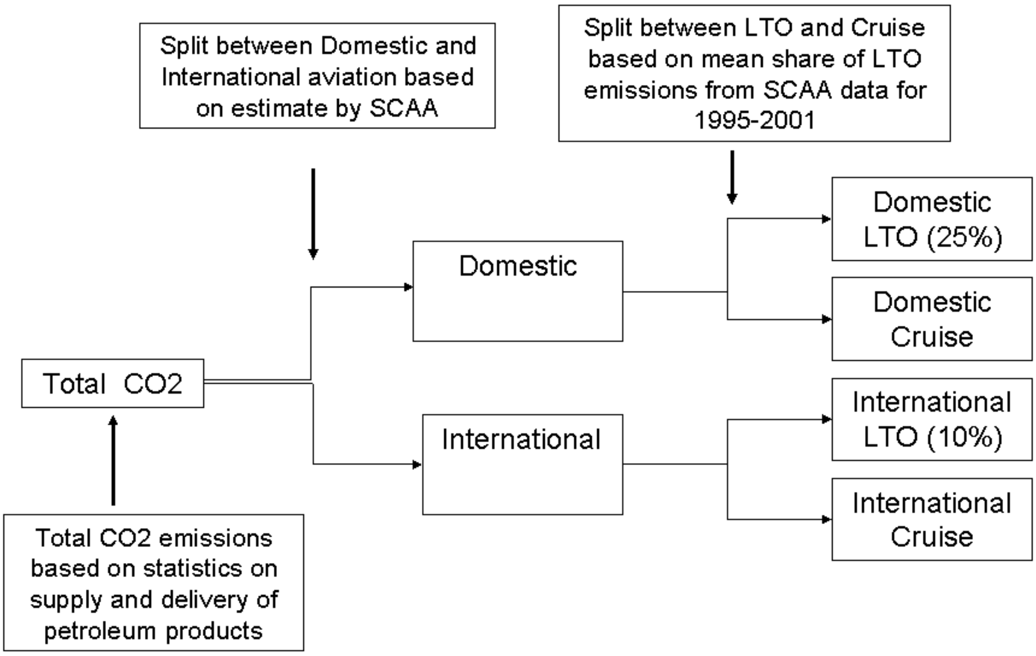

Figure 4.1. Model for estimating Domestic/International LTO/Cruise 1990-1994.

For example, the estimate of domestic emissions for 1990 is calculated based on the share of domestic emissions for 1998 which is approximately 29 %. To adjust for the development of domestic versus international traffic since 1990 the 29 % are multiplied by a factor of approximately 1.16. The factor is supposed to reflect the larger share of domestic traffic in 1990 and is calculated as the share of domestic LTO in 1990 divided by the share of domestic LTO in 1998 (1.156 = 0.724/0.626) based on LTO data from SCAA available in 1998. The share of domestic CO_2 emissions 1990 is then consequently calculated as 1.16 * 0.29 = 34 %. International emissions are estimated as total emissions minus domestic emissions. The distribution of CO_2 emissions for 1991-1994 is estimated using the same method as for 1990.

The last step in estimating emissions from aviation is the split between LTO and Cruise. This is the step that is based on the mean value for LTO cycles for domestic and international flight in 1995-2000, meaning the CO_2 from domestic LTO/total CO_2 from domestic aviation and the equivalent for international traffic.

Due to the lack of activity data, all non-CO_2 emissions for 1990-1994 are calculated by SMED in cooperation with the SCAA. Fuel consumption and SO_2 emissions are estimated based on CO_2 emissions. Emissions of CO are calculated by comparing the 1995 relationship between CO and CO_2 and using the same ratio (4.85 % of CO_2 emissions) for 1990-1994. Emissions of NO_X are calculated in a similar way. The ratio is relatively stable over the years and therefore the mean value of 1995-2004 (4.03 % of CO_2 emissions) is used for 1990-1994. Emissions of HC for 1990-1994 are calculated by extrapolation.

From 1995 and onwards, emissions of SO_2, NO_x, CO and HC are based on information from the SCAA, adjusted to match the delivered amount of aviation fuels. Emissions of NMVOC and CH_4 are estimated based on information on emissions of HC from the SCAA and emission factors from the IPCC guidelines.

N_2O emissions for LTO are estimated using information on the number of LTO cycles from the SCAA together with emission factors from IPCC. N_2O emissions for cruise are based on delivered amounts of fuel for cruise activities estimated by FOI, adjusted to be in line with fuel delivery statistics, together with emission factors according to the IPCC guidelines.

SCAA have received information on LTO emissions for 2001 and 2002 from 19 non-governmental airports and estimated CO_2 and NO_X emissions for all non-governmental airports based on this information. Adding together emissions of CO_2 and NO_X from both governmental and non-governmental airports provides a good estimate of the aviation emissions at national level. A comparison between these data and the ones calculated using the Tier 1 method shows good coherence with a variation of only 2-5 %.

4.3.11 Road transport, NFR 1A3b i-iv

Emissions of SO_2 from road traffic are based on statistics on supply and delivery of petroleum products (see Annex 2), in accordance with the IPCC Guidelines Tier 1.

Emissions of all other substances apart from PM_{10} from gasoline, together with input to the national allocation model for diesel for the road traffic sector, are provided by the Swedish Transport Administration (STA). The STA has since 2004 (submission 2006) used the European road traffic emission model ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) to estimate emission from road traffic, but as from submission 2012 they employ the newly updated road traffic emission model HBEFA 3.1 instead.

HBEFA 3.1 is the most recent version of HBEFA which dates from January 2010 and is a fusion between ARTEMIS and earlier models of HBEFA. The most prominent difference in the new model is the inclusion of the latest exhaust emission control technology (Euro 4 and Euro 5). All emission factors have also been renewed and there has been an update of the vehicle fleet, the composition of the fuel and the current traffic work. There has also been an update of the traffic situations according to the model based on the new speed limits in Sweden for 2010[36].

The HBEFA model has been used for all NFR estimates. The model is a bottom-up approach and is considered as Tier 2.

Data from the HBEFA model are separated by fuel type and four vehicle types: Passenger cars, Light commercial vehicles, Heavy-duty vehicles (including bus) and Mopeds & Motorcycles. Estimated fuel consumption per fuel and vehicle type is used to proportionally allocate national fuel statistics over those categories.

Emissions of SO_2 are then estimated based on the distributed national fuel statistics together with thermal values and information on the sulphur content of dif-

[36]Swedish Transport Administration (STA). Leverans av data till klimatrapportering 2012, vägtrafik. 2011

ferent environmental classes of diesel and gasoline provided by the SNRA. These are in turn based on estimations made by VTI[37] for 1990-2001, and on fuel analysis from SPI from 2001 and onwards.

Emissions of CH_4, N_2O, NO_x, CO and NMVOC are according to HBEFA data adjusted for military transport.

The fuel consumption estimated by the SNRA differs slightly from the national fuel statistics. The SNRA aims to describe what is emitted on Swedish roads, regardless of where the fuel was bought or the nationality of the vehicles. According to IPCC Guidelines, the inventory should only account for emissions from fuel purchased in Sweden. An overview of the two different objectives is presented in Table 4.3.

Table 4.3. Emissions from road transport reported by the SNRA and in the NFR.

Fuel bought in	Traffic on Swedish roads	Traffic in Sweden, not on roads	Traffic to/from other country	Traffic in other countries
Sweden	NFR 1A3b i-iv SNRA	NFR 1A3b i-iv	NFR 1A3b i-iv* SNRA to the Swedish border	NFR 1A3b i-iv *
Other country	SNRA	Not reported	SNRA to the Swedish border	Not reported

* Since the IPCC Guidelines do not consider international bunkers for road transportation, all emissions from road traffic and fuel bought in Sweden are considered to be domestic and thus reported under NFR 1A3b.

Emissions of SO_2 from combustion of gasoline are based on thermal values and country-specific emission factors from Statistics Sweden and the Swedish EPA. Emissions of SO_2 from combustion of diesel are based on thermal values and country-specific emission factors from SPI. Emissions of SO_2 from gasoline and diesel are based on information on the sulphur content of different environmental classes of diesel and gasoline provided by SNRA.

Prior to submission 2007, emissions of SO_2 from diesel and gasoline were based on the maximum allowed sulphur content of different environmental classes. Data on maximum allowed sulphur content was provided by SPI. From submission 2007, emissions of SO_2 are based on the actual sulphur content for the different environmental classes of petrol and diesel fuel. The data on actual sulphur content, provided by SNRA, is based on estimates made by VTI[38] for the years 1990-2001, and on fuel analysis from SPI from 2001 and onwards.

SO_2 from natural gas and biofuels are estimated using statistics on deliveries for natural gas, biogas, ethanol and FAME. Activity data for natural gas is available from 1990, while reliable activity data for biogas exists from 1996 and for ethanol and FAME from 1998. Thermal values and emission factors for ethanol and biogas have been collected from the Swedish Biogas Association. Thermal values and emission factors for FAME are not available but thermal values are

[37] Swedish Road and Transport Research Institute, 2002.
[38] Ibid.

assumed to be the same as for diesel and emission factors for SO_2 the same as for natural gas.

Military transport emissions are reported under NFR 1A5b to be in accordance with the IPCC Guidelines. Military road transport is included in the road traffic emissions estimated by HBEFA. To subtract and separate emissions from military transport from emissions from civil road transport, emissions from HBEFA for each vehicle type are reduced by an amount equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport, according to Equation 4-2:

Equation 4-2: $A = B - \sum((C-D)/C*E_i)$

A = Military transport emissions
B = Total HBEFA emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
E_i = HBEFA emissions per vehicle type

In submission 2012, the allocation of gasoline and diesel oil to road traffic and diesel oil to fisheries and domestic navigation was affected by a revision of the model to estimate emissions from off-road vehicles and working machinery.

In order to calculate emissions of TSP and $PM_{2.5}$ particle size partitioning was made in the calculations, where TSP was assumed to be equal to 100% and $PM_{2.5}$ to be equal to 95 %[39] of calculated PM_{10} emissions.

Data on particle emissions are lacking for the years 1981-1984 and 1986 and are therefore interpolated. It should also be noted that emissions of particles reported under NFR 1A3b for the 1980s include military activities.

Emissions of dioxin from road transport were before submission 2008 not separated into different sub-sectors and were aggregated under Road Transportation (1A3b). In submission 2008 data from 1990 were updated since detailed background information (m3 gasoline and diesel) per vehicle category from the HBEFA model, has made it possible to report emitted dioxin separately for Passenger cars (1A3b i), Light duty vehicles (1A3b ii), Heavy duty vehicles (1A3b iii) and Mopeds & Motorcycles (1A3b iv). In submission 2012 data from the HBEFA 3.1 model were used instead of data from the ARTEMIS model. Therefore in submission 2012 all data from 1990 were updated. The emission factors used are from Finstad et al (2001)[40] (Table 4.4).

Further, from submission 2008 emissions of benso(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene) were reported for 1A3b. As for dioxin, detailed data from the ARTEMIS model (submission 2008-2011) and HBEFA 3.1 (submission 2012) regarding yearly mileages (km x 10^6) per vehicle and fuel category, as well as emission factors, have been used. Therefore in submission 2012 all data from 1990 were updated. Emission factors

39 Sjödin and Ekström, 2003, pers. comm
40 Finstad et al, 2001

presented by Westerholm et al. (2001)[41] are used for the calculations of PAHs from Swedish environmental classified diesel (MK1) used in Heavy duty vehicles. Emission factors for MK1 diesel in Passenger cars and Light duty vehicles are calculated using the relationship Passenger car/Heavy duty vehicle and Light duty vehicle/Heavy duty vehicle in the EMEP-Corinair Guidebook and emission factors for Heavy duty vehicle according to Westerholm et al (2001)[41]. For MK1 diesel the emissions of benzo(k)fluoranthene are included in reported benzo(b)fluoranthene. All other emission estimates are based on emission factors in the EMEP-Corinair Guidebook. The emission factors used are shown in Table 4.4.

Table 4.4. Emission factors used for estimations of dioxin and PAH emissions from fuel combustion in NFR 1 A 3 b i - iv.

	Gasoline		Diesel					
	Leaded	Unleaded	Conventional			MK1		
	All vehicle categories		Passenger cars, Light duty vehicles		Heavy duty vehicles	Passenger cars, Light duty vehicles		Heavy duty vehicles
			Not direct injection	Direct injection		Not direct injection	Direct injection	
Dioxin (µg/Mg)	2.00	0.10	0.10					
Benzo(a)pyrene (µg/km)	0.48	0.32	2.85	0.63	0.90	0.95	0.21	0.30
Benzo(b)fluoranthene (µg/km)	0.88	0.36	3.30	0.60	5.45	0.09	0.18	1.60
Benzo(k)fluoranthene (µg/km)	0.30	0.26	2.87	0.19	6.09			
Indeno(1,2,3-cd)pyrene (µg/km)	1.03	0.39	2.54	0.70	1.40	0.36	0.10	0.20

Time series per vehicle category are calculated for dioxin and PAH-4 from 1980, but data for 1980 - 1989 are not updated in the NFR-tables.

For the dioxin emission estimates the percentage leaded gasoline of the total amount of gasoline must be taken into consideration (Table 4.5). For the PAH calculations the share of diesel Passenger cars and diesel Light duty vehicles with direct injection must be estimated, since these emission factors differ from the emission factors for diesel vehicles without direct injection (Table 4.5). All Heavy duty vehicles are assumed to have direct injection. Also the percentage of MK1 diesel of the total amount of diesel used has to be known (Table 4.5).

[41] Westerholm et al., 2001. Comparison of Exhaust Emissions from Swedish Environmental Classified Diesel Fuel (MK1) and European Program on Emissions, Fuels and Engine Technologies (EPEFE) Reference Fuel: A Chemical and Biological Characterization, with Viewpoints on Cancer Risk

Table 4.5. Distribution of vehicles with respect to fuel type and injection system

	Gasoline		Without direct injection		With direct injection		Diesel type	
Year	Leaded	Un-leaded	Passen-ger cars	Light duty vehicles	Passen-ger cars	Light duty vehicles	MK1	Conven-tional
1980-1985	100%	0%	100%	100%	0%	0%	0%	100%
1986	75%	25%	100%	100%	0%	0%	0%	100%
1987	68%	32%	100%	100%	0%	0%	0%	100%
1988	65%	35%	100%	100%	0%	0%	0%	100%
1989	54%	46%	100%	100%	0%	0%	0%	100%
1990	50%	50%	100%	100%	0%	0%	0%	100%
1991	45%	55%	100%	100%	0%	0%	0%	100%
1992	41%	59%	100%	100%	0%	0%	4%	96%
1993	16%	84%	100%	100%	0%	0%	20%	80%
1994	0%	100%	83%	100%	17%	0%	36%	64%
1995	0%	100%	67%	100%	33%	0%	66%	34%
1996	0%	100%	50%	100%	50%	0%	85%	15%
1997	0%	100%	45%	83%	55%	17%	88%	10%
1998	0%	100%	40%	67%	60%	33%	90%	10%
1999	0%	100%	35%	50%	65%	50%	94%	6%
2000	0%	100%	30%	45%	70%	55%	94%	6%
2001	0%	100%	25%	40%	75%	60%	98%	2%
2002	0%	100%	20%	35%	80%	65%	99%	2%
2003	0%	100%	16%	30%	84%	70%	99%	1%
2004	0%	100%	11%	25%	89%	75%	99%	1%
2005	0%	100%	6%	20%	94%	80%	98%	2%
2006	0%	100%	6%	16%	94%	84%	99%	1%
2007	0%	100%	4%	11%	96%	89%	99%	1%
2008	0%	100%	0%	6%	100%	94%	99%	1%
2009	0%	100%	0%	6%	100%	94%	99%	1%
2010	0%	100%	0%	4%	100%	96%	99%	1%

One important basic parameter for the HBEFA 3.1-model is the vehicle-km, which is calculated through another model. This second model is based on the mileage driven by the vehicle noted at time of MOT (annual testing of the vehicle).

A passenger car that goes through the MOT in the beginning of 2009 has been driven the most part of 2008. If the development of traffic is without interruption this issue is not a problem for the calculations. However, if a sudden event occurs, such as a drop in the economy as seen recently it will not be shown as clearly in the development of vehicle mileage as in statistics on fuel consumption.

4.3.11.1 AUTOMOBILE TYRE AND BRAKE WEAR, NFR 1A3B VI, AND AUTOMOBILE ROAD ABRASION, NFR 1A3B VII

In submissions earlier than 2008, non-exhaust emissions of particles and metals from tyre and brake wear and road abrasion were reported aggregated in NFR 1A3b vi (Automobile tyre and brake wear). The reported emissions were partly based on measurements performed in a road tunnel, and the estimates therefore to some degree also included resuspended particles. EMEP-Corinair Guidebook states that only particles emitted directly as a result of the wear of surfaces are to be reported, and that those particles resulting from resuspension of previously deposited material should be excluded.

From submission 2008 background information (vehicle km x10^6, per vehicle category) from the ARTEMIS model (submission 2008-2011) and from submission 2012 background information from the HBEFA 3.1 model was used and emission factors for particles from the EMEP-Corinair Guidebook (detailed methodology) were used to estimate the particle emissions separately for tyre and brake wear (1A3b vi) and road abrasion (1A3b vii). The calculations also need information concerning the average speed for each vehicle category. These estimates are based on information in ARTEMIS (1990 - 2004) and the same figure per vehicle category is used for the whole time period, 1980 - 2010.

Time series per vehicle category are calculated for TSP, PM_{10}, $PM_{2.5}$, metals and PAH-4 from 1980, but data for 1980 - 1989 are not updated in the NFR-tables.

4.3.11.1.1 Particle emissions from Tyre and brake wear, NFR 1A3b vi

For the tyre and brake wear particle emission calculations for heavy duty vehicles, also the average vehicle size is of importance. For the calculations reported from submission 2012 a load factor of 50 % is set because no information is available. The only available information is that 23 % of the transports are completely empty according to data from Swedish Institute for Transport and Communications Analysis (SIKA)[42]. The average number of truck axles was set to five. The emission factors used for the particle emission calculations reported in 1A3b iv are presented in Table 4.6.

Table 4.6. Emission factors used for particle emission calculations in 1A3b vi.

	Emission factors (g/vehkm) BRAKE WEAR			Emission factors (g/vehkm) TYRE WEAR		
Vehicle category	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Passenger cars	0.0084	0.0082	0.0033	0.0128	0.0077	0.0054
Light duty vehicles	0.0131	0.0128	0.0051	0.0203	0.0122	0.0085
Heavy duty vehicles	0.0453	0.0444	0.0177	0.0610	0.0366	0.0256
Mopeds & Motorcycles	0.0022	0.0021	0.0009	0.0046	0.0028	0.0019

4.3.11.1.2 PAH emissions from Tyre and brake wear, NFR 1A3b vi

The separation between particles from tyre wear and brake wear also made it possible to calculate and report PAH-4 from tyre wear and brake wear in 1A3b vi. The

[42] http://www.sika-institute.se/

emission factors used for the calculations of PAH emissions from tyre wear and brake wear are as presented in the EMEP-Corinair Guidebook (detailed methodology). The emission factors used for the PAH calculations are presented in Table 4.7.

Table 4.7. Emission factors used for PAH emission calculations in 1A3b vi.

	Emission factors, TYRE WEAR (ppm wt.)				Emission factors, BRAKE WEAR (ppm wt.)			
	Benzo(a) pyrene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Indeno (1,2,3-cd) pyrene	Benzo(a) pyrene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Indeno (1,2,3-cd) pyrene
All vehicle categories	3.9	-	-	-	0.74	0.42	0.62	-

4.3.11.1.3 Metal emissions from Tyre and brake wear, NFR 1A3b vi

In Hjortenkrans et al. (2006)[43] mean metal concentrations in retread and non-retread tyre tread rubber are presented. As almost all tyres used on heavy duty vehicles are retread tyre tread rubber[43], the emissions calculated for heavy duty vehicles are based on an emission factor representing retread tyre tread rubber. For all other vehicle categories the calculations are based on emission factors for non-retread tyre tread rubber.

Table 4.8. Emission factors used for metal emission calculations from tyre wear in 1A3b vi.

	Emission factors, TYRE WEAR, (mg/kg)					
Vehicle category	Pb	Cd	Cr	Cu	Ni	Zn
Passenger cars	9.4	1.1	1.7	8.6	3.2	9400
Light duty vehicles	9.4	1.1	1.7	8.6	3.2	9400
Heavy duty vehicles*	9.5	0.86	1.3	7.4	2.9	12000
Mopeds & Motorcycles	9.4	1.1	1.7	8.6	3.2	9400

* retread tyres

Hjortenkrans et al. (2006)[44] also studied the metal content in both branded brake linings and those from independent suppliers. A similar study was made in the late

[43] Hjortenkrans et al. 2006. Metallemission från trafiken i Stockholm – Däck. (in Swedish, results from a study on metal emissions from tyre wear)
[44] Hjortenkrans et al. 2006. Metallemission från trafiken i Stockholm – Bromsbelägg. (in Swedish, results from a study on metal emissions from brake linings)

1990s[45] and the results show that there is a clear reduction of the Pb and Zn content in both branded linings and linings from independent suppliers. Also for Cu the metal content in linings from independent suppliers from 2005[46] is much lower than in 1998[47]. For branded linings the results is the contrary, the Cu content in linings from 2005 is higher compared to linings from 1998. For the brake linings metal emission calculations the same assumption as both Hjortenkrans[46] and Westerlund[47] is made; 40 % of the traffic volume is related to new vehicles using branded linings and 60 % to older vehicles using linings from independent suppliers. For Pb, Cu and Zn the emission factors used are based on results presented by Westerlund[47] for the years 1980 - 1998, and on results presented by Hjortenkrans[46] for 2005 and onwards. The emission factors for 1999 - 2004 are interpolated. For Cd the same emission factor is set for the whole time series[44].

The emission factors used for calculating metal emissions from tyre wear and brake wear are presented in Table 4.9.

Table 4.9. Emission factors used for metal emission calculations from brake wear in 1A3b vi.

	Emission factors, BRAKE WEAR, branded (ppm wt.)				Emission factors, BRAKE WEAR, independent (ppm wt.)			
Vehicle category	Pb	Cd	Cu	Zn	Pb	Cd	Cu	Zn
1980 - 1998	13854	2.6	105070	20164	11381	0.445	61615	12447
1999	12090	2.6	108631	21855	9783	0.445	52835	11340
2000	10327	2.6	112193	23546	8185	0.445	44055	10233
2001	8563	2.6	115754	25237	6587	0.445	35275	9127
2002	6800	2.6	119316	26927	4989	0.445	26495	8020
2003	5037	2.6	122877	28618	3391	0.445	17715	6913
2004	3273	2.6	126439	30309	1793	0.445	8935	5807
2005 -	1510	2.6	130000	32000	195	0.445	155	4700

4.3.11.1.4 Particle emissions from Road abrasion, NFR 1A3b vii

One weak aspect of the current EMEP-Corinair methodology presented in the Guidebook is the use of studded tyres. Studded tyres lead to significant enhanced road surface wear, but due to lack of data no emission factor for studded tyres is included in EMEP-Corinair Guidebook. In Sweden a large share of the passenger cars and light duty vehicles are fitted with studded tyres during winter time. Results from studies on effects of studded tyres on road surface wear show a substantial increase in emitted particles (Gustafsson et .al. submitted; pers. communication)[48].

[45] Westerlund, K.-G. 2001. Metal Emissions from Stockholm Traffics Wear of Brake Linings; Reports from SLB-analys, 2:2001; Environment and Health Protection Administration in Stockholm: Stockholm. 2001.
[46] Hjortenkrans et al. 2006. Metallemission från trafiken i Stockholm – Bromsbelägg. (in Swedish, results from a study on metal emissions from brake linings)
[47] Westerlund, K.-G. 2001. Metal Emissions from Stockholm Traffics Wear of Brake Linings; Reports from SLB-analys, 2:2001; Environment and Health Protection Administration in Stockholm: Stockholm. 2001.
[48] Gustafsson, M., et al., submitted. Particle characteristics and toxicological effects of particles from the interaction between tyres, road pavement and winter traction material. Submitted to The Science of the Total Environment, februari, 2007.

The results justify a correction factor for the use of studded tyres to be included in the estimations of particle emissions from road abrasion.

The following assumptions have been made for the calculation of particle emissions from road abrasion:
studded tyres are used only on passenger cars and light duty vehicles
studded tyres are used during four months per year
70% of the passenger cars and light duty vehicles use studded tyres

$$\frac{4}{12} \times 0.70 = 0.23 \Rightarrow \text{ie. approx. } 20\%$$

A correction factor of 50 x PM_{10} for the use of studded tyres has been adapted to 20% of vehicle kilometres for passenger cars and light duty vehicles. The same particle size distribution as for road abrasion for non-studded tyres has been used.

The emission factors used for the calculation of particle emissions from road abrasion are presented in Table 4.10.

Table 4.10. Emission factors used for particle emission calculations in 1A3b vii.

Vehicle category	Emission factor (g/km) ROAD SURFACE WEAR, non studded tyres			Emission factor (g/km) ROAD SURFACE WEAR, studded tyres		
	TSP	PM10	PM2.5	TSP	PM10	PM2.5
Passenger cars	0.018	0.009	0.005	0.900	0.450	0.243
Light duty vehicles	0.018	0.009	0.005	0.900	0.450	0.243
Heavy duty vehicles	0.099	0.049	0.027			
Mopeds & Motorcycles	0.006	0.003	0.002			

4.3.12 Railways, NFR 1A3c

The Tier 1 method is used.

Information on emissions from railways is provided by the Swedish National Rail Administration, as estimates on the amount of diesel consumed as well as estimates on emissions of SO_2, NO_X, NMVOC, CO and HC.

The estimated diesel consumption are based on fees paid by the rail operators and is considered to be of very high quality. Emission factors used for NO_X and CO estimates are provided by the National Rail Administration. Remaining emissions are based on default emission factors from EMEP/CORINAIR.

Emissions of particles are calculated based on activity data from the Swedish Institute for Transport and Communication[49] for the eighties and from the National Rail Administration for the nineties. The emission factor for TSP is a default emission factor from the CORINAIR Atmospheric Emission Inventory Guidebook. The size distribution of particulate emissions has been calculated according to the TNO/CEPMEIP study[50]. The emission factors for particles are assumed to be constant over the whole period 1980 and onwards.

49 Swedish Institute for Transport and Communication Analysis, 2001
50 CEPMEIP project TNO, 2001

4.3.13 Navigation, NFR 1A3d ii

Emissions from national navigation are estimated using Tier 1.

Emissions from domestic navigation are calculated based on the amount of fuels that are purchased and consumed in Sweden[51]. Emissions from fuels that are purchased in Sweden but used abroad are reported separately as international bunker emissions. The allocation of emissions from navigation is summarized in Table 4.11.

Table 4.11. Reporting of emissions from navigation, according to the Good Practice Guidance.

Fuel bought in	Traffic between Swedish harbours	Traffic between Swedish and international harbours	Traffic between two international harbours
Sweden	Domestic, 1A3d ii	International bunkers, 1A3d i (i)	International bunkers, 1A3d i (i)
Other country	Not included	Not included	Not included

Emissions from gas/diesel oil and residual fuel oils, for 1990-2002, are calculated using emission factors from a SMED study from 2004[52]. Emissions for 2003 and 2004 have been estimated using emissions factors for 2002 while emissions for 2005 and later years have been calculated using emissions factors provided by the Swedish Maritime Administration (SMA). The emission factors provided by the SMA are based on the mentioned study by SMED.

Emissions of SO_2 from leisure boats are calculated based on estimated gasoline consumption together with thermal values and emission factors which are the same as for civil road traffic. Emissions of NO_X, NMVOC and CO are all based on estimated gasoline consumption together with emission factors from CORINAIR for gasoline.

Emissions of NO_X, NMVOC and CO from leisure boats also depend on the ratio between 2-stroke and 4-stroke engines. The estimated ratios between the two are based on a study by Statistics Sweden from 2005. The study indicates that there is a larger share of 4-stroke engines in 2004 than in 1990. Based on the assumption that the move towards a larger number of 4-stroke engines has been gradual since 1990, the ratio for each year between 1990 and 2004 has been estimated by interpolation. From 2005 and onwards, the ratio between 2- and 4-stroke engines is assumed to be the same as for 2004.

The Swedish Maritime Administration also report emissions from domestic navigation. These can however not be compared with emissions from the Swedish national inventory since the former include emissions from the whole Baltic Sea region.

Emissions of particles from leisure boats have been estimated with the assumption that they generate the same amount of emissions per energy unit as for gasoline driven off road vehicles and other machinery for households[53].

In 2008 new emission factors were provided for SO_2, NO_X, NMVOC and CO.

[51] Statistics Sweden EN31SM
[52] Cooper and Gustafsson, 2004.
[53] Kindbom and Persson. 1999

In submission 2012, the allocation of gasoline and diesel oil for all years to road traffic and diesel oil to fisheries and domestic navigation was affected by a revision of the methodology to estimate emissions from off-road vehicles and working machinery.

4.3.14 Other transportation, NFR 1A3e ii

Emissions reported under NFR 1A3e ii refer to off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions is revised in submission 2012 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

Emissions from off-road vehicles and other machinery are also reported under NFR 1A2f, 1A4b and 1A4c, in line with IPCC Guidelines, see Table 4.12.

Table 4.12. Distribution of emissions from off-road vehicles and other machinery

Category	NFR	Definition IPCC Guidelines
Industry	1A2f	The remaining emissions from fuel combustion in industry. This also includes emissions from the construction branch.
Other	1A3e ii	Combustion emissions from all remaining transport activities including ground activities in airports and harbours, and off-road activities not otherwise reported under 1A4c or 1A2f. Including emissions from the public sector.
Residential	1A4b	All emissions from fuel combustion in households. Including emissions from the use of snow mobiles.
Agriculture	1A4c	Emissions from fuel combustion in agriculture and forestry. Highway agricultural transportation is excluded.
Forestry	1A4c	

The size distribution of particles as TSP, PM_{10} and $PM_{2.5}$ was made according to the relations given in the CEPMEIP study[54] Emissions of particles for the 1980's have not been estimated due to lack of sufficient information.

4.3.15 Commercial/institutional, NFR 1A4a

Mobile combustion in this sector is reported included in NFR 1A4b, as it is currently not possible to separate mobile combustion in these two sectors from one another.

For stationary combustion within NFR 1A4a, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1. The main data source for activity data is the yearly energy balances that is further described in Annex 2.

[54] CEPMEIP project TNO, 2001

4.3.15.1 VERIFICATION OF ESTIMATION MODELS AND ALLOCATION METHODS FOR FUEL IN THE OTHER SECTORS

In submission 2005 and earlier, there were large uncertainties in estimation models and allocation methods for fuel in the Other sectors and NFR 1A2f, construction. In 2005, a study was performed by SMED, aiming at identifying and analyzing the methods and models applied for each sub-sector and determine whether they were in line with the IPCC guideline recommendations.[55] In addition, each fuel was traced back to its original source in order to determine whether it had been correctly allocated on stationary and mobile combustion.

The results from the study show good agreement with IPCC guideline recommendations. All fuels but biomass had little or no changes in methodologies, and where changes occurred, no significant inconsistencies in fuel consumption time series were detected. However, for biomass, several significant inconsistencies were identified leading to recalculations of activity data and emissions in NFR 1A4a and 1A4b[56]. Due to these recalculations there are obvious inconsistencies between the national energy balances and the national emission inventory data. Furthermore, all fuels proved to be correctly allocated on stationary and mobile combustion. In the Swedish air emission inventory, this means that all diesel oil and gasoline reported under Other sectors in the energy balances are used by mobile combustion, while all the other fuels are related to stationary combustion.

4.3.15.2 ACTIVITY DATA FOR STATIONARY COMBUSTION IN OTHER SECTORS

In 2008 all available methods to estimate emissions from stationary combustion in Other sectors were overhauled in a SMED study[57]. The main problem is still that the timeline for the inventory is too short for using final data for Other sectors and construction for the latest year. All available alternatives have specific problems including higher uncertainties etc discussed in the study. The method that was considered to give the best data was using annual statistics for all years available, and for the latest year to make a model estimate of fuel combustion that adjusts the amounts from the year before with the trend in the preliminary quarterly fuel statistics, as exemplified for 2007 in Equation 4-3 below:

Equation 4-3:

Estimate 2007 = Annual statistics 2006* preliminary quarterly fuel statistics 2007/ quarterly fuel statistics 2006

As a consequence, emissions from stationary combustion 2002-2006 were revised in submission 2009. Since emissions for the most recent year are based on this model estimate, the uncertainties are a bit higher for this year. Emissions for the most recent year will be revised in the next submission when annual statistics are available.

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[55] Gustafsson, et al. 2005.
[56] Paulrud et al. 2005.
[57] Lidén and Gerner, 2008

Since 2002, and in particular since 2004, the consumption of biomass fuels has increased in this sector. This is partly explained by the general shift from liquid to biomass fuels in recent years. However, a data check performed in 2009 showed that the data for biomass use in the commercial/institutional sector in the energy balances might not be complete. Further investigations were planned to submission 2011, but this issue was not prioritised.

Every year, there are revisions in the annual energy balances for years t-2 and t-3, that is, data published in 2010 contain revisions in fuel consumption in 2007 and 2008. These sometimes large revisions in the annual energy balances lead to large revisions of GHG inventory data as well as for air pollutants, and the estimation model yielded poor estimates for 2008 in submission 2010, particularly for heating oils. Unfortunately no other data sources were available in time to improve these estimates. In submission 2012, activity data and hence also emissions have been revised for 2008 and 2009.

In submission 2010 it was noted that the consumption of biomass, liquid fuels and gaseous fuels within this sector was higher in 2007 than in 2006 and 2008. In submission 2011, the activity data for 2007 and 2008 were revised as described above. The fuel consumption in 2007 is still relatively high. The input data to the energy balances for this sector has not been available for analysis. However, the activity data uncertainty is high in this sector and the time series 1990-2010 shows that interannual variations in total fuel consumption can be high.

4.3.16 Residential, NFR 1A4b

In this sector both stationary and mobile combustion occur. Emissions from stationary combustion is reported in NFR 1A4b i. Mobile combustion in households and in the service sector is included in NFR 1A4b ii, as it is currently not possible to separate mobile combustion in these two sectors from one another. Emissions from mobile combustion refer to emissions from off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions was revised in submission 2012 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1. The main data source is the annual energy balances. One- and two-dwellings statistics, Holiday cottages statistics and Multi-dwellings statistics are used as complementary data sources to get more details on biomass combustion. Biomass fuel consumption for heating residences are surveyed on the three most common combustion technologies: boiler, stoves and open fire places. Since 1998 biomass activity data is separated on wood logs, pellets/briquettes and wood chips/saw dust. Historical biomass data has been estimated by inter- and extrapolation.

Estimation models and allocation methods for fuel in the Other sectors as discussed in section 4.3.15.1 and use of preliminary data for stationary combustion in Other sectors as discussed in section 4.3.15.2 also applies to NFR 1A4b. As a consequence, emissions from stationary combustion 2002-2006 were revised in submission 2009. Emissions for the most recent years will be revised in the next submission when annual statistics are available. In submission 2012, activity data for 2008 and 2009 has been revised.

4.3.17 Agriculture/Forestry/Fisheries, NFR 1A4c i

In this sector both stationary and mobile combustion occur.

For stationary combustion, all activity data is on national level by fuel type and estimated emissions are therefore considered to correspond to Tier 1.

For stationary combustion, activity data is based on models and results from a survey from 1985 repeated in 2007 (see Other statistics from Statistics Sweden in Annex 2).

Estimation models and allocation methods for fuel in the Other sectors as discussed in section 4.3.15.1, and use of preliminary data for stationary combustion in other sectors as discussed in section 4.3.15.2 also applies to NFR 1A4c. As a consequence, emissions from stationary combustion 2002-2006 were revised in submission 2009. Emissions for the most recent year will be revised in next submission when annual statistics are available. Note that as a consequence of this revision, emissions from biomass are inconsistent with a sharp increase to a higher level in 2003. There is no information available to improve data 2002 and earlier years. Emissions 1990 are considered to be of sufficient quality as the 1985 survey then was only five years old.

Emissions from off-road vehicles and other machinery including various mobile vehicles and machines as for example tractors, dumpers, lawn movers, snow mobiles, cranes, trimmers, forklifts and any other mobile machine that run on petroleum fuels. The methodology for estimating emissions was revised in submission 2012 and is considered to correspond to Tier 2. The methodology is quite complex and described in Annex 2.

Emissions from Fisheries, NFR 1A4c, were first reported in submission 2006. The estimated fuel consumption is based on a survey on energy consumption within the fishing industry by Statistics Sweden[58] together with data on the Swedish fishing fleet’s total installed effect in kW from the Swedish Board of Fisheries. The estimate on fuel consumption provided by Statistics Sweden refer to 2005, and for the previous and following years the fuel consumption is estimated by adjusting the 2005 value according to the development in total installed effect.

The emissions factors used to estimate emissions from Fisheries are based on a SMED study from 2005[59], producing emission factors for CO_2, SO_2, NO_x, NMVOC, CH_4 and N_2O for 1990-2004. From 2005 estimates are based on the same consumption estimate and emission factors as for 2004.

Emissions from fisheries are derived under the assumption that the fishing fleet operates using medium speed diesel engines running on marine distillate fuel.

58 Statistics Sweden, 2006 ENFT0601.
59 Cooper et al., 2005a.

The emission abatement technologies used by the fleet (e.g. Selective Catalytic Reduction (SCR) for NO_X reduction) is assumed to be negligible.

4.3.18 Other stationary combustion, NFR 1A5a

In submission 2012, no emissions are allocated to this category. Minor consumption of natural gas that was previously reported in this category has been reallocated to NFR 1A1a, and energy losses within the iron and steel industry previously reported in this category are accounted for in the related categories (mainly in the industrial processes sector, NFR 2C1).

4.3.19 Military transport, NFR 1A5b

Emissions from military transport are based on data on fuel consumption including all military activities and are considered to correspond to Tier 1. Fuel consumption from some more administrative military activities, such as the Swedish Defence Material Administration (FMV), the Swedish Fortification Department (FORTV), the Swedish Defence Research Agency (FOI) and the National Defence Radio Institute (FRA), are not included in the calculations.

Emissions from military aviation are based on an average of LTO and cruise emission factors. Emissions from military navigation are estimated using emission factors from civil navigation. Emissions from the use of diesel oil by military stationed abroad is reported under Multilateral operations, NFR 1C2.

Military road transport is included in the road traffic emissions estimated by the road emission model HBEFA 3.1. To subtract and separate emissions from military transport from emissions from civil road transport, emissions according to the HBEFA model for each vehicle type are reduced by an amount equal to the weight of the fuel consumption reported by the Swedish Armed Forces relative to the fuel consumption from national statistics allocated to civil road transport, according to Equation 4-4:

Equation 4-4: $A = B - \sum((C-D)/C*E_i)$

A = Military transport emissions
B = Total HBEFA emissions
C = Total fuel consumption National Statistics
D = Military fuel consumption Swedish Armed Forces
E_i = HBEFA emissions per vehicle type

Please note that for 1980-1989, only emissions of particles from jet gasoline in military aviation is reported due to the lack of sufficient information for the other sub-sectors. Also note that emissions from FAME were only calculated for 1999-2002, since the military estimated their use of FAME for those years only.

4.3.20 Fugitive emissions from fuels, NFR 1B

4.3.20.1 SOLID FUELS, NFR 1B1

There are no coal mines in Sweden and hence no fugitive emissions from coal mines occur.

SO_2 and PAH-4 emissions from quenching and extinction at coke ovens are reported in NFR 1B1b.

Flaring of coke oven gas is reported in NFR 1B1c. The emissions from flaring are calculated with Tier 2, i.e. with activity data directly from the plants, in the same way as for emissions from stationary combustion. It should however be noted that uncertainties are still high, since the amount of flared gas are not measured as carefully as combusted gas (this statement is true for any plant).Table 1B1 is not really designed to include flaring, but since NFR 1B2 only refers to liquid and gaseous fuels, it is not possible to report flaring from coke oven gas, blast furnace gas and steel converter gas in NFR Table 1B2.

Particulate emissions from handling of solid fuels have been calculated for all years since 1980 and are allocated to NFR 1B1c.

Due to problems with data files on energy consumption in energy industries and manufacturing industries for 1980-1989, it has not been possible to recalculate emissions as has been done for different sectors for 1990 and onwards. Hence, time series for the eighties are not directly comparable with later years for NFR 1B1b and 1B1c.

4.3.20.1.1 Production of coke, NFR 1B1b

SO_2 and PAH-4 emissions from quenching and extinction at coke ovens have been calculated for the time period 1987-2010. Estimated emissions of PAH-4 from coke production are based on activity data in combination with emission factors for extinction and quenching from US EPA (United States Environmental Protection Agency, EPA-454/R-98-014). Activity data, produced amount of coke, has been acquired from official statistics (1987 - 2000) and from the annual environmental reports for the two facilities producing coke (2001 and onwards). The same emission factors have been used for the whole time series. For the time period before 1987 no reliable activity data are available.

Fugitive emissions of particles from handling of coke have not been included since these emissions are included in the reporting of particle emissions from the industrial facilities that produce or use coke in the process. Separate calculations based on statistics on coke and petroleum coke, using emission factors for handling of coal from CEPMEIP results in a rough estimate of 300 tons TSP/year.

4.3.20.1.2 Other, NFR 1B1c

Particle emissions arising from handling of solid fuels have been calculated from 1980 and onwards. Activity data include import and export of peat and also import of coal (pit and brown). Data is available from 1980 and onwards. Emission factors used for handling of coal and peat are those suggested for handling of coal from the CEPMEIP-project[60]. The TSP emission factor is 0.15 kg/ton where PM_{10} constitutes 40 % and $PM_{2.5}$ 4% of the total particulate emissions. The same emission factors have been used for the entire time series.

No production of coal occurs in Sweden but peat production does occur and from submission 2011 particulate emissions from production of milled peat is included in the estimates of particle emissions.

Activity data (as m^3 produced peat) is available from official statistics from 1980 and onwards and is divided in peat used for energy purposes and peat used for agricultural purposes. Furthermore there are different methods for peat production. Most particle emissions arise from the production of milled peat.

Production data from official statistics divide peat used for energy purposes in milled peat and other types of peat. However, this split is not used when reporting production data for peat used for agriculture purposes. Milled peat is mostly used for energy purposes, but some may also be used for agricultural purposes, hence the production data for milled peat may be underestimated.

The TSP emission factors used for milled peat production are from Nuutinen *et. al.* (2007)[61] and the share of PM_{10} and $PM_{2.5}$ are from Tissari *et. al.* (2006)[62]. There are different methods that can be used when harvesting milled peat and the size of the particle emissions depends on which method is used. Since no information is available about the share between the different methods in Sweden an average emission factor is used, Table 4.13.

Table 4.13. Particle emission factors for milled peat production.

Harvesting method	Particle emission factors (g/m^3) for peat production		
	TSP	PM10	PM2.5
HAKU method	0.09	0.042	0.030
Mechanical collector	0.14	0.066	0.046
Pneumatic collector	0.12	0.056	0.039
Average	**0.12**	**0.055**	**0.039**

4.3.20.2 OIL AND NATURAL GAS, NFR 1B2

4.3.20.2.1 Hydrogen production plants at refineries, NFR 1B2A i

According to the 2006 IPCC Guidelines, emissions from hydrogen production plants should be reported in this sector. The first such facility in Sweden was taken into operation in 2005, and in this facility, butane is used as raw material. Since

[60] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

[61] Nuutinen, J., Yli-Pirilä, P., Hytönen, K., Kärtevä, J., 2007, Turvetuotannon poly- ja melupäästöt sekä vaikutukset lähialueen ilmanlaatuun, Symo

[62] Tissari, J. M., Yli-Tuomi, T., Raunemaa, T. M., Tiitta, P. T., Nuutinen J. P., Willman, P. K., Lehtinen, K. E. J., Jokiniemi, J. K., 2006, Fine particle emissions from milled peat production, Boreal Environmental research 11:283-293, Helsinki 30 August 2006

2006, a second facility is operative, and that one presently uses naphtha as raw material. Emissions from these facilities are reported in NFR 1.B.2.A.i in accordance with 2006 IPCC Guidelines.
The Tier 2 method is used. Activity data as consumed amounts of butane and naphtha are taken from the EU ETS system. The emissions are calculated using plant specific activity data and thermal values. For butane, national emission factors are used. For naphtha, national emission factors for “other petroleum fuels” are used. The butane-fuelled facility accounts for the larger part of the emissions.

4.3.20.2.2 Refineries, NFR 1B2a iv

Sweden estimates emissions by using the Tier 2 method.

The Tier 2 method requires data at plant level and Sweden uses data provided by the refineries in their annual environmental reports. Emissions are reported from catalytic cracking (CO, SO_2, NO_X, particulates), desulphurisation (SO_2) and from the storage and handling of oil (NMVOC). Catalytic cracking occurs at one plant in Sweden. CO emissions from catalytic cracking are calculated as:

$$CO = \left(\frac{\text{Batched amount of raw material in the cracker}}{\text{Total batched amount of raw material in the plant}} \right) \times \text{Total CO emission for the plant}$$

Due to some problems at the plant the total emissions of CO were high for 1997 and 1998 compared to the other years.

The emissions of SO_2 from desulphurisation increased in year 2006 compared to previous years due to operational disturbances at one facility.

Particle emissions from catalytic cracking have only been estimated since 1990 due to lack of data for earlier years. The emissions from cracking have been compiled from information from the company. The particle size distributions have been estimated with expert judgement. The assumed size distribution is 95% for PM_{10} and 85% for $PM_{2.5}$ of estimated TSP for the whole time-series.

Fugitive emissions of NMVOC from refineries include emissions from the process area as well as emissions from the refinery harbours when loading tankers. The estimates are mainly based on reported data from the facilities' environmental reports and older reports from the Swedish EPA[63],[64],[65],[66] and Statistics Sweden[67]. The activity data, as throughput of crude oil, is known for almost all years. Implied emission factors have been developed, based on reported emissions and known activity data. Reported data for years for which either activity data or emission data is missing have been calculated using the implied emission factors thus developed. In Table 4.14, the reported emissions as well as activity data can be seen.

[63] Swedish EPA, 1990.
[64] Swedish EPA, 1994a.
[65] Swedish EPA, 1994b.
[66] Swedish EPA. 1995.
[67] Statistics Sweden. 1996 Emissions to air in Sweden of volatile organic compounds (VOC) 1988 and 1994.

Table 4.14. Throughput of crude oil at oil refineries and estimated fugitive emissions of NMVOC (Mg) 1988-2010 in NFR 1B2a iv.

Year	Throughput of crude oil Mg	Total emissions of NMVOC Mg
1988	15 600 000	16 318
1989	16 440 000	16 850
1990	17 330 000	14 408
1991	16 810 000	12 900
1992	17 870 000	10 961
1993	18 723 684	10 311
1994	18 192 000	8 933
1995	19 430 000	7 643
1996	20 305 000	9 661
1997	20 130 000	9 749
1998	20 254 000	9 507
1999	19 483 034	10 350
2000	20 253 120	11 568
2001	19 592 852	9 795
2002	19 681 182	10 195
2003	19 661 646	11 602
2004	20 611 941	8 957
2005	19 919 968	7 691
2006	20 050 576	8 269
2007	17 706 518	8 877
2008	20 420 061	8 575
2009	19 669 472	8 779
2010	20 278 888	8 924

4.3.20.2.3 Gasoline handling and distribution, NFR 1B2A v

The calculation of the NMVOC time series for fugitive emissions from gasoline distribution, 1988-2010, is based on methods given by Concawe[68], including annual national gasoline consumption and assumptions on the share of gasoline evaporated at different stages of the handling procedure, as well as effects of applied abatement technology at gasoline stations[69]. The basic assumptions are presented in Table 4.15.

Table 4.15. Assumptions for calculating fugitive emissions from the handling and distribution of gasoline.

Parameter	Assumption	
Density of gasoline	730 kg/m^3 1988 - 1996 750 kg/m^3 1997 -	
Distribution of gasoline to gas stations	0.16 %	of distributed volume
Spill	0.01 %	of distributed volume
Filling of car tanks	0.18 %	of filled volume
Measures at distribution to gas station	90 %	Efficiency of measures
Measures at filling cars	70 %	Efficiency of measures

[68] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.
[69] Andersson, 2000.

The measures at distribution and filling were introduced over a period of time from 1991-1994, to the extent presented in Table 4.16. The amount of gasoline sold at large and small gas stations, respectively, was assumed to be 50/50 for the years 1988-1994. Data on the distributed amounts of gasoline is taken from the HBEFA model, Table 4.17. The HBEFA model is based on a bottom-up approach considered to be Tier 2.

Table 4.16. Fraction of gasoline stations with technical measures installed

Year	Large gas stations >2000 m^3	Small gas stations
1988 – 1990	0%	0%
1991	50%	0%
1992	75%	25%
1993	100%	75%
1994 -	100%	100%

Calculated fugitive emissions of NMVOC from the storage of oil products have been obtained from SPI[70]. The calculations are based on the amount of gasoline handled in the depots. The calculations cover the years 1990 and onwards and are based on methods given by Concawe 85/54[71] for the years 1990-2006 and on Concawe 03/07[72] for the years 2007 and onwards. More than 30 depots have been considered during later years. Gas recovery systems and the recovered amount of gas have been considered in the calculations. For five depots the reported NMVOC emissions are based on emission measurements in the depot areas and not on calculations based on the amount gasoline handled in the depots. The reporting of measured emissions instead of calculated emissions are based on recommendations from SPI[73]. For some years, for which no data was provided, data were interpolated. Handled amount of gasoline and fugitive emissions of NMVOC from depots for 1990 and onwards are presented in Table 4.17.

[70] Per Brännström, 2009-, personal communication; Leif Ljung -2009, personal communications
[71] Concawe, 1986, Hydrocarbon emissions from gasoline storage and distribution systems, Report No 85/54.
[72] Concawe Report No. 3/07, Air pollutant emission estimation methods for E-PRTR reporting by refineries
[73] Per Brännström, 2010, personal communication

Table 4.17. Handled and distributed amount of gasoline and estimated fugitive emissions of NMVOC (Gg) from storage at depots and at gasoline stations, 1988-2010.

Year	Volume of gasoline m^3	Fugitive emissions of NMVOC at depots Gg	Fugitive emissions of NMVOC at gasoline stations Gg
1988	5 151 784	6.70	13.16
1989	5 402 877	4.59	13.80
1990	5 189 807	2.48	13.26
1991	5 256 027	2.22	10.84
1992	5 290 374	2.15	8.30
1993	5 139 186	2.08	4.27
1994	5 218 913	2.01	3.05
1995	5 239 592	1.93	3.06
1996	5 227 011	1.86	3.05
1997	5 173 195	1.91	3.10
1998	5 140 906	1.97	3.08
1999	5 147 524	2.02	3.09
2000	5 116 795	2.07	3.07
2001	5 128 792	2.13	3.08
2002	5 217 271	2.18	3.13
2003	5 225 288	2.23	3.14
2004	5 244 608	2.24	3.15
2005	5 116 408	2.31	3.07
2006	5 089 367	2.47	3.05
2007	5 038 847	2.35	3.02
2008	4 980 296	2.53	2.99
2009	4 793 299	2.41	2.88
2010	4 602 776	2.21	2.76

4.3.20.2.4 Transfer losses of gas works gas, NFR 1B2a v

Losses of gas works gas are reported from the producers of gas works gas to Statistics Sweden and published in Statistics on the delivery of gas products. Emissions are calculated with emission factors for stationary combustion.

4.3.20.2.5 Flaring, NFR 1B2C ii

Flaring of liquid fuels was estimated and reported for the first time in the Swedish inventory in Submission 2005. Data includes flaring of refinery gases at the refineries and one chemical industry, and flaring of LPG at three iron and steel plants and one pulp industrial plant. Data has been collected directly from the plant operators. For 2007 and onwards, activity data is mainly taken from the EU ETS system. Plant specific thermal values are used when available.

4.3.21 Fuel bunkers, NFR 1A3ai and 1A3d i

Emissions from international bunkers for aviation and navigation are not included in the national total but instead reported separately as a memo item in NFR 1A3ai and 1A3di respectively, in accordance with the IPCC Guidelines.

4.3.21.1 INTERNATIONAL AVIATION, NFR 1A3A I

International bunkers from aviation are fuels purchased in Sweden and used for flights to non-Swedish destinations. This includes the whole flight cycle, i.e. both LTO and Cruise, see also section 4.3.10.

4.3.21.2 INTERNATIONAL NAVIGATION, NFR 1A3D I

International bunkers from navigation are defined as fuels bought in Sweden, by Swedish or foreign-registered ships, and used for transport to non-Swedish destinations. The division on international and domestic fuels is based on information from the monthly survey on supply and delivery of petroleum products. Sweden has not yet had the possibility to verify how well this data corresponds to how international and domestic marine transport is defined in the IPCC Good Practice Guidance.

Emission from multilateral operations are not included in the national total but instead reported separately as a memo item in NFR 1A3d i. These emissions are derived from fuel purchased in Sweden and used abroad by Swedish forces participating in UN related operations. These emissions account for very small amounts.

4.4 Uncertainties and time-series consistency

4.4.1 Uncertainty analysis

For the energy sector, the largest uncertainties come from activity data for the 1980's and from emission factors.

The distribution of marine distillate fuels and residual fuel oils over domestic and international navigation (bunkers) entail additional uncertainties. The current distribution is provided by the respondents of the survey on supply and delivery of petroleum products, but these are suspected to lack full information on the end-use of all the fuels they provide. Hence, the distribution between domestic and international use might vary considerably for some years. As a result fuel consumption by national and international navigation has been looked into in a SMED study[74]. Fuel data in the Monthly fuel, gas and inventory statistics, which is used as activity data for estimating emissions from national navigation and international maritime bunkers, has been analyzed. The fuel data is collected from oil companies and other fuel providers who have stocks of petroleum products and coal. The survey also collects stock data from companies with a large consumption of oil in the manufacturing industries and energy industries.

[74] Eklund et al. 2011. Emissions from navigation and fishing including international bunkers

Data on domestic and international bunker fuel in the Monthly fuel, gas and inventory statistics has been found to be of good quality. As a consequence of that VAT is applied on national fuel consumption, but not on international bunkers, all respondents to the survey are able to separate these fuel amounts with high accuracy. Fuels used for domestic and international navigation have been separated correctly and in line with IPCC Guidelines.

The fuel consumption in 2010 for national navigation has increased noticeably since 2009. The data has been verified and is correct according to reported amounts of fuel deliveries. Note that the amount of fuel used by national navigation is relatively small compared to the total amount of fuel for navigation, including international navigation (bunkers).

4.4.2 Time series consistency

Due to problems with data files on energy consumption in energy industries and manufacturing industries 1980-1989, it has not been possible to recalculate emissions as has been done for different sectors 1990 and later years (described below). Because of this, time series 1980-89 and 1990-2010 are not directly comparable. The differences are largest for NFR 1A1b, 1A1c, 1A2a, 1A2c, 1B1b and 1B1c.

No recalculations have been performed for emissions in the mobile sector for the eighties, and thus there are inconsistencies in time series between the eighties and later years.

4.5 Source specific QA/QC and verification

4.5.1 Quality Assurance

Experts at the Swedish EPA conduct a review of the inventory estimates, methodologies and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

4.5.2 Quality control

All quality procedures according to the Swedish QA/QC plan (including the Manual for SMED’s Quality System in the Air Emission Inventories) have been implemented during the work with this submission.
All Tier 1 general inventory level QC procedures and all QC procedures listed in GPG section 8.1.7.4 applicable to this sector are used. The activity data has, of course, been subject to QA/QC procedures prior to the publishing of quarterly fuel statistics. In addition, the consumption of every type of fuel in the last year is checked and compared with previous years. If large variations are discovered for certain fuels, the consumption of these fuels is studied on facility level and if necessary, the staff responsible for the quarterly fuel survey is contacted for explanations. IEFs for all reported substances are calculated per fuel, substance and NFR-code and checked against the emission factors to make sure that no calculation errors have occurred when emissions were computed.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable. Data has, when possible, been compared with information from companies' legal environmental reports and/or other independent sources. Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

4.5.3 Verification

As part of the inventory procedure for submission 2007, a separate study[75] was performed to verify the quality of all fossil fuel combustion-related activity data from the largest plants (in terms of CO_2-emissions) in Sweden in 2005. The verification consisted of a comparison of plant-specific SMED-data (energy statistics from the quarterly fuel statistics) with data from the EU Emission Trading System (ETS). The results showed that for 21 plants, accounting for about 50 % of the fossil fuel consumption of the 63 plants included in the study, no significant differences between the two data sources were identified. For a number of plants, large differences occurred between the two data sources. In 2007, 19 of these plants were further surveyed in another study[76]. Again, energy statistics (the quarterly fuel statistics) and ETS data by plant were compared and analyzed.

The results show that the reported fuel amounts differ slightly between the data sets and since ETS data are verified, they are likely to be more correct. Another deficiency in the quarterly fuel statistics is that unconventional fuels are often grouped and the emission factors of these fuels are associated with very large uncertainties, since they are not specific for the current fuel and plant. Finally, another problem is that some of those unconventional fuels are incorrectly classified. According to data reported to ETS, some of these fuels are often partly biogenic and should hence be classified as "Other biomass".

The improvements in methodology and allocation of emissions from the integrated iron and steel industry in submission 2010 were made based on a study[77] carried out in 2008 looking at emissions from several industrial plants, including the two largest iron and steel plants in Sweden, where inventory data from submission 2008 was compared with data from environmental reports. In 2010, activity data and emission factors for the chemical industry and the most important metal foundries were verified against data from environmental reports in a similar study.[78]

4.6 Source specific recalculations

In this section explanations and justifications for recalculations in the Energy sector are made. In general, recalculations made in submission 2012 have small impacts on reported emission levels. Significant implications are described below.

[75] Backman & Gustafsson, 2006
[76] Nyström, 2007
[77] Skårman, T., Danielsson, H., Kindbom, K., Jernström, M., Nyström, A-K. 2008.
[78] Gustafsson, T., Nyström, A-K., Gerner, A., 2010

NFR 1A1a:

- Minor emissions from natural gas combustion have been reallocated from NFR 1A5a, and thus emissions of e.g. NO_x and NMVOC are slightly higher compared to submission 2011. This applies to the years 1991-98, 2000-2001 and 2006.

NFR 1A2f, 1A4a-c:

- Activity data for liquid, gaseous and biomass fuels at small industries and in the other sector have been revised for 2008 and 2009. The reason is that data for these industries are not ready in time for the GHG inventory, and thus preliminary data is estimated by a model. Hence, in every new submission, the activity data for the second latest year is revised.
- The methodology for estimating emissions from off-road vehicles and working machinery was revised in submission 2012. The revision did not imply an updated methodology but aimed to simplify the use of the model and at the same time update some emission factors, activity data and the allocation of emissions to different sectors. Allocation of emissions from off-road vehicles and working machinery is based on a report by Flodström (et al)[79]. This is the most recent inventory including an allocation of working machinery to sectors carried out in Sweden.

NFR 1A3a ii (i-ii):

- Incorrect activity and emission data was used in submission 2011. This was due to the problem with exclusion of private aviation as well as educational training flights and military in the calculations of fuel consumption and emissions executed by SCAA (Swedish Transport Agency). The data has been corrected and adjusted to correspond to national fuel consumption.

NFR 1A3b (and sub-categories):

- The change of the road vehicle emission model from ARTEMIS to HBEFA 3.1 model have resulted in revised estimates of SO_2, NO_X, NMVOC, CO, NH_3, dioxin, PAHs, particles and metals for 1990-2009.

NFR 1A3d:

- The total amount of delivered diesel (excluding FAME) for mobile combustion is first allocated to those subsectors for which accurate and precise information on diesel consumption is available, whereof one is “off-road vehicles and working machinery”. The remaining amount of the total delivered diesel is allocated to subsectors where the estimated diesel consumption is more uncertain. These subsectors are fisheries, domestic navigation, and civil road traffic. As the model for estimating emissions from

[79] Flodström et al 2004. Uppdatering av utsläpp till luft från arbetsfordon och arbetsredskap för Sveriges internatonella rapportering.

off-road vehicles and working machinery has been updated for all years (1990-2009), this will consequently also affect the emissions from national navigation.

NFR 1B2a v:

- Due to the switch of the national road emission model, from ARTEMIS to HBEFA3.1, the reported fugitive emissions of NMVOC from gasoline stations have been updated for the period 1990 – 2009.

NFR 1B2a v:

- NMVOC emissions from storage of oil products have been revised for 2006 due to an error in the reported data in previous submissions.

4.7 Planned improvements

All relevant data are kept under constant review. For future submissions a number of actions are planned in order to, where appropriate, improve the quality of the inventory for the Energy sector.

5 Industrial processes (NFR sector 2)

5.1 Overview

For Sweden the most important industries within the industrial sector has historically been base industries such as mining, iron and steel industry and pulp and paper industry. Other important industries when considering emissions from industrial processes include the cement industry, primary aluminium production and some processes in the chemical industry.

Generally three sources of information concerning activity and emission data for the industrial process sector have been used:

- Emission data as reported annually by facilities in legally required environmental reports to the authorities.
- National production statistics or similar information at national level.
- Plant specific data collected by direct contacts with facilities

Under Swedish environmental laws, operators performing environmentally hazardous activities that require a permit by law are obliged to compile and submit an annual environmental report to their supervisory authority. The environmental report consists of three parts:

- Basic identification information about the facility.
- Text section (for example, a description of the facility and the processes, the use of energy, chemicals and raw materials, emissions and conditions in the permit).
- Emission declaration (for example, production data, fuel consumption data, emission data and, in some cases, information on how emission data has been determined).

The data in the environmental reports often originate from measurements or mass balances. The use of default emission factors is limited. Only operators that exceed the thresholds for the sub-stances, listed in the Swedish environmental law concerning environmental reports[80], are obliged to compile the emission declaration.

The County Administrative Boards audit the data presented in the operators' environmental reports. Since the beginning of year 2007 environmental reports can be submitted electronically via the Swedish Portal for Environmental Reporting (SMP)[81]. This database includes not only emissions, but also basic information about the facilities, such as their activity code (national code system, adjustment of NACE four digits), IPPC code and permit, location coordinates, etc. The procedure for updating the database is not regulated by legislation, which results in some incompleteness and inconsistencies in the database.

The use of emission factors in the Swedish inventory for NFR sector 2 is limited and, when used, they are nationally derived or specific for a facility. In cases

[80] Swedish EPA, NFS 2000:13, Naturvårdsverkets föreskrifter om miljörapport för tillståndspliktiga miljöfarliga verksamheter.
[81] Svenska Miljörapporteringsportalen. https://smp2.naturvardsverket.se/

with a large number of companies within a specific sector, and when all environmental reports are not available, a combination of information from environmental reports and production statistics on the national level, are used to estimate the sector's emissions on a national scale.

Emissions of metals have not been reported for the period 1980 - 1989 due to lack of reliable data for some important sources.

Sweden's emission inventory is in accordance with EMEP/ EEA Air Pollutant Emission Inventory Guidebook [82], the Revised 1996 IPCC Guidelines[83], and the Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution[84].

5.2 Mineral products, NFR 2A

5.2.1 Source category description, NFR 2A

Reported emissions include estimates for cement production (NFR 2A1), lime production (NFR 2A2), limestone and dolomite use (NFR 2A3), asphalt roofing (NFR 2A5), road paving with asphalt (NFR 2A6), and other (NFR 2A7). In the source category other (NFR 2A7), non-iron ore dressing plants, glass and mineral wool production, glass production, battery manufacturing and emissions from construction work are included.

5.2.1.1 CEMENT PRODUCTION, NFR 2A1

Cement production occurs at three facilities in Sweden, with one being dominant. Emission data is taken from environmental reports and by direct contacts with the facilities. Calculation methods have been discussed with industry.

5.2.1.2 LIME PRODUCTION, NFR 2A2

In Sweden, conventional lime is produced at a number of facilities, owned by two companies. There are facilities that produce lime for their own processes. This produced lime is, for instance, used in blast furnaces, in sugar and carbide production and in the pulp and paper industry to bind impurities and purify the produced material.

5.2.1.3 LIMESTONE AND DOLOMITE USE, NFR 2A3

Limestone and dolomite are used in various processes, such as glass production, mineral wool production and iron sinter production (further described below in

[82] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

[83] IPCC (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

[84] UNECE 2003, Guidelines for Estimating and Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution. Air Pollution Studies No. 15.

NFR 2A7). Limestone and dolomite are also used in the production of cement (NFR 2A1), lime (NFR 2A2), carbide (NFR 2B4) and glass (NFR 2A7 b).

5.2.1.4 ASPHALT ROOFING, NFR 2A5

Emissions to air linked to the asphalt roofing industry consist mainly of particles and non-methane volatile organic compounds (NMVOC), which are emitted from asphalt storing tanks and blowing stills, as well as from coater-mixer tanks and coaters. According to EMEP/EEA Air Pollutant Emission Inventory Guidebook [85] emissions of CO are also likely to occur. Since the end of the 1990's there have only been two companies in Sweden producing asphalt-saturated felt. Production and emission data provided by the manufacturers have been used for developing emission factors for estimations of the NMVOC emissions. No measurements or estimations on CO emissions have been performed by the industry and are consequently reported NE, not estimated, for the whole time-series.

5.2.1.5 ROAD PAVING WITH ASPHALT, NFR 2A6

Large changes have occurred in asphalt paving technology over the last decade, with a gradual change towards use of water-based emulsions instead of solvent-containing bitumen solutions. Industry representatives estimated that the naphtha content in the solutions used for road paving was on average 23 % in 2002 and 33 % in 2010. In this inventory, only NMVOC emitted in the process of paving the roads is included. Particle emissions have not been estimated due to lack of information.

5.2.1.6 OTHER, NFR 2A7

Specified sub-categories under this heading are "Glass production (2A7.1)", "Non-iron ore mining and dressing", "Glass and mineral wool production", "Battery manufacturing" and "Construction".

5.2.1.6.1 Glass production

In Sweden there is one facility for float glass production, one for container glass and several small facilities for manual glass production. From the float glass production, the total emissions of SO_2 and NO_X from the glass furnace are allocated to 2A7 since a separation in energy-related and process-related emissions is not possible. From the container glass production, SO_2 emissions originating from the raw material and small amounts of NMVOC are reported.

Emissions of particulate matter have been reported from the production of container and manual glass for the period 1990-2010, whereas particle emissions from float glass production are reported for the whole time period, 1980 – 2010. Heavy metals from glass production are reported 1990-2010.

All other emissions from the glass production facilities originate from combustion for energy purposes, and are allocated to the Energy sector (NFR 1).

[85] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

5.2.1.6.2 Non-Iron ore mining and dressing

The use of mining explosives causes emissions of mainly carbon monoxide, CO, and nitrogen oxides, NO_X[86]. The dominating source for emissions of particulate matter and heavy metals are the ore dressing plants. Data on emissions of NO_X, particulate matter and heavy metals are mainly collected from the companies' environmental reports to the authorities. No data concerning the CO emissions are available and the time series from 1990 and onwards is thus reported NE.

5.2.1.6.3 Glass and mineral wool

Glass and mineral wool have been produced at approximately 5-7 different facilities during the time period 1980-2010. Presently, glass and mineral wool production occurs at three facilities run by two companies.

5.2.1.6.4 Battery manufacturing

There is currently one battery producing facility in Sweden. This battery producer of NiCd-batteries previously used iso-propanol in their processes, which gave rise to emissions of NMVOC. The process was changed in 1998 and, since then, no NMVOC emissions occur from this source. Before 2000 another two battery producing facilities were included of which one was emitting NMVOC until 1991. Emissions of lead, cadmium and nickel are reported for the time period from 1990 and onwards.

5.2.1.6.5 Construction

Time series of emissions of particles from construction work has been compiled. The basis for the calculations is national data on construction activity. Emission factors from the CEPMEIP study were used[87].

5.2.2 Methodological issues, NFR 2A

5.2.2.1 CEMENT PRODUCTION, NFR 2A1

All three cement-producing facilities (owned by one company) are covered in the reported estimates and the time series are considered accurate and consistent. Emissions have been estimated based on direct information from the company or from the environmental reports to the authorities. Emissions of NO_x are allocated from the energy sector (NFR 1A2f) to industrial processes. The reason for this is that there is a lack of correct emission factors due to the fact that the companies use such a large variety of waste as fuel. The use of different waste as fuel varies within and between years.

[86] Wieland, 2004.
[87] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

As the larger proportion of emitted SO_2 originates from the sulphur containing raw material, SO_2 emissions are allocated to industrial processes, according to the IPCC Guidelines. Reported SO_2 emissions for 2009 have increased compared to the previous year. Emissions of TSP, PM_{10} and $PM_{2.5}$, also allocated to the industrial processes, have been estimated for the time period 1980 – 2009. The size distribution of the particles between PM_{10} and $PM_{2.5}$ has been done by expert judgement. Reported emissions of TSP, PM_{10} and $PM_{2.5}$ for 2009 have decreased compared to previous years.

Emissions of heavy metals, PAH-4 and dioxins were calculated based on energy statistics, since most of these substances originate from the fuels used. These emissions have been allocated to the energy sector (NFR 1).

5.2.2.2 LIME PRODUCTION, NFR 2A2

Emissions of SO_2 from the production of quick lime have been estimated from 1990 onwards using emission factors presented in environmental reports by one of the producers[88]. The emission factor provided by the lime producer is substantially higher for 2008 owards than for earlier years. This resulted in an increase of reported SO_2 emissions compared to earlier years. However, in 2009 the reported SO_2 emissions were on the same level as before 2008 due to less use of lime.

Emissions of particles have also been estimated and include particles from quarrying, crushing and grinding, and from the production of quick lime. Estimates were made for the period from 1980 onwards. Particle emissions from quick lime production were calculated using emission factors presented in environmental reports by one of the producers[88] and after expert judgement on the size fractions. For corresponding emissions concerning the production of other lime products, emission factors published by the CEPMEIP project[89] were used.

Previous reporting of activity data from lime production within the pulp and paper industry has led to comments and recommendations from the UNFCCC Expert Review Team (ERT). The comments concern the methodology used and Sweden has been recommended to improve the reporting of activity data. In order to improve the reporting of activity data, detailed data from the Swedish Lime Association and The Swedish Lime Industry[90] have been used since submission 2010.

Emissions of SO_2 from quick lime production intended for the pulp and paper industry are, as in earlier submissions, not included in the estimates reported in NFR 2A2 but are reported in NFR 2D2. Emissions originating from the production of quick lime for the iron and steel industry are from 2000 and henceforth included in NFR 2A2. Before 2000, these emissions are included in 2C1.

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[88] Nordkalk, http://www.nordkalk.com

[89] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

[90] Swedish Lime Association and The Swedish Lime Industry, Svenska Kalkföreningen, personal communication

5.2.2.3 LIMESTONE AND DOLOMITE USE, NFR 2A3

The emitted amount of particulate matter from limestone and dolomite use is included and reported in NFR-codes 2A1, 2A2, 2A7, 2B4 and is consequently reported IE under the code NFR 2A3.

5.2.2.4 ASPHALT ROOFING, NFR 2A5

Data on the total Swedish production of asphalt-saturated felt was provided by the producing companies. Emission factors for asphalt roofing manufacture are presented in EMEP/EEA Air Pollutant Emission Inventory Guidebook.[91] These are based on studies performed during the 1970s in the USA and presented by EPA.[92] As stated in the guidebook, the level of uncertainty regarding the suggested emission factors is high, and it is recommended that better factors should be developed and used. The notation key for activity data has been changed from NE to C.

After contact with the industry, emission factors based on measurements and calculations made by the manufacturers were developed before submission 2005 for estimating the NMVOC emissions from the Swedish production of asphalt-saturated felt[93] (Table 5.1).

[91] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

[92] Shrager, Brian and Marinshaw, Richard. 1994. Emission Factor Documentation for AP-42, Section 11.2, Asphalt Roofing, Final Report. For U.S. Environmental Protection Agency , Office for Air Quality Planning and Standards, Emission Inventory Branch. MRI Project No. 4601-01.

[93] Danielsson, 2004.

Table 5.1. Estimated emissions of NMVOC and particles from manufacturing of asphalt-saturated felt (NFR 2A5) in Sweden 1988 – 2009.

Year	Emission of NMVOC from asphalt roofing 1988 – 2007, NFR 2A5 Mg	Emission of particles from asphalt roofing 1988 – 2007, NFR 2A5 Mg		
		TSP	PM_{10}	$PM_{2.5}$
1988	81.5*	0.285*	0.257*	0.242*
1989	81.5*	0.285*	0.257*	0.242*
1990	77.7	0.279	0.251	0.237
1991	80.2	0.283	0.255	0.240
1992	79.8	0.282	0.254	0.240
1993	89.5	0.297	0.267	0.253
1994	97.4	0.309	0.278	0.263
1995	98.6	0.311	0.280	0.265
1996	92.4	0.302	0.271	0.256
1997	99.6	0.305	0.275	0.260
1998	99.1	0.304	0.274	0.258
1999	98.4	0.302	0.272	0.257
2000	111.1	0.341	0.307	0.289
2001	112.9	0.351	0.316	0.299
2002	109.2	0.347	0.313	0.295
2003	101.1	0.337	0.304	0.287
2004	113.7	0.356	0.321	0.303
2005	139.7	0.371	0.334	0.315
2006	132.7	0.350	0.315	0.297
2007	142.4	0.357	0.321	0.303
2008	138.6	0.350	0.315	0.298
2009	103.1	0.296	0.266	0.252
2010	105.4	0.138	0.124	0.117

* Emissions based on estimated production

The NMVOC emissions from the production of asphalt-saturated felt originates from the felt saturation and coating processes and from leakage from the asphalt storage tanks, of which the latter is the dominating source. For the calculation of the NMVOC emissions separate emission factors, 0.068 kg/Mg and 1.56 kg/Mg, respectively, were used. The emission factors are based on measurements/estimations from 2003 and 1997. The factor used for estimating the TSP emission includes particles emitted from the mineral surfacing process as well as from storage and handling of the mineral products (0.005 kg/Mg), and are based on data from 1997. No measurements or estimations on CO emissions have been performed by the industry. The CO emissions originating from the production of asphalt-saturated felt in Sweden are most likely small. Using the emission factor given in EMEP/EEA Air Pollutant Emission Inventory Guidebook [94], an estimated CO emission of around 0.5 Mg per year can be calculated.

[94] The EMEP/EEA Guidebook: http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook/emep

5.2.2.5 ROAD PAVING WITH ASPHALT, NFR 2A6

Estimates for the late 1980s and early 1990s are taken from investigations and inventories made in the early 1990s. Data for the years 2002 – 2010 has been calculated based on information from the asphalt producers on the average amount of solvent (naphtha) in the mixtures used for road paving. The producers have also provided figures on the total amount of road paving mixtures delivered in Sweden. It is assumed that all solvents in the solvent-based bitumen are emitted when used. In the calculations emissions from imported solvent-based bitumen are not included. The amount of imported solvent-based bitumen is most likely very small. Emissions of NMVOC reported for the years in mid- and late 1990s were interpolated (Table 5.2). Table 5.2 shows that the emissions of NMVOC in 2005 were much higher than adjacent years. This is due to that the production of solvent-based bitumen in 2005 was extremely high, since it was used to repair roads that had been damaged by a severe storm (“Gudrun”) that hit large areas of southern Sweden in early 2005.

Table 5.2. Emissions of NMVOC 1988–2009 from road paving with asphalt.

Year	NMVOC from road paving with asphalt Mg
1988	6 600
1989	6 400
1990	6 200
1991	5 900
1992	5 600
1993	5 000
1994	4 400
1995	3 800
1996	3 200
1997	2 600
1998	2 000
1999	1 600
2000	1 170
2001	1 080
2002	845
2003	603
2004	920
2005	1 230
2006	750
2007	935
2008	855
2009	341
2010	256

5.2.2.6 OTHER, NFR 2A7

Specified sub-categories under this heading are “Glass production (2A7.1)”, “Non-iron ore mining and dressing”, “Glass and mineral wool production”, “Battery manufacturing” and “Construction”.

5.2.2.6.1 Glass production

The emission data sources for glass production are mixed. Some data derives from reports from the Swedish EPA and some have been received from the companies environmental reports or from data bases containing data from the environmental reports. For earlier years in the time series emission data are from national reporting to HELCOM and from the Swedish EPA[95]. Data for missing years and parameters have been estimated or interpolated.

Manual glass production used to be an important source of lead emissions. In the early 1990's emissions of lead from the production of manual glass represented roughly 80% of the total reported lead emission from glass production. Ten years later, the manual glass production adds up to only around 10% of the lead emissions from glass production. This reduction is probably due to the reduced production of lead crystal glass.

5.2.2.6.2 Non-Iron ore mining and dressing

NO_X emissions originating from the use of mining explosives are only reported for the years 2002 - 2010 due to lack of data for earlier years. Emissions of particles are reported for the time period from 1980 and for metals from 1990.

5.2.2.6.3 Glass and mineral wool production

For glass and mineral wool production, the reported emission data on NMVOC consists of the sum of formaldehyde and phenol.

The data on particulate emissions from glass and mineral wool production provided for the 1990´s and 2000 - 2010 are primarily based on measurements whereas for earlier years, estimates made by the companies are based on known circumstances influencing emissions. Concerning the particle emissions, only the TSP emissions were provided by industry, and the fractions of TSP as PM_{10} and $PM_{2.5}$ were calculated from emission factors for production of glass fibres provided in the CEPMEIP study[89].

5.2.2.6.4 Battery manufacturing

The time series from 1990 - 2010 is based on emission data representing three individual facilities. From 2000 there is only one active facility. Between 1988 and 1991 reported NMVOC represents emissions from two facilities. From 1992 to 1998 only NMVOC from one facility is included. This battery manufacturer of NiCd-batteries used isopropanol in their processes, which gave rise to emissions of NMVOC. The process was changed in 1998 and, since then, no NMVOC emissions occur from this source. The heavy metal emissions from the battery manufac-

[95] Bjärborg, 1998.

ture nowadays originate from one facility producing nickel-cadmium batteries. For some years information on emissions is not available, and data has been interpolated.

5.2.2.6.5 Construction

The data chosen as a basis for the particle emission estimates from construction work are national statistics on building permits for housing and non-residential buildings (in m^2)[96], 1996 - 2010, and economic statistics on annual investments in construction-related activities[97], 1980 - 2002. As only information on economic investments used for construction work are available for the years 1980 - 1995 this information had to be transformed into a unit where emission factors can be used. For the calculations of the time series of emissions, the economic information was normalised to the 1995 level, and the costs per square meter was assumed to be constant through-out the time series. The investments in construction work in 2002 expressed in SEK and normalised to the 1995 level was used as the base year for the transformation of investment information into constructed square meters 1980 - 1995. The data is divided into four sub-groups; dwellings, industries, other buildings and construction. The latter three are considered to be utilities and are treated as a sum. Emission factors used for calculations of particulate matter from construction activities are all found in the CEPMEIP database[98].

5.2.3 Recalculations

NFR 2A7:

- Construction activities: Activity data for calculation of particle emissions from construction were updated for 2001, 2005 - 2009 due to revised data in the database at Statistics Sweden.

5.2.4 Coming improvements

A study on emissions from mining activities is planned. The aim is to improve the calculation methods used for estimating SO_2 and NO_X emissions from use of mining explosives and also to improve the estimates of particulate and metal emissions from mining activities.

5.3 Chemical industry, NFR 2B

5.3.1 Source category description NFR 2B

[96] Statistics Sweden. http://www.scb.se. Housing and construction, Statistics on building permits for housing and non-residential buildings
[97] The Swedish Construction Federation. http://www.bygg.org. Personal communication
[98] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

Sources covered in the Swedish inventory are nitric acid production (2B2), carbide production (2B4) and other (2B5), which include a large variety of processes in the chemical industry. Neither ammonia production (2B1) nor adipic acid production (2B3) occur in Sweden.

5.3.1.1 AMMONIA PRODUCTION, NFR 2B1

There is an annual production of about 5 Gg of ammonia in Sweden, according to UN statistics[99]. This ammonia is however not intentionally produced, but is a by-product in one chemical industry producing various chelates and chelating agents, such as EDTA, DTPA and NTA[100]. Emissions from this industry are included in NFR code 2B5. Ammonia production, 2B1, is thus reported as NO in the NFR-tables.

5.3.1.2 NITRIC ACID PRODUCTION, NFR 2B2

Production of nitric acid has taken place at three facilities in Sweden. One of these was shut down in the end of 2000, and a second one was shut down during 2001. Therefore, there is currently only one facility producing nitric acid in Sweden. Data on emissions have been obtained directly from the facilities and from official statistics.

5.3.1.3 CARBIDE PRODUCTION, NFR 2B4

Carbide production occurs at only one facility in Sweden. The reported emissions are based on information from the company. The distribution of particulates between TSP, PM_{10} and $PM_{2.5}$ has been done by expert judgement.

5.3.1.4 OTHER, NFR 2B5

This sub-category includes various chemical industries, such as sulphuric acid production, the pharmaceutical industry, production of base chemicals for plastic industry, various organic and inorganic chemical productions and other non specified chemical production, which is not covered elsewhere. Approximately 70 larger industrial facilities are included in the emission estimates. Emissions of NO_X, CO, NMVOC, SO_2, NH_3 and TSP are reported. It is possible that some emissions of NMVOC reported in NFR 2B5 should be reported in NFR 3C (e.g. pharmaceutical industries), but since it has been difficult to make the distinction clear between process emissions and solvent use, all NMVOC emissions from these facilities are included in NFR 2B5.

The mercury emissions reported originate from the chloralkali and the sulphuric acid industries. The dioxin emissions reported in 2001 originate from three facilities, in 2002 from four, and for 2003 from six facilities. Due to lack of information about emissions in earlier years, dioxin emissions are reported NE (Not Estimated) for 1980 – 2000.

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[99] UN. Commodity Production Statistical Database. Department of Economic and Social Affairs, Statistics Division, as referred in FCCC Synthesis and Assessment report 2002 Part I.

[100] Kindbom, 2004.

5.3.2 Methodological issues, NFR 2B

5.3.2.1 NITRIC ACID PRODUCTION, NFR 2B2

Emission data on NO_X and NH_3 originating from the nitric acid production has been obtained directly from the facilities and from official statistics. Emissions for all years, except 1991-1993, are as reported from the facilities. The reduction of the reported NO_X emissions in 2001 and 2002, compared to earlier years, is a result of one facility being shut down in late 2000 and a second one during 2001. The higher level of NO_X emissions in year 2004 is a result of a long lasting leakage of NO_X from one of the production units at the active facility. During year 2007 catalytic abatement was installed at one of the production units at the active facility and as a result the emissions of NO_X and NH_3 were reduced compared to previous years. According to the company the increased NH_3 emissions in 2010 is a result of prioritizing low NO_X emissions. NH_3 is used as a reducing agent in the deNO_X catalyst and hence lower NO_X implies more injected NH_3. NH_3 that do not react in the catalyst is emitted to the air.

Documentation has been received from the facility concerning production data, production capacity and abatement measures, emission factors used and the method of estimating emissions as well as uncertainty in emission estimates. However, this information is confidential.

5.3.2.2 CARBIDE PRODUCTION, NFR 2B4

The time series of emissions of particles from carbide production are considered complete and consistent in methodology. TSP, PM_{10} and $PM_{2.5}$, emissions from the carbide as well as from the quick lime production are included and the dominating part of reported emissions arises from flaring of the carbide oven gas. The partitioning of particles between TSP, PM_{10} and $PM_{2.5}$ has been done by expert judgement, after discussions with the company.

5.3.2.3 OTHER, NFR 2B5

The primary information on emissions of NO_X, CO, NMVOC, SO_2, NH_3 and TSP are as reported by the companies in their environmental reports. A total of approximately 70 facilities are included, but not all of them report on all emissions. The time series have been reviewed and are considered to be consistent.

Mercury emissions reported in NFR 2B5 originate from processes in the chlor-alkali industry and from sulphuric acid production. Reported emissions of mercury were derived from information in the SMP database, from the industries' environmental reports or unpublished earlier estimates[101].

Hardly any information on dioxin emissions from the chemical industry has been available, and it has not been possible to compile any time series of dioxin emissions from these sources. There is only information on dioxin emissions available from a few facilities from 2001.

[101] Levander, 1989.

The SO_2 emissions reported in 2B5 decreased dramatically in 2004 in comparison to earlier years. This is due to that in December 2003 one facility for production of viscose staple fibre was shut down. The yearly SO_2 emissions from this facility represented between 8 and 20 % of the totally reported SO_2 emission in NFR 2 – Industrial Processes, 1990 - 2003. In 2007 the CO-emissions were very low from one facility producing PVC. NH_3-emissions decreased since 2007 due to that one facility are working on replacing NH_3 in the production process.

In 2010, emissions in this sub-category were reviewed as part of a quality control project carried out by SMED on behalf of the Swedish EPA, aiming at increasing the quality and reducing the uncertainties of the emissions of the most important substances from chemicals industries in Sweden[102]. Emissions reported in the environmental reports were compared to plant-specific data. Significant discrepancies were investigated, and recommendations were provided on feasible improvements for submission 2011 as well as recommendations on further investigations[103].

Overall, the QC-project showed that total reported emissions from the chemical industries in the Swedish inventory are in coherence with the emission data reported by the plants.

5.3.3 Recalculations

NFR 2B2
Emissions of NOx and NH_3 2009 have been corrected. The correction was due to errors in the company's environmental report for 2009.

NFR 2B5
Minor revisions of the NH_3 and NMVOC emissions for 2009 have been done.

5.3.4 Coming improvements

No major improvements are currently planned.

5.4 Metal production, NFR 2C

5.4.1 Source category description, NFR 2C

Processes that are included in this category are primary and secondary iron and steel production, aluminium production and other non-ferrous metal production. All sub-categories are covered in the estimates, i.e. iron and steel production (2C1), ferroalloy production (2C2), aluminium production (2C3) and Other (2C5), which consist of estimates for one large and a few smaller non-ferrous smelter plants.

[102] Swedish EPA . 2010.
[103] Most recommendations on further investigations refer to the energy sector

5.4.1.1 IRON AND STEEL PRODUCTION, NFR 2C1

In Sweden, there are three primary iron and steel facilities and about ten steel plants equipped with electric arc furnaces. In total, there are approximately 20 different facilities included in the estimates. Processes occurring beside the primary processes and secondary steel production are rolling mills, pickling and other steel-related processes.

From submission 2009 and onwards, emissions from two major iron ore mines and three facilities producing pellets in Sweden are reported in 2C1 (reallocated from previous reporting in 2A7). Emissions from a sinter producing facility are also included until 1995, when the production closed down.

5.4.1.2 FERROALLOY PRODUCTION, NFR 2C2

Ferroalloy production is reported for only one facility in Sweden. There is also ferroalloy production at another plant, but since the main production at this facility is of iron and steel, these emissions are reported in NFR 2C1- Iron and steel production.

5.4.1.3 ALUMINIUM PRODUCTION, NFR 2C3

There is one facility that produces primary aluminum in Sweden. The facility consists of two halls. One of the potlines includes 56 closed prebake cells (CWPB), each of 150 kA. The other plant consisted of 262 cells and, until the beginning of 2008, operated three prebake cells and 259 open cells with Söderberg anodes (VSS). The Söderberg anodes were produced in an electrode pulp factory at the facility.

In 2008 a project was started to convert all Söderberg ovens to ovens with prebake cells. By the end of December 2009, 120 of a total of 262 cells had been converted to the prebake technology and the conversion to prebake cells continued under 2010. All pot-lines operating the Söderberg technology were shut-down by December 2008. At the end of 2010 113 converted prebake ovens were in operation.

PAHs are emitted during the anode production. Emissions of PAHs during the electrolysis process are negligible for pre-bake plants but for Söderberg plants emissions do occur due to the self-baking anode.

5.4.1.4 OTHER METAL PRODUCTION, NFR 2C5

This sub-category includes emission estimates from one large smelter producing different non-ferrous metals as copper, lead, zinc etc, one metal recycling company mainly producing lead and seven smaller smelters of various kinds. Emissions of particles have been obtained from the large smelter from 1980, for one facility from 1985 and for most of the smaller smelters from 1990. Time series of metal emissions are reported from 1990, and includes also the smaller facilities. In the dioxin time series reported emissions from the large smelter, from the metal recycling company and from two smaller smelters are included.

5.4.2 Methodological issues, NFR 2C

5.4.2.1 IRON AND STEEL PRODUCTION, NFR 2C1

Process emissions arising from reducing agents in the primary steel works and secondary iron and steel works are reported in NFR 2C1. As the plants also genreate emissions from fuel combustion (NFR 1A1c and NFR 1A2a) and fugitive emissions (NFR 1B1c) the text in this section is closely connected to the text in the energy section.

In the Swedish inventory, emissions from primary iron and steel production and secondary steel production are estimated separately but reported together under 2C1 iron and steel production. In 2C1 also emissions from two major iron ore mines and three facilities producing pellets in Sweden are included.

5.4.2.1.1 Primary iron and steel production

In Sweden there are three producers of primary iron and steel, i.e. the basis of their production is iron ore pellets. Two plants produce pig iron and steel, and one plant produces iron sponge and iron powder.

5.4.2.1.1.1 Production of iron powder

In Sweden there is one producer of iron ore based iron powder. The emissions are as reported by the plant but are verified by collecting and comparing the carbon contents in the amounts of coke, anthracite and out-put material. To be consistent with calculations of emissions from production of pig iron, limestone used in the production is included in the emissions from the production of iron powder in NFR 2C1. Activity data reported is produced amount of direct-reduced iron (iron sponge).

5.4.2.1.1.2 Production of primary pig iron and steel

The other two plants reported in this sector are primary iron and steel producing plants as part of integrated coke ovens, blast furnaces and steel converters. The primary purpose of the use of coal and coke in the blast furnace is to secure oxidation and act as reducing agents, and the associated emissions are reported as industrial processes from iron and steel production in NFR 2C1, according to the Revised 1996 IPCC Guidelines and Good Practice Guidance.

Figure 5.1 gives an overview of the input and output materials, the carbon flows between the different processes (plant stations), and the CO_2-emitting sources. Note that for non-CO_2 emissions, the different emission sources may vary considerably. The flow chart is however giving a general introduction to the two integrated iron and steel production plants in Sweden.

In the coke ovens (battery), coking coal is turned into coke through dry distillation. During the process, coke oven gas (COG) and by-products are formed. The coke oven gas is purified through several procedures and used as fuel in other plant stations, but smaller amounts are also flared. Produced amounts of coke are fed into the blast furnace together with injection coal to act as reduction agent when pig iron is produced from iron ore pellets. Limestone is added to extract slag and other by-products from the pig iron. Besides pig iron and by-products, blast furnace gas (BFG) is produced in the process. The main use for the blast furnace gas is to heat the cowpers (and in one plant used in the coke oven), but some excess gas is released through flaring.

In the steelworks, pig iron is transformed into various qualities of steel depending on the demand. Dolomite, pig iron, carbide, etc., are added depending on the different metallurgic processes. LD-gas is produced in the steel converter and used as fuel or flared. Some steel is treated in the rolling mills where LPG and different oils are used as fuel.

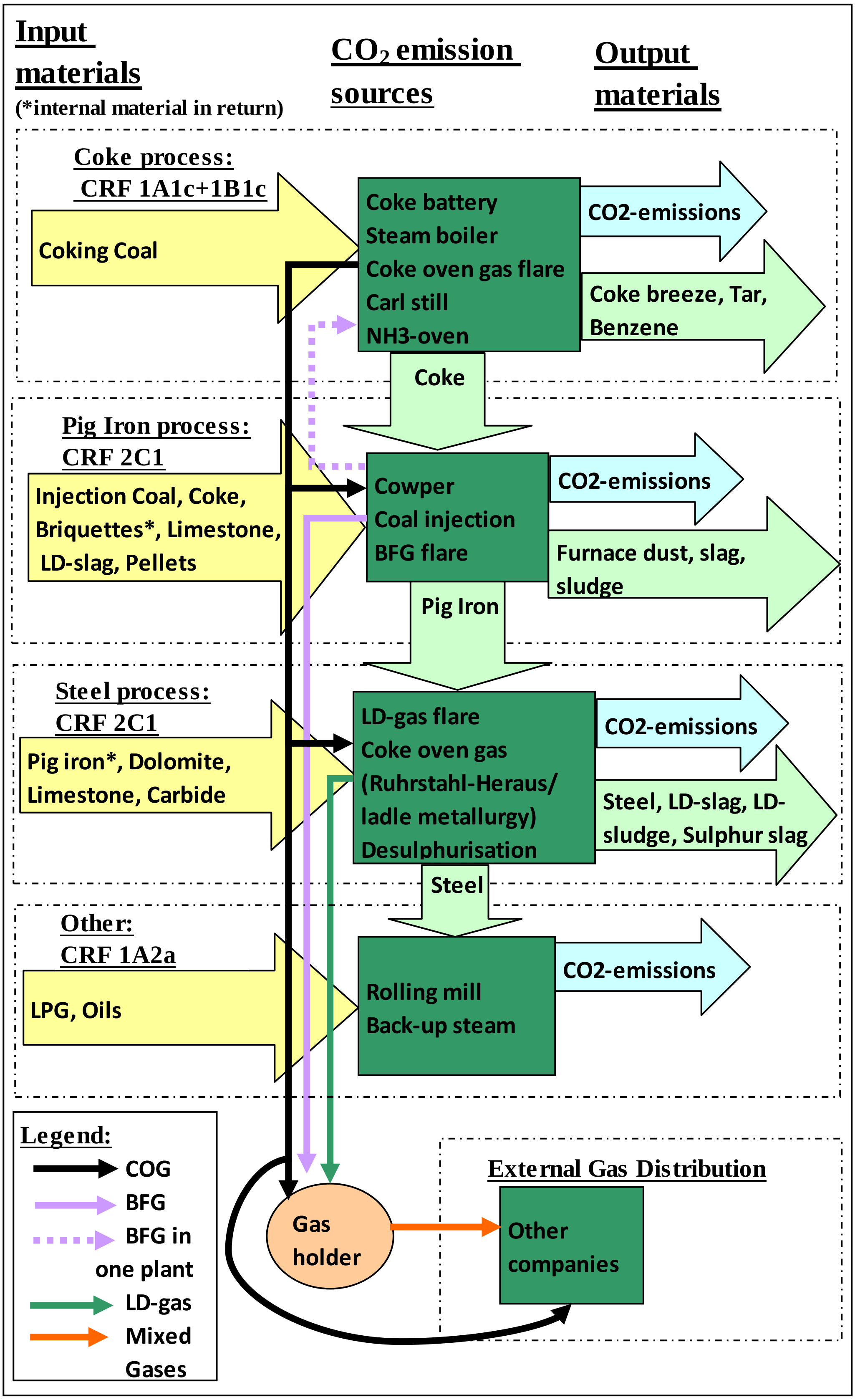

Figure 5.1. Carbon flow chart of integrated primary iron and steel plants in Sweden. CRF = NFR.

Considerable amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) from the different processes are collected in a gas holder and sold to external consumers (mainly in NFR 1A1a electricity and heat production). These amounts of gases and their associated emissions are allocated to the source category where they are consumed and thus not accounted for in the iron and steel production. This is not in accordance with the 1996 Guidelines as they fall under the category "Auto producers[104]", but in line with the 2006 IPCC Guidelines[105] where allocation of emissions from delivered gases is described. Sweden has chosen to follow the 2006 IPCC Guidelines in this case as they are more in line with the emission reporting for the annual environmental reports and the EU ETS reporting. During the whole process from raw material to final product, emissions are released.

From 2003, the plant specific annual environmental reports consists of plant station data on consumed amounts of energy gases (coke oven gas, blast furnace gas and LD-gas) and other fuels, emissions of CO_2, NO_x, SO_2, several heavy metals, TSP and dioxin (one plant only), but lack information on emissions of NMVOC, CO and some heavy metals. In previous submissions, time series for several pollutants (NO_x, SO_2, NMVOC and CO) were based on information from various sources (e.g. Statistics Sweden and environmental reports). As of submission 2010, the inventory reporting of all emissions is based on information from the environmental reports and some additional information from direct contact with the plants. In order to achieve consistent time series and to estimate emissions of missing pollutants, different IPCC splicing techniques were applied.

Emissions of NO_X, SO_2 and TSP are derived from the environmental reports and direct contact with the plants for the entire time series. The allocation of both plants total emissions of NO_X, SO_2 and TSP on plant stations and consequently NFR category is presented in Table 5.3.

NMVOC and CO emissions are estimated based on consumed amounts (including flared amounts) of energy gases multiplied by country specific emission factors (see Appendix 1). Emissions of NMVOC and CO from coke oven gas, blast furnace gas and LD-gas in the blast furnace and steel converter are allocated to NFR 2C1. Consumed amounts of different energy gases and other fuels 1990-2002 are derived by applying the Good Practice Guidance surrogate method using the average values 2003-2007 and the CO_2 emissions as the surrogate parameter.

[104] See IPCC Guidelines: Reporting instructions 1.3
[105] See 2006 IPCC Guidelines: Volume 3: Industrial Processes and Product Use, Box 1.1 (page 1.8)

Table 5.3. Allocation of NO_X, SO_2 and TSP emissions 2010 in integrated primary iron and steel production.

NFR	Plant station	NO_X emissions 2009 (Gg)	SO_2 emissions 2009 (Gg)	TSP emissions 2009 (Gg)
1A1c	Coke Oven	0.45	0.21	274
1A2a	Combustion in Rolling Mills + Power and Heat Production	0.46	0.35	51
1B1b	SO_2 from quenching and extinction at coke ovens		0.01	
1B1c	Flare in Coke Oven (COG)	<0.01	0.01	<1
2B5	Sulphuric acid production		0.01	
2C1	Blast Furnace + Steelworks (including Flaring of BFG and LD-gas)	0.17	0.69	387
Total		1.08	1.28	712

Inventory emissions of heavy metals, TSP and dioxin are mostly obtained from the environmental reports. In some cases, especially for the early 1990's and for one of the plants, information on heavy metal emissions are lacking and thus estimated by extrapolation using IEF and TSP as a surrogate parameter. Emissions of heavy metals are all reported under NFR 2C1. The PM size fractioning has been made according to reported emissions of PM_{10} and $PM_{2.5}$ from one of the plants.

5.4.2.1.2 Secondary iron and steel production

For reported emissions from secondary iron and steel production, the companies' environmental reports are the main source of information. NO_X, NMVOC and SO_2 emissions emitted from electric arc furnaces are reported in 2C1. NO_X emissions may also arise from pickling and NMVOC emissions from rolling mills. These sources are also included in the estimates.

The estimated TSP emissions are based on information from the trade association[106] for almost all years 1980-1999 but for 2000 and onwards the information was derived from the companies' environmental reports. TSP data for missing years have been interpolated. The PM size fractioning has been made according to expert judgement, and are based on knowledge about changes in production methods and abatement technology.

The estimated metal emissions from secondary iron and steel processes are based on produced amount of steel, published by the trade association[106], and emission factors, for the years 1990 - 2000. The emission factors used are based on compiled information from older trade specific reports made by the Swedish EPA for some years during the 1990's. Emission factors have been calculated for Cd, Cr; Cu, Hg, Ni, Pb and Zn. For years where the Swedish EPA did not provide trade

106 The Swedish Steel Producers Association. http://www.jernkontoret.se.

specific reports, or when the trade was not fully covered in the reports, data has been interpolated. Data on As emissions from iron and steel production is somewhat uncertain since reported data are scarce. From 2001 and onwards the emissions are mainly derived from the companies' environmental reports. For years when information is missing in the environmental reports, emissions are estimated using IEF for earlier years and production volumes or amounts of particles emitted.

Dioxin emissions have been compiled for the whole time series. According to the US-EPA[107], dioxin emissions from steel production are strongly dependent on a number of parameters, likely to vary between steel plants. Whether steel is produced from primary metals or from scrap metal is one very important factor, with the latter giving much higher dioxin emissions. Since the emission factors vary widely depending on several process factors, no straightforward calculations using an emission factor were made when compiling a time series of national dioxin emissions from the iron and steel industry. Instead, the estimates for the time period 1980 - 2000 are based on a combination of information concerning production data for scrap-based steel, results from dioxin measurements, earlier estimates and expert judgement in co-operation with the trade association[108]. From 2001 the information concerning the dioxin emissions were derived from the companies' environmental reports.

Measurements of PAH emissions from electric arc furnaces in 1990 showed non-detectable levels of the four specified compounds of interest[109], thus the emissions of PAH-4 from the steel industry were assumed to be insignificant, and were not further considered.

5.4.2.1.3 Iron ore mining, dressing, sintering and iron ore pellets production

There are currently two major iron ore mines and three facilities producing pellets in Sweden. Until 1995, emissions from a now closed sinter producing facility are also included. Emissions considered are SO_2 from the sulphur content in the ore and NO_X emitted as a result of the use of explosives. Metals are reported for the time period from 1990, whereas emissions of dioxins and particles are reported for the period 1980 onwards.

The figures are based on data reported by the companies in their environmental reports. For years with missing data figures have been interpolated or estimated, using expert judgement in cooperation with industry. For distributing the emission of particulates between TSP, PM_{10} and $PM_{2.5}$ the same ratio has been used as the one used in the CEPMEIP study[110]. Content of heavy metals in particulate matter has been calculated using an analysis provided by the leading company. The analysed samples were from the pellets production, but in the emission estimates the factors have been used on the sum of produced sinter and pellets.

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[107] U.S. Environmental Protection Agency, 1997.
[108] The Swedish Steel Producers Association. http://www.jernkontoret.se.
[109] Boström & Cooper, 1993.
[110] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

The reported emissions of dioxins are based on an emission factor developed using measurements in 2001 and known production data for the same year. Since the production methodology and other circumstances have not changed significantly during the time period, this developed emission factor has been used to calculate the time series of dioxin emissions for the period 1980 - 2001. For 2002 – 2010, data on dioxin emissions provided by the companies are reported.

5.4.2.2 FERROALLOY PRODUCTION, NFR 2C2

Emission data for SO_2 and NO_X has been obtained directly from the company for all years. Production of ferrosilicon leads to larger emissions of SO_2 compared to production of ferrochromium. From 2005 the production of ferrosilicon has been much reduced and from 2008 no ferrosilicon is produced. This leads to a distinct decrease in SO_2 emissions in later years.

The TSP emissions 1980-1999 have been calculated based on activity data provided by the company and emission factors derived from reported emissions of TSP in the company's environmental reports in later years. The calculated average emission factor has been used for all years during the 1990's and was doubled for the period 1980-1989, as suggested by the company experts. From 2000, data on TSP emissions from the company's environmental report were used. An expert who has performed measurements at the facility since the beginning of the 1980's has estimated the size distribution of particulates between PM_{10} and $PM_{2.5}$[111]. The same particle size distribution was assumed for the time series 1980 - 2001. From 2002 and onwards the reported PM_{10} emissions are as presented by the company in their environmental reports. For the years after 2001 the reported $PM_{2.5}$ emissions are estimated as for earlier years due to lack of specific information on $PM_{2.5}$ emissions from the company.

Metals emitted to air from ferroalloy production are primarily Cr, Pb, Ni and Zn. Chromium emission have been reported in the environmental reports to the EMIR database since 1992. The chromium (Cr) emissions in the database and the activity data obtained from the company have been used to derive emission factors. The average emission factor for 1992-1994 was used for 1990-1991. Zinc and lead emissions have only been sporadically reported to the EMIR database during the 1990's. In order to estimate emissions of Zn and Pb, information from older Swedish EPA reports were combined with the reported EMIR-data on emissions to calculate emission factors for the 1990's. Emissions of Ni from ferroalloys production has been derived from the company's environmental reports for the years 2003 – 2009. For earlier years no data is available and Ni emissions are hence reported NE (Not Estimated) for the time period 1980 – 2002.

5.4.2.3 ALUMINIUM PRODUCTION, NFR 2C3

Primary aluminium production takes place in one facility, where historically both the Prebaked and the Söderberg processes have been used. All pot-lines operating the Söderberg technology were shut-down by December 2008.

[111] Peterson, 2002.

The time series of emissions compiled for primary aluminium production include emissions of NO_X, CO, NMVOC and SO_2, particles and PAH. Reported production statistics and emissions data are based on information in the environmental reports or received directly from the company.

Emissions of NO_X have been calculated from production statistics using emission factors defined by Swedish EPA[112]. NMVOC emissions have been calculated from reported emissions of tar, assuming that 70 % of the tar is emitted as NMVOC[112]. Closing down the Söderberg ovens also ended the need for anode production in late 2008. Since there was no anode production there was no tar emissions and therefore NMVOC for 2009 is reported NA. CO emissions were reported for the first time in submission 2008 and are for 2002 - 2009 as reported in the company's environmental reports. For the period 1990 - 2001 the CO emissions are calculated using production statistics and emission factor provided by the company as also the SO_2 emissions, 1990 - 2005. For 2006 - 2009 SO_2 is as reported by the company in their environmental reports.

Information concerning production statistics and emissions of TSP and benzo(a)pyrene (BaP) were provided by industry, and only a few missing years have had to be interpolated. The reported emissions also include particles from the foundry located at the site of the primary production plant. The particle size fractions of PM_{10} and $PM_{2.5}$ have been assumed for the whole time period, as given in the CEPMEIP project[113] for primary aluminium production. For particles from the foundry the same particle size fractions of PM_{10} and $PM_{2.5}$ have been used. The assumption is thus that PM_{10} constitutes 95 % and $PM_{2.5}$ 43 % of the reported TSP emissions. Emissions of benzo(a)pyrene and “PAH” have been reported from the facility as far back as 1984. It is not known which compounds are included in the term “PAH”. In 1984 and 1986, benzo(a)pyrene emissions occurred from plant 1 and 2. From 1987 until 2008, emissions occurred only from plant 2, which represents the production of Söderberg anodes and anode baking in the so-called Söderberg ovens. Since 2008 no Söderberg ovens has been in operation and no anodes have been produced in the electrode pulp factory. Hence, PAH-4 for the emission year 2009 is reported NA.

According to UNEP[114] primary production of aluminium has no significant emissions of dioxins to air. This was confirmed by measurements made at the facility in the late 1970´s and early 1980´s. The measurements in the early 1980´s showed no detectable amounts.

5.4.2.4 OTHER, NFR 2C5

The reported emissions of SO_2 mainly originate from the sulphur content in the raw materials used in the large non-ferrous smelter, but also represent emissions from the metal recycling company and from one of the smaller smelters. Reported NO_X

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[112] Ahmadzai, H. Swedish EPA. Personal communication. 2000.
[113] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html
[114] UNEP, 2001. Standardized Toolkit for Identification and Quantifications of Dioxin and Furan Releases. http://www.chem.unep.ch/pops/pdf/toolkit/toolkit.pdf

in 2C5 represents the same facilities. The SO_2 and NO_X time series are considered complete and consistent.

At the large smelter, a variety of processes occur, including both primary and secondary processes, and a number of products are produced. This facility has a long history of submitting environmental reports to the authorities, why emission estimates for all substances were readily available, except for the size fractions of emitted particles. Emission factors for PM_{10} and $PM_{2.5}$, as fractions of emitted TSP, have for the period before 1995 been assigned by expert judgement, in cooperation with company experts. Fractions range from 60 to 95% for PM_{10} from 1980 until 2003 and from 30 to 80 % for $PM_{2.5}$ during the same period of time. The suggested emission factors according to CEPMEIP[115], valid for 1995, correspond to a value of 90% for PM_{10} and 80 % for $PM_{2.5}$. For the years after 2003 the emission factors for PM_{10} and $PM_{2.5}$ are the same as for 2003.

Emissions of particles and metals from nine secondary non-ferrous metal smelters have been compiled. Emissions are for TSP and the metals as reported by the companies in environmental reports, and further into an emission database. The data in the database are for early years not complete and consistent, and several instances of missing values have had to be interpolated in order to complete the time series. Estimates of the emissions of PM_{10} and $PM_{2.5}$ were made using the same assumptions concerning particle size fractions as was applied for the large smelter.

Primary non-ferrous metal production is not associated with major dioxin emissions to air. From secondary processes, however, dioxin emissions are known to occur. In submission 2012, emissions from the large smelter, from the metal recycling company and from two smaller smelters are included for the whole time series, 1990 – 2010.

5.4.3 Recalculations

NFR 2C1:

Primary iron and steel plants:

- PM_{10} and $PM_{2.5}$ emissions corrected for one plant for 2009.
- Iron ore mining, dressing, sintering and iron ore pellets production:
- TSP, PM_{10} and $PM_{2.5}$ emissions corrected for one plant for 2008 and 2009 and for one plant for 2009.
- The correction of the particulate emission for 2008 and 2009 leads to corrections in reported emissions of Pb, Cd, Hg, As, Cr, Cu, Ni and Zn.

NFR 2C5:

- CO time series 1990 – 2009 for one plant included in submission 2012.
- Cu and dioxin added for one plant for 2009.
- TSP, PM10 and $PM_{2.5}$ added for one plant for the time series 1990 – 2009

[115] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

5.4.4 Coming improvements

No major improvements are currently planned.

5.5 Other production, NFR 2D

5.5.1 Source category description, NFR 2D

The source category “Other production” covers the pulp and paper industry (NFR 2D1) as well as estimates from the production of food and drink (NFR 2D2).

5.5.1.1 PULP AND PAPER, NFR 2D1

The pulp and paper industry in Sweden is an important source of industrial process emissions. 42 individual pulp and paper facilities are included in the reported emissions, as well as two manufacturers of cardboard. One of these facilities shut down during 2008 and during 2009 another two plants closed down their pulp and paper production. The Kraft process (sulphate) dominates in Sweden but there are also emissions from four sulphite and 16 CTMP (Chemo Thermo Mechanical Pulp) or TMP (Thermo Mechanical Pulp) facilities reported in NFR 2D, 1990 - 2010. Reported emissions from the pulp and paper industry are for SO_2, NO_X and TSP based on information in the companies’ environmental reports, while other air pollutants are calculated using nationally derived emission factors.

5.5.1.2 FOOD AND DRINK, NFR 2D2

The food and drink industry is a moderate source of NMVOC in Sweden. The industry consists of beer, wine and liquor producers, bread, sugar, yeast and margarine and solid cooking fat producers, coffee roasters and animal feed producers.

5.5.2 Methodological issues, NFR 2D

5.5.2.1 PULP AND PAPER, NFR 2D1

Reported SO_2, NO_X and TSP emissions from the pulp and paper industry are primarily based on information about production and emissions in the companies' environmental reports. The industrial organisation within this sector has for several years co-operated closely with its members in developing sector-specific methods of measuring and calculating emissions, which have resulted in high quality emissions data. The emission factors that are used for the other pollutants are derived from national measurements and from international literature. The reported emissions of NMVOC do not include therpenes.

5.5.2.2 FOOD AND DRINK, NFR 2D2

Estimations of NMVOC emissions are based on activity data from different official statistics. For wine the estimation of NMVOC emissions are based on data on sold amount[116] together with figures on import and export[117]. NMVOC emissions from beer production are based on the Swedish annual total production of beer[118] [119]. NMVOC emissions originating from the production of liquors, bread, sugar, yeast, margarine and solid cooking fat, coffee roasters and animal feeds are all based on statistics available at Statistics Sweden's website[117]. For the NMVOC emission estimations emission factors presented in Table 5.4, were used.

116 Systembolaget. Försäljningsstatistik. http://www.systembolaget.se
117 Statistics Sweden. http://www.scb.se. Data from the Industrial production database.
118 Carlsberg Sweden. http://www.carlsberg.se
119 Bryggeriföreningen. http://sverigesbryggerier.se

Table 5.4. NMVOC emission factors for the reported production activities in NFR 2D2 - Food and drink.

Production activity	Emission factor	Unit	Reference (footnote)
Wine	0.8	kg/1000 litres	120
Beer	0.35	kg/1000 litres	120
Liquors	0.6	kg/1000 litres	EF based on emission and activity data from one producer, 2001
Bread (sponge dough)	8	kg/Mg	120
Bread (white)	4.5	kg/Mg	120
Bread (wholemeal and light rye)	3	kg/Mg	120
Bread (dark rye)	0	kg/Mg	120
Cakes	0.1	kg/Mg	120
Biscuits	0.1	kg/Mg	120
Breakfast cereals	0.1	kg/Mg	120
Sugar	10	kg/Mg	120
Yeast	18	kg/Mg	121
Margarine and solid cooking fats	10	kg/Mg	120
Coffee roasting	0.55	kg/Mg	120
Animal feed	0.1	kg/Mg	120

5.5.3 Recalculations

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5.5.4 Coming improvements

No major improvements are currently planned.

5.6 Time series consistency

All time series from industrial processes reported in NFR codes 2A-2D have been reviewed in later years and are consistent.

5.7 QA/QC and verification for NFR 2A-2D

5.7.1 Quality assurance

Experts at the Swedish EPA conduct a review of the inventory, estimates, methodology and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

5.7.2 Quality control

[120] EMEP/CORINAIR Emission Inventory Guidebook: http://reports.eea.eu.int/EMEPCORINAIR4/en
[121] Finnish Environment Institute. 2001.

All quality procedures according to the Swedish QA/QC plan (Manual for SMED's Quality System in the Air Emission Inventories) have been implemented during the work with this sub-mission.

All Tier 1 general inventory level QC procedures and some specific Tier 2 QC procedures, listed in Good Practice Guidance section 8, have been performed and are documented in check-lists.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable.

Data have, when possible, been compared with information in environmental reports and/or other independent sources.

Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

According to the Good Practice Guidance, the method of calculating emissions at facilities should be documented. This is currently not done in most cases and will be improved in the future.

6 Solvent and other product use (NFR sector 3)

6.1 Overview

This chapter describes emissions from solvents and other product use. Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC) when emitted to the atmosphere. In addition to solvents, this sector also includes emissions of particles from product use.

In 2005 a new method for estimating emissions from solvent and other product use was developed by SMED in cooperation with the Swedish Chemicals Agency[122]. The method is more complete, accurate and transparent, and data can easily be updated on a yearly basis. The Swedish method is consumption-based with a product-related approach. With the new method emissions are calculated with activity data from the Products Register hosted by the Swedish Chemicals Agency, and country-specific emission factors.

The Products Register is a register over chemical products imported to or manufactured in Sweden. Official statistics from the Products Register is only available with a two years delay.

6.1.1 Description of method for estimating emissions from solvent use

A list of substances defined as NMVOCs, and found in the Products Register in quantities over 100 tonnes, has been compiled. The threshold of 100 tonnes is based on the fact that substances found in the Products Register in quantities less than 100 tonnes are equivalent to 0.03 % of the total solvent sales of 400 000 tonnes. The following definition of NMVOC has been used:

> Volatile organic compound (VOC) mean any organic compound having a vapour pressure of 0.01 kPa or more at 293.15 K, or having a corresponding volatility under the particular conditions of use. The fraction of creosote which exceeds this value of vapour pressure at 293.15 K shall be considered a VOC[123].

The list includes 397 substances (Cas-nr, name, carbon contents for each substance), and was used for extracting quantities of NMVOC in substances found in the Products Register for year 2010.

The sold amount of solvents and solvent based products, (production + import – export), is derived from the Products Register at the Swedish Chemicals Agency. When a company is reporting to the Products Register it should be stated, among

[122] Skårman, Tina. et al., 2006, Revised Method for Estimating Emissions of NMVOC from Solvent and Other Product Use in Sweden. SMED Nr 18 2006

[123] COUNCIL DIRECTIVE 1999/13/EC of 11 March 1999 and UNECE Emission Reporting Guidelines

other things, to which industrial sectors the product is sold, and the intended use of the product.

The substance list has been used to extract quantities of NMVOC in substances found in the Products Register. Due to confidentiality, data cannot be delivered on substance level. Consequently, data are delivered on product and industrial category level. An advantage of making a more targeted selection like this on product and industry category is that the risk that chemicals are double-reported in the Products Register is minimized. Hence it is highly unlikely that the same chemical will appear in a particular product that is sold twice to the same industrial sector.

Data extractions have been made for each year from 1995 to 2009 since reliable activity data, for this purpose, only can be obtained from 1995. The extractions show for each year:

- The intended use of the product and the type of product (product code)
- Industry to which the product is sold (industry category)
- Quantity NMVOC
- Quantity C

The extractions from the Products Register for 1995-2009 have been used in order to compile a connection diagram with all combinations of "product codes" and "industry categories". In order to avoid double-counting of reported emissions within other sectors, decisions whether to include or exclude a combination have been made, based on expert judgements. The industries that are excluded in the extractions from the Products Register are considered to be reported in NFR 1, 2 or 6. If the combination should be included, its specific NFR code has been identified. Furthermore, it has to be determined if the product is used as raw material or not. The quantities of NMVOC used as raw material in processes have been identified and treated separately from remaining quantities for each NFR code, due to that most of the solvents used as raw material will not be emitted. An Excel macro has been written in order to compile time series with quantities of NMVOC for each sub-code within NFR sector 3.

Sold amount of solvent is not always identical to the amount of solvent used, i.e. stock of solvents. Therefore activity data has been recalculated using a moving average over three years. This leads to the need for updating of reported emissions for the latest three years in the time series in every new submission.

Country-specific emission factors for solvents used as raw material and for remaining solvents were developed for each reported activity within each NFR code (see Annex 3). The emission factors have been based on the old emission time series 1988-2001, which were developed by SMED in 2002[124]. The old time series were mostly based on information in earlier national reports, investigations and estimations of national NMVOC emissions. These investigations were dedicated specific emission inventories focusing on NMVOC, which is why they are still to be considered as reliable. The emission factors have been developed also considering the application techniques, the reported emissions presented in environmental

[124] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

reports for specific industries, as well as other pathways of release (e.g. waste or water). The emission factors for raw material are set very low, since most of the solvents will not be emitted during production, but will end up in the product.

Since accurate data for compiling time series for NMVOC from "Solvents and other product use" only can be found in the Products Register from 1995, reported emissions for NFR codes 3A-D for 1990 until 1994 were taken from the old time series[125] and in some cases emission data for 1990 - 1994 has been interpolated. The reported time series are considered to be consistent, except for last year (2010) where data for previous year (2009) has been reported. The reason for the procedure is due to the fact that activity data from the Product Register is not official at the time data is needed to be able to perform the calculations and report in a timely manner. Data for 2010 will be updated in the next submission.

Activity data obtained from the Product Register are considered as complete, but it is important to keep in mind that an expert judgement is made in order to avoid double-counting of reported emissions within other sectors.

The uncertainty analysis tables (Tier 1 methodology described in the EMEP CORINAIR Guidebook 2009) are presented in Annex 6 and a general description of the uncertainty analysis is presented in section 2.6.

6.2 Paint application, NFR 3A

6.2.1 Source category description

Includes paints sold for “industrial use” (NFR 3A2) and for “consumer and other professional use” (NFR 3A1). “Other coating application” (NFR 3A3) is included in NFR 3A1.

6.2.2 Methodological issues

All activity data from 1995 has been obtained from the Products register at the Swedish Chemicals Agency. Emissions from 1988 are taken from the time series that were compiled in a special study concerning NMVOC emissions, which was carried out by SMED in 2002[125]. The emissions for 1989-1994 have been interpolated based on the information from the late 1980´s and known data for 1995. The time series (summarised as 3A) between 1988 and 2010 are presented in Table 6.1, below.

[125] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Table 6.1. Estimated emissions of NMVOC from paint application 1988-2010.

Year	Emissions of NMVOC Gg	Sources for emissions of NMVOC
1988	37.00	SMED, 2002[126]
1989	35.81	Interpolated between 1988 and 1995
1990	34.61	-"-
1991	33.42	-"-
1992	32.23	-"-
1993	31.03	-"-
1994	29.84	-"-
1995	28.65	Products register
1996	27.19	-"-
1997	27.76	-"-
1998	24.80	-"-
1999	22.15	-"-
2000	22.02	-"-
2001	21.85	-"-
2002	18.93	-"-
2003	16.68	-"-
2004	15.95	-"-
2005	15.57	-"-
2006	14.30	-"-
2007	13.00	-"-
2008	12.02	-"-
2009	11.19	-"-
2010	11.19	-"-

6.2.3 Recalculations

NFR 3A:

- Recalculation of NMVOC emissions has been performed for year 2009, due to the recurring one year lag of updating of the data from the Product Register of the Swedish Chemicals Agency.
- Due to use of moving average for compiling the NMVOC time series in NFR 3A, the reported emissions for 2007 - 2009 in submission 2011 are updated in submission 2012.
- A minor correction has been performed in the calculation model for emission year 2006 and consequently the reported emissions for 2004 - 2006 have been recalculated

6.2.4 Coming improvements

No major improvements are planned for the next submission.

[126] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

6.3 Degreasing and Dry cleaning, NFR 3B

6.3.1 Source category description

Includes solvents sold to the laundry and dry cleaning industry (NFR 3B2). Degreasing (NFR 3B1) is included in "Other product use" (NFR 3D3).

6.3.2 Methodological issues

All activity data from 1995 and onwards have been obtained from the Products register at the Swedish Chemicals Agency. Emission data for 1988 is based on reported quantities of tetrachloroethylene from the Swedish Chemical Agency. Since not only tetrachloroethylene is included in the time series after 1995, the NMVOC emissions reported 1988 is recalculated using a correction factor based on the proportion of other NMVOCs of the total NMVOC for 1995 (tetrachloroethylene plus 30%). Emissions between 1989 and 1994 have been interpolated based on the information from the late 1980´s and known data for 1995. The time series between 1988 and 2010 are presented in Table 6.2.

Table 6.2. Estimated emissions of NMVOC from dry cleaning 1988-2010.

Year	Emissions of NMVOC Gg NMVOC	Sources for emissions of NMVOC
1988	1.26	SMED, 2002[127]
1989	1.02	Interpolated between 1988 and 1995
1990	0.77	-"-
1991	0.68	-"-
1992	0.59	-"-
1993	0.50	-"-
1994	0.41	-"-
1995	0.32	Products register
1996	0.29	-"-
1997	0.30	-"-
1998	0.30	-"-
1999	0.24	-"-
2000	0.16	-"-
2001	0.13	-"-
2002	0.12	-"-
2003	0.13	-"-
2004	0.14	-"-
2005	0.13	-"-
2006	0.14	-"-
2007	0.13	-"-
2008	0.13	-"-
2009	0.13	-"-
2010	0.13	-"-

[127] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

6.3.3 Recalculations

NFR 3B:

- Recalculation of NMVOC emissions has been performed for year 2009, due to the recurring one year lag of updating of the data from the Product Register of the Swedish Chemicals Agency.
- Due to use of moving average for compiling the NMVOC time series in NFR 3A, the reported emissions for 2007 - 2009 in submission 2011 are updated in submission 2012.

6.3.4 Coming improvements

No major improvements are planned for the next submission.

6.4 Chemical products, Manufacture and Processing, NFR 3C

6.4.1 Source category description

Includes solvents sold for car manufacturing, paint industry and rubber industry. According to the Guidelines, NMVOC emissions from production of glue should be allocated to 3C. In the Swedish reporting, these NMVOC emissions are allocated to NFR 2B5, since the industries concerned often produce other chemical products as well, and are classified as chemical industries in the Products Register.

6.4.2 Methodological issues

The sector includes emissions from car manufacturing, paint industry and from rubber industry. Emissions from car manufacturing contribute by approximately 50%, paint industry by 30% and rubber industry by 20% of the reported emissions in NFR 3C. Emission data for car manufacturing has been compiled from environmental reports for 1990. Data for 1988 and 1989 has been extrapolated and data for 1991 - 1994 has been interpolated. For paint industry emission data for 1988 - 1994 has been taken from the old time series given in a special study concerning NMVOC emissions, carried out by SMED in 2002[128]. Emission data for the rubber industry is known for 1988[128] and data for 1989 - 1994 have been interpolated based on the information from the late 1980´s and known data for 1995. The time series between 1988 and 2010 are presented in Table 6.3.

[128] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

Table 6.3. Estimated emissions of NMVOC from chemical products, manufacture and processing 1988-2010.

Year	Emissions of NMVOC Gg NMVOC	Sources for emissions of NMVOC
1988	3.90	SMED, 2002[128]
1989	3.75	Interpolated between 1988 and 1995
1990	3.61	-"-
1991	3.18	-"-
1992	2.71	-"-
1993	2.23	-"-
1994	1.75	-"-
1995	1.33	Products Register
1996	0.96	-"-
1997	0.98	-"-
1998	1.00	-"-
1999	1.00	-"-
2000	0.88	-"-
2001	0.82	-"-
2002	0.75	-"-
2003	0.78	-"-
2004	0.76	-“-
2005	0.70	-“-
2006	0.61	-“-
2007	0.52	-“-
2008	0.46	-“-
2009	0.42	-“-
2010	0.42	-“-

6.4.3 Recalculations

NFR 3C:

- Recalculation of NMVOC emissions has been performed for year 2009, due to the recurring one year lag of updating of the data from the Product Register of the Swedish Chemicals Agency.
- Due to use of running average for compiling the NMVOC time series in NFR 3A, the reported emissions for 2007 - 2009 in submission 2011 are updated in submission 2012.
- New activity data has been obtained from the Swedish Chemicals Agency for emission year 2008 concerning rubber industry and consequently emissions for 2006-2008 have been recalculated.

6.4.4 Coming improvements

No major improvements are planned for the next submission.

6.5 Other, NFR 3D

6.5.1 Source category description

Includes solvents sold to the printing industry (NFR 3D1), for preservation of wood, to leather industry and to textile industry (NFR 3D3). “Other product use” (NFR 3D3) also includes solvents used by other industries not reported separately in sector 2, and solvents for domestic use. Emissions originating from “Domestic use including fungicides” (NFR 3D2) is included in NFR 3D3, since it not is estimated separately in the developed model. Emissions of particles from product use are allocated to this sub sector.

6.5.2 Methodological issues

6.5.2.1 EMISSIONS OF NMVOC FROM SOLVENT USE

Solvents used in printing industry, for preservation of wood, in leather industry and in textile industry have been estimated separately. The code also includes solvents used by other industries not reported separately, and also solvents for domestic use. The printing industry contributes by 8 %, preservation of wood 1 %, leather and textile industry < 1 % and general solvent use 90 % of the total reported emissions in NFR 3D. Emission data for 1988 is known for most industries included in NFR 3D and in most cases the emissions for 1989-1994 have been interpolated based on information from the late 1980´s and known data for 1995. The time series between 1988 and 2010 are presented in Table 6.4. The emissions from the printing industry have increased in later years due to introduction of two new solvent products.

Table 6.4. Estimated emissions of NMVOC from other solvent use 1988-2010.

Year	Emissions of NMVOC Gg NMVOC	Sources for emissions of NMVOC
1988	70.21	SMED, 2002[129]
1989	66.66	Interpolated between 1988 and 1995
1990	63.04	-"-
1991	60.01	-"-
1992	56.59	-"-
1993	53.75	-"-
1994	50.91	-"-
1995	47.48	Products Register
1996	44.92	-"-
1997	46.63	-"-
1998	47.76	-"-
1999	47.22	-"-
2000	43.13	-"-
2001	41.60	-"-
2002	44.00	-"-
2003	50.07	-"-
2004	55.10	-"-
2005	56.73	-"-
2006	60.70	-"-
2007	67.17	-"-
2008	71.12	-"-
2009	75.69	-"-
2010	75.69	-"-

6.5.2.2 EMISSIONS FROM TOBACCO SMOKING AND USE OF FIREWORKS

Emissions of particles from product use, included in NFR 3D, cover the use of fireworks and tobacco smoking. Emissions are based on activity data from official statistics on sold amounts of tobacco and fireworks for the whole time series from 1980. Activity data include only "legal" purchases of tobacco products in Sweden; products that are purchased through tax-free and cross-border trading are not included. For fireworks the activity data for 1980-1987 has been assumed, based on available data after 1987, which shows an increasing trend in the use of fireworks. An increasing tendency has been applied also to the years where activity data are lacking. Emission factors were all in earlier submissions from the CEPMEIP[130] study but are in submission 2012 for estimates of emissions from tobacco smoking from EMEP/EEA emission inventory guidebook 2009[131]. In EMEP/EEA emission inventory guidebook 2009 also emission factors for several other substances are

[129] Kindbom, K., Boström, C-Å., Skårman, T., Gustafsson, T. and Talonpoika, M. 2003. Estimated Emissions of NMVOC in Sweden 1988-2001.

[130] CEPMEIP, 2001. TNO. http://www.mep.tno.nl/wie_we_zijn_eng/organisatie/kenniscentra/centre_expertise_emissions_assessment.html

[131] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

presented. Hence submission 2012 also include time series 1990 – 2010, for NO_X, CO, NMVOC, Pb, Cd, Hg, As, Cr, Cu, dioxin and PAH.

Generally emissions from tobacco smoking have decreased during the years. Emissions from the use of fireworks show an increasing trend over the years with the highest reported emissions for 2007. The reported particulate emissions for 2008, 2009 and 2010 have decreased compared to 2007 since less fireworks was imported.

6.5.3 Recalculations

- Recalculation of NMVOC emissions has been performed for year 2009, due to the recurring one year lag of updating of the data from the Product Register of the Swedish Chemicals Agency.
- Due to use of running average for compiling the NMVOC time series in NFR 3A, the reported emissions for 2007 - 2009 in submission 2011 are updated in submission 2012.
- Minor corrections have been performed in the calculation model for NFR 3D5 Other, other non-specified use of solvents, for emission year 2004, 2005, 2008. The corrections affect the reported emissions from year 2002 - 2008.
- For printing industry new activity data has been obtained from the Swedish Chemicals Agency for emission year 2008 and consequently emissions for 2006 - 2008 have been recalculated.
- The emission factors for particulate emissions from tobacco smoking given in CEPMEIP, 2001 (40 kg/Mg) have been replaced with emission factors from EMEP/EEA emission inventory guidebook 2009 (40 g/Mg). This leads to 99.9 % reduction of reported TSP, PM_{10} and $PM_{2.5}$ emissions.

6.5.4 Coming improvements

No major improvements are planned for the next submission.

6.6 QC for NFR 3A-3D

6.6.1 Quality assurance

Experts at the Swedish EPA conduct a review of the inventory, estimates, methodology and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

6.6.2 Quality control

All quality procedures according to the Swedish QA/QC plan (Manual for SMED's Quality System in the Air Emission Inventories) have been implemented during the work with this sub-mission.

All Tier 1 general inventory level QC procedures and some specific Tier 2 QC procedures, listed in Good Practice Guidance section 8, have been performed and are documented in check-lists.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable.

Data have, when possible, been compared with information in legal environmental reports and/or other independent sources.

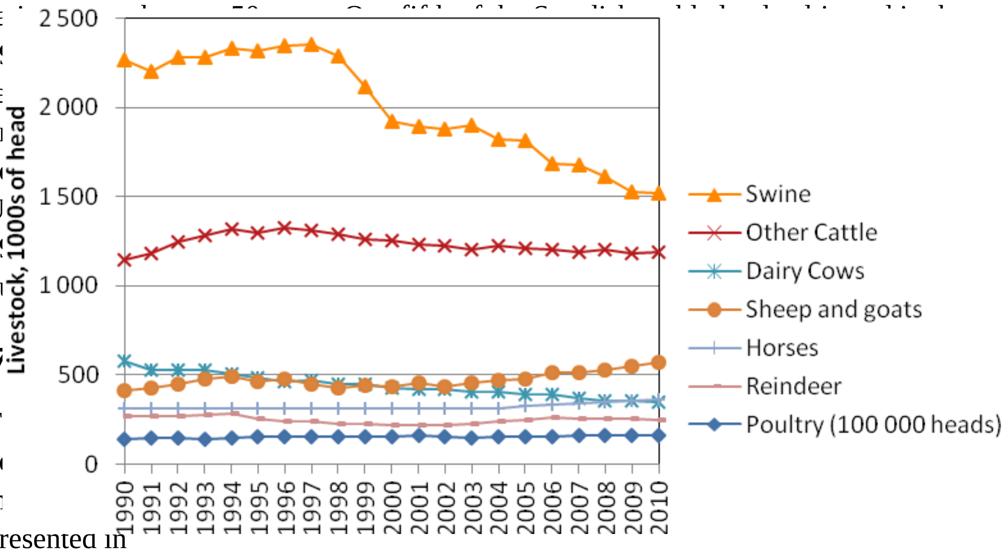
Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

7 Agriculture (NFR sector 4)

7.1 Overview

Under NFR sector 4, ammonia emissions and particles ($PM_{2.5}$ and PM_{10}) are reported.

The agriculture in Swedish has undergone radical structural changes and rationali-



presented in

Figure **7.1**.

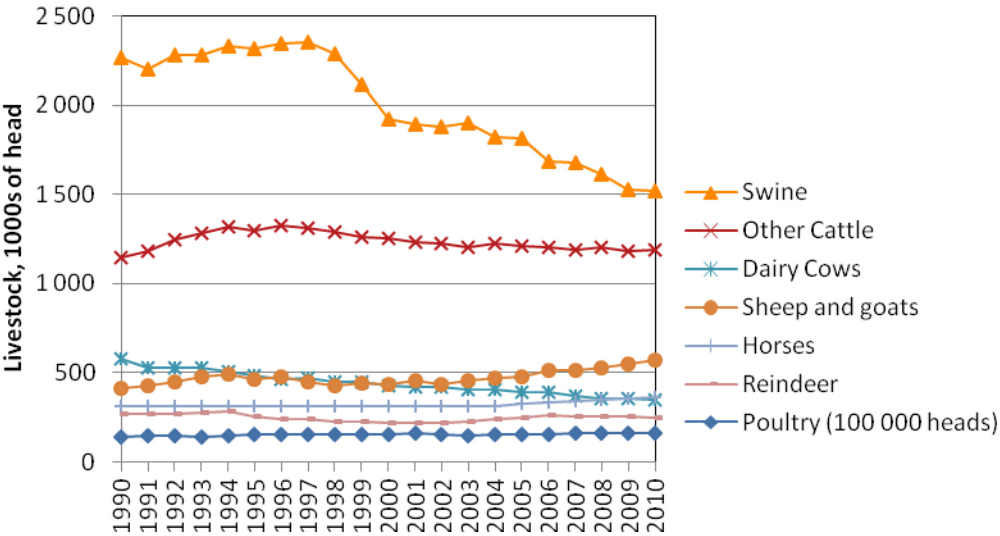


Figure 7.1. Livestock in Sweden, 1990 – 2010.

132 Ministry of the Environment, 2001.

7.3 Emissions of ammonia

Emissions of ammonia mainly derive from manure management. That is storage, handling and application of stable manure. The total emission of ammonia includes emissions from fertilisers and animal manure in agriculture and use of fertilisers in horticulture and forestry.

Table 7.1 shows the emissions of ammonia from cattle, in the stable from 1996 to 2010. The emission of ammonia from cattle has decreased for both dairy and non-dairy cattle.

Table 7.1. Emissions of ammonia from Cattle 1996-2010, in 1 000 tons of ammonia.

Year	Dairy cattle	Non-dairy cattle	All cattle
1996	16.97	15.25	32.22
1997	17.21	15.19	32.40
1998	16.71	15.00	31.72
1999	16.31	14.21	30.52
2000	15.93	14.08	30.00
2001	15.31	12.63	27.94
2002	14.09	12.46	27.56
2003	14.10	12.99	27.09
2004	14.46	13.25	27.71
2005	13.64	13.22	26.86
2006	13.47	13.17	26.64
2007	12.66	12.51	25.17
2008	12.27	13.27	25.54
2009	11.15	13.00	24.15
2010	11,20	13,32	24,52

7.3.1 Statistical sources

The emissions from agriculture have been calculated in detail from data of handling and use of manure and fertilisers. Information about the type and amount of used commercial fertilisers, consumed quantity and handling of different types of manure (solid-, liquid-, semi-liquid manure and deep litter) as well as time and method of spreading manure, time for mulching manure and data on stable periods has been obtained from a special field investigation made by Statistics Sweden. This investigation is carried out every second year as a random sample survey, the latest was in 2009. The field investigation includes telephone interviews with about 3 500 farmers and was performed by interviewers from Statistics Sweden. Detailed information about the design and implementation of the field investigation can be found in the report MI 30 SM 1002[133].

Information about the number of animals has mainly been collected from the Farm register of Swedish Board of Agriculture but also from some other sources for slaughter chicken, horses and furred animals.

[133] Statistics Sweden 2010

Data on gross content of nitrogen in stable manure, dung and urine from different types of animals and handling systems has been obtained from the Swedish Board of Agriculture[134]. The data is derived from national practices but not from national surveys, which means that the results may lose some accuracy when generalising across the whole country. Figures about milk production per dairy cow and county, which affect the amount of nitrogen in the manure, have been obtained from the Swedish Dairy Association.

Emission factors of ammonia from stable manure, through ventilation in stables, during storing and spreading of manure has been obtained from the Swedish University of Agricultural Sciences and from the Swedish Institute of Agricultural and Environmental Engineering (JTI)[135]. Emission factors from commercial fertilisers were obtained from the EMEP/EEA Emission Inventory Guidebook 2009.

7.3.2 General method

The calculations are mainly built on differentiated data collected through Statistics Sweden's field investigation among farmers. Swedish EPA and Statistics Sweden in collaboration with the Swedish Board of Agriculture and the Swedish Institute of Agricultural and Environmental Engineering have developed the calculation method[136]. The ammonia emission from the agricultural sector has been calculated by Statistics Sweden since 1990 at national and regional levels. Regional results are published for 2007 at the web-site of Statistics Sweden[137]. The results from 1990-1994 are not comparable with these from 1995 and onwards, due to changed questionnaire in Statistics Sweden's field investigation among farmers and changed methods for calculating the emissions.

Table 7.2 shows the consumption of nitrogen in stable manure from different types of animals based on results from the field investigation. These values are the basis of the ammonia emission.

Table 7.2. Consumption of nitrogen in stable manure from different types of animals, 1996-2010, in 1 000 tons of nitrogen.

Types of animals	Year										
	1996	1998	2000	2002	2004	2005	2006	2007	2008	2009	2010
Dairy cattle	42.72	42.16	41.65	40.82	39.81	38.98	38.52	37.06	35.22	33.96	33.25
Non-dairy cattle	35.84	35.31	32.57	30.55	30.54	30.16	30.05	28.38	29.94	30.46	30.70
Swine	20.78	20.11	16.98	16.76	18.41	18.29	17.35	17.21	16.36	15.69	15.70
Poultry	6.79	6.75	6.85	6.53	6.67	6.64	6.28	7.01	7.04	6.87	6.38
Horse	6.90	7.05	7.26	7.09	7.08	7.08	7.08	7.08	7.08	7.08	9.07
Sheep	1.50	1.38	1.47	1.46	1.63	1.64	1.80	1.79	1.86	1.88	1.88
Other (Mink)	1.03	1.03	1.09	1.07	1.19	1.19	1.19	1.19	0.82	0.74	0.74

134 Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001
135 Swedish Institute of Agricultural and Environmental Engineering (JTI) 2002
136 Swedish Environmental Protection Agency 1997
137 Statistics Sweden 2007

7.3.2.1 COMMERCIAL FERTILISERS IN AGRICULTURE

Calculations of ammonia emissions from commercial fertilisers for every production area and type of fertilisers:

$$A = T * N * F(f) * 1.21$$

where A = emission of ammonia, kg
T = total consumption of a special type of fertilisers, kg
N = content of nitrogen in fertilisers, %
F (f) = emission of nitrogen in percentage of content of nitrogen[138]
1.21 = conversion ratio from nitrogen to ammonia.

Total consumption of different types of fertilisers in production areas originates from the Swedish Board of Agriculture's statistics on sales of fertilisers in Sweden[139].

7.3.2.2 STABLE MANURE

Calculations for every production area and type of manure:

$$A = (V + L + S) * 1.21$$
$$V = D * N * P * F(v)$$
$$L = D * N * P * (1 - F(v)) * F(l)$$
$$S = D * N * P * (1 - F(v)) * (1 - F(l)) * F(s)$$

where: A = emission of ammonia, kg
V = emission of nitrogen through stable ventilation, kg – depending on the handling, type of animal and type of manure
L = emission of nitrogen during storing, kg – depending on type of manure, storing method and type of animal
S = emission of nitrogen during spreading, kg – depending on type of manure, time of spreading, method of spreading and time period between spreading and mulching
1.21 = conversion ratio from nitrogen to ammonia
D = number of animal[140]
N = production of nitrogen, kg, per type of animal, year and handling[141]
P = stable period[142]
F (v) = emission of nitrogen through stable ventilation, % of total nitrogen content in stable manure[143].
F (l) = emission of nitrogen during storing, % of total nitrogen content in stable manure after ventilation losses[144].

138 EMEP/EEA
139 Swedish Board of Agriculture 2009a
140 Swedish Board of Agriculture 2008 and other sources
141 Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000; Swedish Board of Agriculture 2001
142 Statistics Sweden 2008
143 Swedish Board of Agriculture 2005
144 Swedish Institute of Agricultural and Environmental Engineering 2002

F(s) = emission of nitrogen during spreading, % of ammonium nitrogen content in stable manure after ventilation and storing losses[145].

The calculated data is differentiated by type of animal, type and handling of manure, milk production, time and method of spreading and time period between spreading and mulching. Type of manure, way of storing and time of spreading etc. are estimated from the field investigation among farmers[146]. Ventilation-, storage- and spreading-losses originate from a data calculating program (called STANK) from Swedish Board of Agriculture and from Swedish Institute of Agricultural and Environmental Engineering. The emission factors used in 2008 are the same as those used for earlier years. The yearly production of nitrogen in manure from swine has been changed as from 2003, both for sows/boars and for pigs for meat production[147].

7.3.2.3 MANURE FROM GRAZING ANIMALS

Calculations for every production area and type of animal:

A = D * N * B * F (b) * 1.21

where A = emission of ammonia, kg

D = number of animal

N = production of nitrogen per animal and year, kg[148]

B = grazing period[149]

F (b) = losses of nitrogen during grazing, % of total nitrogen content in manure during grazing[150]

1.21 = conversion ratio from nitrogen to ammonia.

Type of animal and length of grazing period are taken into account in the calculation. Grazing periods for cattle are estimated from the field investigation while for horses and sheep the grazing period is fixed at 6 months.

7.3.2.4 COMMERCIAL FERTILISERS IN HORTICULTURE AND FORESTRY

For horticulture the calculations are based on the assumption (made by the inventory team in the early nineties) that the consumption is 5% of the consumption of fertilisers in agriculture. The calculations for forestry are based on information from the Swedish National Board of Forestry (NBF).

7.3.3 Comparability of data between different years

In 2005 the nitrogen content in swine manure was revised. A report [151] from the Swedish Board of Agriculture showed an increase in the nitrogen content for swine

145 Swedish Institute of Agricultural and Environmental Engineering 2002
146 Statistics Sweden, 2010
147 Swedish Board of Agriculture, 2001
148 Swedish Board of Agriculture 1995; Swedish Board of Agriculture 2000
149 Statistics Sweden 2010
150 Statistics Sweden 2004d
151 Swedish Board of Agriculture 2001

manure. For sows/boars the content was increased from 29.0 to 34.0 kg N/year. On a yearly basis the manure production from one pig for meat production was increased from 9.5 to 10.8 kg N/year. For deep litter the nitrogen content from sows/boars was increased from 37.0 to 38.0 kg N/year and for pigs for meat production from 10.5 to 11.9 kg N/year. The new figures for nitrogen content in swine manure have been utilized as from 2002 and not for earlier years since the report from Swedish Board of Agriculture with new values for swine was published in 2001.

In 1997 an overhaul of the model for collecting activity data and of the method for calculating ammonia from agriculture was made. The overhaul was mainly focused on improving the statistics of manure handling since manure is by far the greatest source for emissions of ammonia in Sweden. The overhaul ended up with the following complement in input data, from the questionnaire used in the field investigation of Statistics Sweden:

A changed and refined classification of the different systems for handling manure due to different animals

- Questions about filling and covering of tanks for slurry and urine
- Detailed questions about time for spreading the manure
- Questions about spreading method for slurry and urine
- Questions about the length of the stable period for different kinds of cattle

In connection with the overhaul the sampling model for collecting data was changed as well. The change has resulted in a greater part of farms with livestock production in the sample, which gives better quality in the estimations of ammonia emissions from agriculture.

The questionnaire has, by and large, been unchanged for the investigations following 1997.

Since 1995 is the base-year for the national environmental goal considering emissions of ammonia, Statistics Sweden has recalculated the emissions from agriculture for 1995 by using the number of animals from 1995 and the information of systems for handling manure from 1997.

However, the information of ammonia emissions from agriculture for the years before 1995 is still not comparable with results for the years after 1995.

7.3.4 Reliability of the data

All results must be considered with caution regarding the uncertainty in the input data. A model mainly calculates the emission of ammonia from the agriculture sector. The calculated emissions have a significant uncertainty even on the national level. Since there are no figures about the uncertainty in the emissions factors it is hard to estimate the total uncertainty but more than the double uncertainty in the statistical uncertainty is most likely.

The emission factors and the nitrogen production from different kind of animals, which originates from the STANK-program, Swedish Board of Agriculture[152] and from Swedish Institute of Agricultural and Environmental Engineering are based on a limited number of measurements with special conditions and thus are associated with uncertainties.

However, an estimate of statistical errors for the ammonia emissions has been made. The calculations are based on information from the farmers given in Statistics Sweden's field investigation and these results are afflicted with standard errors. Commissioned by the Swedish Board of Agriculture, Statistics Sweden made an overhaul of the manure and fertilisers' investigation and the calculations of emissions of ammonia in 2001[153]. Within this overhaul the mean errors were calculated for emissions of ammonia in 1997 from cattle and swine for eight production areas and with a separation in ventilation losses, storing losses and spreading losses.

Table 7.3 shows that the results of ammonia losses are of good quality for the whole country considering the statistical error.

Table 7.3 also shows that the statistical errors are of acceptable quality in most production areas. At a national level the mean error is around 2-3% for cattle and swine manure in total, even after a differentiation between ventilation losses, storing losses and spreading losses. For many production areas the mean error is less than 10%. When the calculation of ammonia emission have been made in the same way since 1997 it is likely that the mean errors are of the same magnitude in the current calculations. The uncertainty in the emission factors is probably much higher than the statistical errors, since there is limited information to create emission factors. The figures in the STANK report are assumed to be true for all farms with animal. This is probably not the case. The variations in ammonia losses between farms can be great. Nonetheless, the figures used are the best available at present.

Table 7.3. Mean error for ammonia losses from manure of cattle and swine in 1997.

Production area	Mean error			
	Ventilation losses, %	Storing losses, %	Spreading losses, %	Total losses, %
Gss- Plain district in southern Götaland	7	8	7	6
Gmb- Central districts in Götaland	7	5	6	5
Gns- Plain district in northern Götaland	6	6	6	5
Ss- Plain district in Svealand	6	5	5	4
Gsk- Forest districts in Götaland	8	7	5	6
Ssk- Forest districts in central Sweden	9	9	8	8
Nn- Lower parts of Norrland	6	6	6	4
Nö- Upper parts of Norrland	8	5	7	5
Whole country 1997	3	3	2	2

[152] Swedish Board of Agriculture 2005
[153] Swedish Board of Agriculture and Statistics Sweden 2005

7.3.5 Activity data

7.3.5.1 LIVESTOCK GROUPS

Livestock is the main contributor to ammonia emission from agriculture. The Farm Register provides the main basis for agricultural statistics in Sweden. The register is administrated by the Swedish Board of Agriculture and Statistics Sweden and provides yearly information on the number of animals of different categories on Swedish farms (Table 7.4 &

Table 7.**5**). The information on livestock refers to the situation existing in mid-June for the respective year, and it is considered equivalent to a one-year average. According to the Farm Register, there are about 99 000 horses on farms in Sweden. However, the total number of horses, including horses used for leisure activities, was for 2004 estimated to be about 280 000[154]. This larger number has been used from 1990 to 2009. In 2011 a new survey was conducted that estimated number of horses for 2010[155] and the new estimate (362 700) is used from 2010 and onwards.

During later years the number of slaughter chicken (mean number of chicken kept during the year) is much smaller in the Farm Register than in annual statistics from the Swedish Poultry Meat Association. For the calculation of ammonia emissions we have used the figures from the Swedish Poultry Meat Association. In 2010 the procedure for estimating number of slaughter chickens was slightly adjusted. As a consequence the estimate for number of slaughter chickens decreased with about 17 %. The number of minks has been received from the Swedish Furred Animals Association. Reindeers, piglets, goats and lambs are not included in the calculations.

[154] Statistics Sweden 2004
[155] Swedish board of agriculture, 2011

Table 7.4. Population size for different types of animals 1990-2009 in 1 000 of animals.

Year	Type of animal: Dairy cattle	Beef cows	Growing animals (12-24 months)	Calves	Sows/ Boars*	Pigs for meat production
1990	576	75	543	524	230	1 025
1991	528	98	543	537	227	993
1992	526	136	565	548	233	1 017
1993	525	154	549	581	249	941
1994	509	165	561	592	249	1 264
1995	482	157	596	542	245	1 300
1996	466	164	617	543	280	1 303
1997	468	169	614	530	274	1 313
1998	449	170	611	509	260	1 293
1999	449	165	600	499	224	1 239
2000	428	167	589	500	206	1 145
2001	418	165	573	494	216	1 089
2002	417	169	553	498	212	1 096
2003	403	165	527	512	208	1 127
2004	404	172	539	514	195	1 095
2005	393	177	527	508	188	1 085
2006	388	178	530	496	187	1 001
2007	370	186	516	489	181	1 015
2008	357	196	513	492	170	974
2009	357	192	502	488	160	943
2010	348	197	513	479	154	937

* The reason for the increase between 1995 and 1996 is that as from this year also uncovered gilts were included in this group.

Table 7.5. Population size for different types of animals 1990-2009 in 1 000 of animals.

	Type of animal					
Year	Laying hens	Chicken	Slaughter chicken	Horses and foals	Sheep excl. lambs	Breeders of mink*
1990	6 391	2 176	6 600	283	162	250
1991	6 145	2 580	7 000	283	168	250
1992	6 063	2 166	7 600	283	180	250
1993	5 764	1 908	7 600	283	189	250
1994	5 918	2 175	8 200	283	196	250
1995	6 100	1 812	8 500	283	195	250
1996	5 709	2 189	8 700	283	203	250
1997	5 725	1 881	9 400	283	195	250
1998	5 362	2 155	9 400	283	187	250
1999	5 648	2 202	9 400	283	194	250
2000	5 670	2 654	9 500	283	198	265
2001	5 687	1 721	10 450	283	208	280
2002	4 732	1 537	10 600	283	198	260
2003	4 498	1 509	10 402	283	210	290
2004	4 995	1 625	10 502	283	220	290
2005	5 065	1 697	10 064	283	222	290
2006	4 524	1 625	10 067	283	244	290
2007	5 328	1 753	10 710	283	242	290
2008	5 546	1 649	10 770	283	251	200
2009	5 261	1 898	10 240	283	254	180
2010	6 191	1 647	8 565	363	273	180

* Breeders of mink are reported under NFR 4B13.

7.3.5.2 NITROGEN PRODUCTION FROM DIFFERENT ANIMALS

The Swedish Board of Agriculture publishes data on nitrogen content in manure from the animal subgroups in the inventory. The data is derived from national practices but not from national surveys, which means that the results may lose some accuracy when generalising across the whole country. Data on dairy cattle are presented for different levels of milk production. Since the productivity varies between counties, the data on dairy cattle (

Table 7.6) has been used for interpolating an accurate mean value for each county. Values for nitrogen production per animal in each of the other animal groups are also given in

Table 7.6.

Table 7.6. Nitrogen production from different animal groups, kg N/year in 2009*.

Nitrogen production	Kg N/year
Dairy cattle	126**
Beef cows	63
Growing animals (12-24 months)	47
Calves	28
Sows/boars	34
Pigs for meat production (3 production cycles per year)	10.8
Laying hens	0.64
Chicken (2,5 production cycles per year)	0.28
Slaughter chicken (6,5 production cycles per year)	0.29
Horses/foals	50
Sheep exclusive lambs	13
Breeders of mink	4.1

*Values are calculated according to the STANK model (Swedish Board of Agriculture)[156]

** Mean value. The exact value depends on average milk production for different counties.

7.3.6 Emission factors

The main source for ammonia emission is stable manure. In Table 7.7,

[156] Swedish Board of Agriculture, 1993. Swedish Board of Agriculture 1995. Swedish Board of Agriculture 2001. The given values are calculated according to the model STANK – "Stallgödselnäring i kretslopp" the official model for input/output accounting on farm level in Sweden (Linder, 2001). STANK is currently being evaluated in a study launched by The European Commission.

Table 7.8 and Table 7.9 below, the emission factors used for ammonia in the different calculation steps are shown.
Other sources of ammonia emissions are grazing animal (cattle, horses and sheep), and use of commercial fertilisers. The used emission factors for ammonia are shown in Table 7.10 and Table 7.11.

Table 7.7. Nitrogen losses caused by ventilation in stables, % of Total-N.

Type of animal	Solid-manure	Deep litter	Liquid manure	Semisolid manure	Urine
Cattle	4	20	4	4	4
Swine	10	25	14	10	10
Laying hens	10	35	10		
Chicken	10	20	10		
Slaughter chicken			10		
Horses	4	15			
Sheep	4	15			

Table 7.8. Nitrogen losses caused by ammonia emission during storage of manure, % of total-N.

	Type of animal					
Type of manure, handling	Cattle	Swine	Laying hens/ chicken	Slaughter chicken	Horses	Sheep
Solid manure	20	20	12		25	25
Semisolid manure	10	10				
Liquid manure, uncovered						
Filled from underneath	6	8	8			
Filled from above	7	9	9			
Liquid manure, covered						
Filled from underneath:						
roof	1	1	1			
floating crust	3	4	4			
other	2	2	2			
Filled from above:						
roof	1	1	1			
floating crust	4	5	5			
other	3	3	3			
Urine, uncovered						
Filled from underneath	37	37				
Filled from above	40	40				
Urine, with cover						
Filled from underneath:						
roof	5	5				
floating crust	17	17				
other	10	10				
Filled from above:						
roof	5	5				
floating crust	20	20				
other	12	12				
Deep litter manure	30	30	20	5		33

Table 7.9. Nitrogen losses caused by ammonia emission during spreading of manure (% of total-N).

Season/ Spreading method		Spreading strategy and tillage timing	Solid manure	Urine	Liquid manure (slurry)
Early spring/late winter					
	Broadcast	Spread on frozen ground	20	40	30
	Trailing hoses			30	20
Spring					
	Broadcast	Immediately	15	8	10
		Mulching within 4 h	33	14	15
		Mulching within 5-24 h	50	20	20
		Spread on pasture	70	35	40
		Spread on grain		11	20
	Trailing hoses	Immediately		7	5
		Mulching within 4 h		14	8
		Mulching within 5-24 h		20	10
		Spread on pasture		25	30
		Spread on grain		10	15
	Shallow injection	Spread on pasture		8	15
Early summer, summer					
	Broadcast	Spread on pasture	90	60	70
		Spread on grain		10	20
	Trailing hoses	Spread on pasture		40	50
		Spread on grain		10	7
	Shallow injection	Spread on pasture		15	30
Early autumn					
	Broadcast	Immediately	20	15	5
		Mulching within 4 h	35	23	18
		Mulching within 5-24 h	50	30	30
		No mulching	70	45	70
	Trailing hoses	Immediately		10	3
		Mulching within 4 h		18	9
		Mulching within 5-24 h		25	15
		No mulching		30	40
Late autumn					
	Broadcast	Immediately	10	10	5
		Mulching within 4 h	15	15	8
		Mulching within 5-24 h	20	20	10
		No mulching	30	25	30
	Trailing hoses	Immediately		4	3
		Mulching within 4 h		11	4
		Mulching within 5-24 h		18	5
		No mulching		25	15

Table 7.10. Nitrogen losses caused by ammonia emission during grazing (% of total-N).

Type of animal	Losses, %
Cattle	8
Horses	8
Sheep	4

Table 7.11. Nitrogen losses caused by ammonia emission from commercial fertilisers (% of total-N).

Type of fertilisers	Losses, %
Ammonium sulphate	5
Ammonium nitrate	1
Liquid ammonium	4
Calcium ammonium nitrate	1
Nitrogen solution	8
Urea	15
NPK, all	1
NP, all	1
NK, all	1

Source: CORINAIR

7.4 Emissions of particles, NFR 4B and 4D

Particle emissions from animal production are allocated to specific animal groups in NFR 4 B; 4 B 1 a Cattle Dairy , 4 B 1 b Cattle Non-Dairy, 4 B 6 Horses, 4 B 8 Swine, 4 B 9 a Laying Hens, 4 B 9 b Broilers and 4 B 9 c Turkeys. Emissions from agricultural crop operations are allocated to NFR 4 D 2 a (Farm-level agricultural operations including storage, handling and transport of agricultural products).

7.4.1 Emission factors

The particle emissions are estimated using emission factors from EMEP/EEA emission inventory guidebook 2009. The Guidebook does not present emission factors for TSP and hence TSP emissions are reported as NE (Not Estimated).

As in previous submissions no changes in emission factors over time have been assumed.

The particulate emissions reported in NFR 4 D 2 a are calculated using emission factors from the EMEP/EEA emission inventory guidebook 2009, representing the Tier 2 methodology and wet conditions. These emission factors are presented in Table 7.12 and are assumed to include emissions from the use of fertilizers.

Table 7.12. Emission factors in EMEP/EEA Air Pollutant Emission Inventory Guidebook, Revision, 2007/2008 from agricultural crop operations. All represents kg ha^{-1}.

	Soil cultivation		Harvesting		Cleaning		Drying	
Crop	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Wheat	0.25	0.015	0.49	0.02	0.19	0.009	0.56	0.168
Rye	0.25	0.015	0.37	0.015	0.16	0.008	0.37	0.111
Barley	0.25	0.015	0.41	0.016	0.16	0.008	0.43	0.129
Oat	0.25	0.015	0.62	0.025	0.25	0.0125	0.66	0.198
Other arable	0.25	0.015	NA	NA	NA	NA	NA	NA
Grass	0.25	0.015	0.25	0.01				

7.4.2 Activity data

7.4.2.1 ANIMAL PRODUCTION

Statistics on the number of dairy and non-dairy cattle, pigs and laying hens are all from Statistics Sweden and the number of slaughter chicken are obtained from the Swedish Poultry Meat Association. The numbers of horses are for 1980 – 1990 based on information from the Swedish Equestrian Federation and for later years on information from Statistics Sweden. The activity data used for particulate emission estimates in NFR 4 are as activity data used for the ammonia emission estimates. In Table 7.13 activity data used for the estimates 1990 – 2010 are presented. For the calculation of particle emissions from laying hens, information on the proportion of hens held in cages and in percheries is needed since different emission factors are used for these two production systems. This information has been obtained from The Swedish Board of Agriculture[157].

7.4.2.2 AGRICULTURAL CROP OPERATIONS

For the estimates of particle emissions from agricultural crop operations the cultivated area of each crop has to be known. This data has for the period 1981 onwards been obtained from the Swedish Board of Agriculture[158]. For 1980 the activity data of 1981 has been used. The frequency of soil cultivation, harvesting, cleaning and drying has been set to one time per year for all crops but for grass for hay making. For estimates of particle emissions from grass/pasture, soil cultivation is assumed to take place every third year. In the southern and middle parts of Sweden pasture is assumed to be harvested three times per year and in the northern parts, two times per year[159]. Table 7.14 presents the activity data, 1990 – 2010, used for particulate matter emission estimates from crop operations.

[157] Sveriges genomförande av förbudet mot icke inredda burar för värphöns. Report 2007:6 (in swedish).
[158] http://www.sjv.se
[159] Personal communication 2008-10-14,Nilla Nilsdotter-Linde and Göran Bergkvist, Swedish University of Agricultural Sciences

Table 7.13. Annual average population (AAP) used for particulate emission estimates from animal production in Sweden. All represents number AAP^{-1} $year^{-1}$.

Year	4 B 1 a Cattle Dairy	4 B 1 b Cattle Non-Dairy	4 B 6 Horses	4 B 8 Swine (fattening pigs)	4 B 8 Swine (sows and boars)	4 B 9 a Laying Hens, cages	4 B 9 a Laying Hens, perchery	4 B 9 b Broilers	4 B 9 c Turkeys
1990	576 409	1 142 034	315 600	2 034 000	229 683	7 992 365	575 254	5 500 000	121 549
1991	528 212	1 178 566	315 600	1 975 000	226 839	8 064 480	660 614	5 833 333	121 549
1992	525 948	1 249 354	315 600	2 046 000	233 133	7 535 836	693 626	6 333 333	121 549
1993	524 520	1 282 846	315 600	2 028 000	249 314	6 960 300	712 472	6 333 333	121 549
1994	509 431	1 317 058	315 600	2 079 234	249 171	7 272 455	820 897	6 833 333	121 549
1995	482 118	1 294 977	315 600	2 068 187	244 950	7 041 483	870 296	7 083 333	121 549
1996	466 265	1 323 974	315 600	2 068 726	280 028	6 752 140	1 145 100	7 250 000	121 549
1997	467 981	1 312 842	315 600	2 076 716	274 486	6 236 851	1 369 065	7 833 333	121 549
1998	449 130	1 289 366	315 600	2 025 897	260 133	5 900 398	1 616 032	7 833 333	121 549
1999	448 520	1 264 400	315 600	1 890 833	224 380	5 887 382	1 962 461	7 833 333	121 549
2000	427 621	1 256 146	315 600	1 711 860	206 057	5 382 933	1 940 785	7 916 667	121 549
2001	418 471	1 233 040	315 600	1 675 690	215 766	5 333 930	2 074 306	8 708 333	121 549
2002	417 082	1 220 383	315 600	1 670 181	211 562	3 770 597	2 498 059	8 833 333	121 549
2003	402 520	1 204 154	315 600	1 694 654	208 472	2 901 031	3 105 244	8 668 333	121 549
2004	403 702	1 224 762	315 600	1 622 982	195 054	2 628 125	3 991 837	8 751 667	121 549
2005	393 263	1 211 670	323 450	1 623 104	188 112	2 758 911	4 003 125	8 386 667	121 549
2006	387 530	1 202 879	331 300	1 493 591	186 944	2 474 298	3 696 022	8 891 667	111 146
2007	369 646	1 190 079	339 150	1 494 883	181 444	2 761 359	4 319 048	8 925 000	100 743
2008	357 194	1 201 187	347 000	1 439 457	169 832	2 834 735	4 360 024	8 975 000	110 355
2009	356 776	1 181 505	354 850	1 368 474	160 265	2 820 489	4 338 113	8 533 338	119 966
2010	348 095	1 188 563	362 700	1 363 912	155 962	3 391 620	4 316 608	8 564 824	129 578

Table 7.14. Activity data used for particulate emission estimates from agricultural crop operations in Sweden. All represents the cultivated area in ha^{-1} year^{-1}.

Year	Wheat	Rye	Barley	Oat	Other arable	Grass/Pasture, southern-middle Sweden	Grass/Pasture, northern Sweden
1990	349 715	106 088	513 343	387 823	286 751	811 238	157 306
1991	259 089	83 421	504 075	360 872	250 826	814 828	153 385
1992	270 325	82 017	463 760	360 859	238 621	882 285	155 811
1993	304 399	106 359	359 382	321 963	241 788	641 419	137 682
1994	251 818	106 905	404 314	341 416	221 405	649 574	138 226
1995	261 383	111 395	381 215	278 323	209 129	652 688	137 145
1996	332 736	128 984	392 484	282 898	191 178	867 200	157 707
1997	344 043	125 692	403 397	315 466	208 569	856 117	157 136
1998	397 206	126 348	376 493	311 469	215 540	814 023	155 840
1999	275 419	90 117	395 643	305 659	242 445	837 711	150 648
2000	401 567	120 590	346 144	295 545	184 469	800 900	128 351
2001	399 165	99 414	337 257	278 173	175 826	828 741	137 583
2002	339 597	77 827	343 844	295 000	198 795	847 653	138 196
2003	411 349	94 262	305 194	279 807	181 767	838 344	138 991
2004	403 409	95 293	324 557	229 696	212 055	842 882	139 937
2005	354 752	90 523	305 480	200 121	212 331	921 771	157 974
2006	360 906	96 275	258 466	206 055	207 000	953 587	159 088
2007	361 546	93 949	268 011	207 911	189 579	981 122	160 706
2008	361 535	92 804	333 180	227 589	194 903	997 945	162 053
2009	375 118	107 229	312 296	196 036	226 065	1 010 361	162 646
2010	399 987	79 611	263 216	164 386	256 963	1 030 898	162 305

7.4.3 Reported emission

The calculated emissions of PM from the agricultural sector contribute a substantial part of national total emissions. In 2010 estimated PM_{10} emissions from animal production and agricultural crop operations contribute approximately 9 % of the calculated national total emissions of PM_{10}. The corresponding figure for $PM_{2.5}$ is 2 %. As can be seen in Figure 7.2 and in Figure 7.4 emissions of particulate matter from swine and poultry contributes to more than half of the total PM_{10} and $PM_{2.5}$ emissions from animal production.

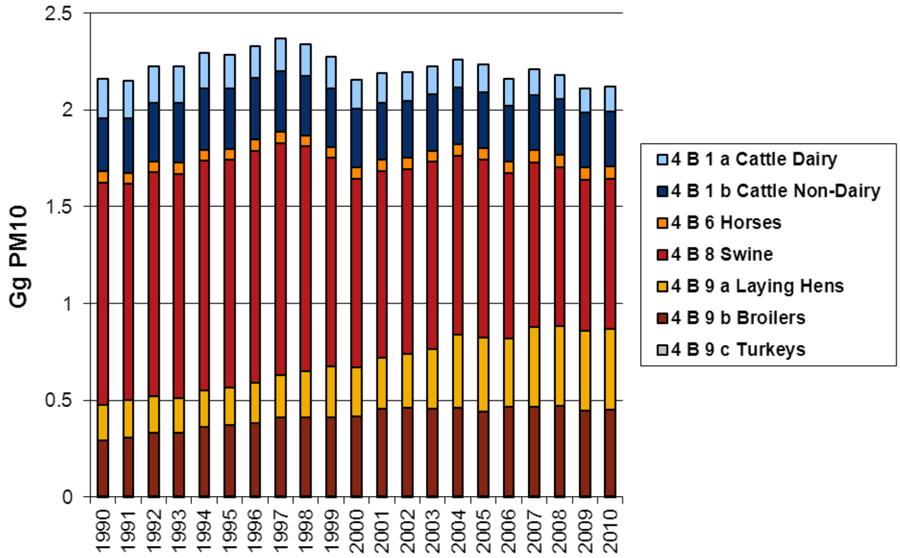


Figure 7.2. PM_{10} emissions from animal production.

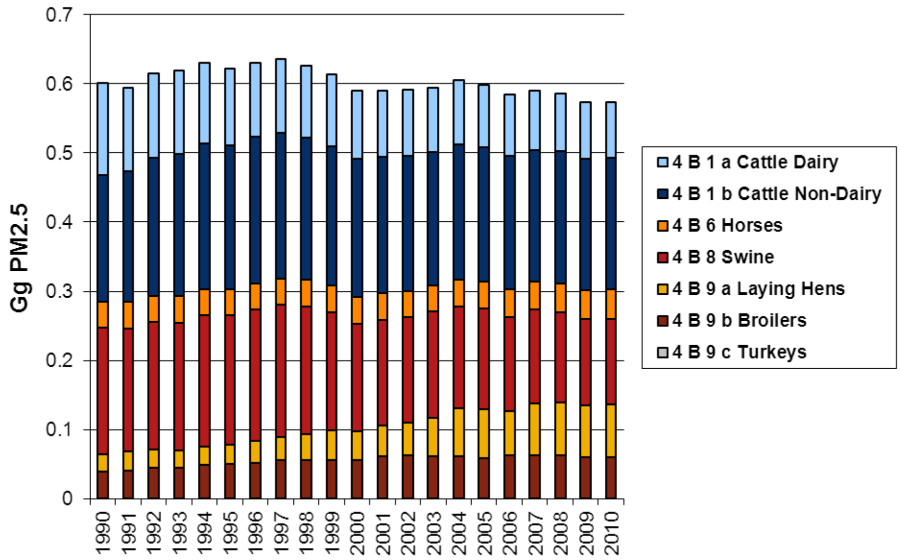


Figure 7.3. $PM_{2.5}$ emissions from animal production

In Figure 7.2 and in Figure 7.3 it can also be seen that particle emissions from swine show a decreasing trend over time due to the reduced number of swine under 20 kg. As a result of an increased share of laying hens in perchery compared to laying hens in cages, PM_{10} and $PM_{2.5}$ emissions from laying hens are showing an increasing trend.

The emissions of PM_{10} and $PM_{2.5}$ for 1990 – 2010 from agricultural crop operations are presented in Figure 7.4. The PM_{10} emissions from NFR 4 D are of the same magnitude as from NFR 4 B (animal production), around 2.4 Gg in 2010. For crop production the fraction of small particles is lower in comparison to $PM_{2.5}$ from animal production, and agricultural crop operation contributes to around 28 % of $PM_{2.5}$ in NFR 4 in 2010.

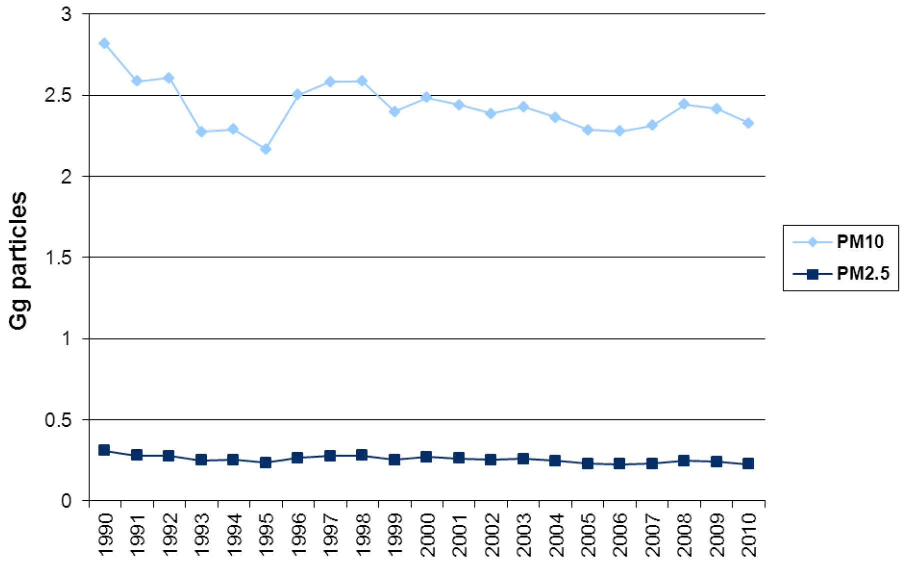


Figure 7.4. PM_{10} and $PM_{2.5}$ emissions from agricultural crop operations

7.4.4 Recalculations

- PM_{10} and $PM_{2.5}$ emissions from horses, broilers and turkeys are updated due to new activity data 1990 – 2009.
- PM_{10} and $PM_{2.5}$ emissions from swine are updated due to new activity data 1990 – 1993.

7.5 Coming improvements

No major improvements are planned for the next submission.

7.6 QC for NFR 4

7.6.1 Quality assurance

Experts at the Swedish EPA conduct a review of the inventory estimates, methodologies and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

7.6.2 Quality control

All quality procedures according to the Swedish QA/QC plan (Manual for SMED's Quality System in the Air Emission Inventories) have been implemented during the work with this sub-mission.

All Tier 1 general inventory level QC procedures and some specific Tier 2 QC procedures, listed in Good Practice Guidance section 8, have been performed and are documented in check-lists.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable.

Data have, when possible, been compared with information in legal environmental reports and/or other independent sources.

Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

8 Waste (NFR sector 6)

8.1 Overview

Emission estimates from the waste sector include waste-water handling, incineration of hazardous waste (including cremation) and various types of fires such as landfill fires, bonfires and open burning of garden waste. Combustion of municipal waste is accounted for in the energy sector, since it is used as fuel for energy production.

8.2 Solid waste disposal on land, NFR 6A

8.2.1 Source category description

This source covers emissions of NMVOC, CO, NH_3, NO_x and particulate matter (PM). EMEP/EEA emission inventory guidebook 2009 describes the emission quantities from the sector as small. At the moment, no emissions are estimated from the sector because of lack of emission factors (with an exception for an emission factor for NMVOC).

8.2.2 Methodological issues

There is a Tier 1 emission factor for NMVOC (5.65 g/m^3 landfill gas) from UK presented in EMEP/EEA emission inventory guidebook 2009, which has not been used for any calculations yet.

US Environmental Protection Agency (USEPA) evaluates that 98.7 % of the landfill gas is methane and 1.3 % are other VOCs. It remains yet to be analyzed if this result is applicable for the conditions in Sweden.

8.2.3 Recalculations

No recalculations were made to this submission.

8.3 Waste-water handling, NFR 6B

8.3.1 Source category description

This source covers estimated emissions of ammonia from the part of the population that is not connected to municipal wastewater treatment.

8.3.2 Methodological issues

The estimated emissions of ammonia are based on a model developed in the beginning of the nineties and the same value (0.4 Gg NH_3) has been reported for all years since 1990. The model is based on the estimated population in Sweden in rural areas that is not connected to municipal wastewater treatment and an emission factor.

A recent study shows no significant national trend or variation over the years in the estimated population to be applied in the calculations. There may be reasons to adjust the level of the emissions produced by the calculation model, after comparing the estimated population data used with the new population estimates.

There is also a Tier 2 emission factor for NH_3 (1.6 kg/person/year) presented in EMEP/EEA emission inventory guidebook 2009, which has not been used, since a national emission factor has been chosen.

8.3.3 Recalculations

No recalculations were made to this submission.

8.4 Waste incineration, NFR 6C

8.4.1 Source category description

Emissions from incineration of hazardous and industrial waste and, since 2003, also MSW from one large plant are reported in NFR 6Cb. In NFR 6Cd emissions of mercury, dioxin and PAH-4 from cremation are reported and in 6Ce particulate matter and PAH-4 from small scale waste burning are reported. Other possible emissions from garden burning, bonfires and landfill fires are currently not reported due to lack of suitable emission factors.

Concerning incineration of medical waste, no national activity and emission data for this source category is available.

8.4.2 Methodological issues

8.4.2.1 EMISSIONS FROM INCINERATION OF HAZARDOUS WASTE

Incineration of hazardous waste, other than cremation, occurs at nine plants in Sweden. There is one major plant for handling and destruction of hazardous waste, which is the only one for which emission data are available. For 2004 around 88% of the total amount of incinerated hazardous waste was incinerated in the major plant. The emissions are reported in 6Cb. Emissions from incineration of hazardous waste not reported in 6Cb are included in 1A1A and in 1A2c, d, e, f.

The facility included in NFR 6Cb was operated with an electrostatic precipitator (ESP) from the start in 1983 until 1990, when a textile filter with coal injection replaced the ESP. During 2000, wet flue gas cleaning was installed after the textile filter.

Reported emissions are for the whole time series obtained from the facility's environmental report or directly from the facility on request. Emissions reported are NO_X, SO_2, NMVOC, CO, particulate matter, Pb, Cd, Hg, As, Cr, Cu, Ni and dioxin. SO_2, NO_X, CO, particulate matter and Hg are continuously measured in the flue gases. Dioxins in flue gases have been measured by spot tests, but are continuously collected and analysed once a week since June 2001.

The time series for Pb, Cd, As, Cr, Cu and Ni are not consistently reported due to lack of emission information in the environmental reports for later years. For most of the years with reported notation key NE, the reason is that the amounts of metals emitted in the flue gas are below the detection limit.

The activity has increased over time. In 1995 the plant combusted about 22 000 ton and in 2002 the corresponding value was about 33 000 ton. In 2003 the capacity of the plant was increased substantially by taking a new incinerator into operation. In this new incinerator, the facility incinerates a mixture of MSW, industrial waste and hazardous waste. As a consequence of increased capacity, the emissions from 2003 are increased compared to earlier years.

8.4.2.2 MERCURY, PAH AND DIOXIN EMISSIONS FROM CREMATION

Estimated emissions of mercury, Hg, PAH-4, benzo(a)pyrene and dioxin from cremation have been calculated based on emission factors and statistics on the number of annual cremations. An expert[160] has provided emission estimates for Hg for the years 1980 - 2002, From the late 1990´s, abatement techniques have been considered in the estimations of mercury emissions. For 1980 - 1995 the estimates are given for each year as an interval. Reported emissions for these years are the average of the intervals. For 1996 - 2002 one estimate per year is given. From 2003 and onwards the IEF for 2002 is used for the emission estimates. The IEFs for 1980 - 2002 are presented in Table 8.1.

Table 8.1. Implied emission factors for Hg emission estimates 1980 – 2002. All represents kg cremated body^{-1}.

Year	IEF
1980	0.004
1981	0.004
1982	0.004
1983	0.004
1984	0.004
1985	0.004
1986	0.004
1987	0.004
1988	0.004
1989	0.004
1990	0.004
1991	0.004
1992	0.005
1993	0.005
1994	0.005
1995	0.005
1996	0.005
1997	0.004
1998	0.003
1999	0.003
2000	0.002
2001	0.002
2002	0.002

[160] Åkesson, A. Personal communication.

Emission factors used to calculate PAH-4 emissions from cremation are from USEPA[161] and for dioxin a suggested emission factor from the European Dioxin Inventory[162] was used.

UNEP[163] presents emission factors for dioxins in the range 0.4 – 90 µg TEQ/cremation, while an earlier Swedish Inventory[164] suggested 6-12 µg TEQ/cremation, referred to in the European Dioxin Inventory. An average of 9 µg TEQ/cremation has been used in the present emission estimates. This agrees with a recent experimental study that recommends 6-13 µg TEQ/cremation[165]. The number of annual cremations has increased from 47 000 in 1980 to more than 65 000 in later years, and associated dioxin emissions have thus increased from 0.42 g TEQ to approximately 0.6 g TEQ during the same period.

1.1.1.1 PARTICLES AND PAH FROM GARDEN BURNING AND BONFIRES

In order to estimate emission of PAH from burning of garden waste, emission factors from USEPA were used, while emission factors for open burning of waste suggested by CEPMEIP[166] were used to estimate emissions of TSP, PM_{10} and $PM_{2.5}$. Emission factors presented in EMEP/EEA Guidebook 2009[167], chapter “Small-scale waste burning” represents emissions from open burning of agricultural waste. A study in 2004[168] reveals that it is very rare that the farmers practice field burning in Sweden. Thus, only PAH and particle emissions are reported in NFR 6Ce.

As there are no national statistics regarding the extent of garden burning and bonfires, the data should be considered as indicative levels of emissions from these sources.

8.4.3 Recalculations

No recalculations have been made for this submission.

8.5 Other waste, NFR 6D

8.5.1 Source category description

In the sector Other waste, emissions of dioxin, PAH-4 and Hg from landfill fires (1996 and onwards) are included. Emissions of NH_3 from cats and dogs are also included in NFR 6D (1990 and onwards). No emissions from compost production

161 USEPA. 1998. Locating and Estimating Air Emissions from Sources of Polycyclic organic matter. EPA-454/R-98-014. Office of Air Quality Planning and Standards, USA
162 Quass et al., 2001. http://europa.eu.int/comm/environment/dioxin/pdf/stage1/cremation.pdf
163 UNEP, 2001. www.chem.unep.ch/pops/pdf/toolkit/toolkit.pdf
164 deWit. 1993, unpublished
165 Wang, 2003.
166 CEPMEIP, 2001. TNO.
167 http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009
168 Wikström, H. and Adolfsson, R. 2004. Field Burning of Crop Residues.

from waste are calculated because of lack of emission factors (with an exception for an emission factor for NH_3).

8.5.2 Methodological issues

8.5.2.1 EMISSIONS FROM LANDFILL FIRES

All emissions from landfill fires are in this submission based on the frequency and duration of fires in Sweden[169] and emission factors derived from measurements performed during landfill fires[170]. The fires were classified as "underground fires" (> 48 hours) or "surface fires" (< 48 hours) depending on the duration of the fire. In Table 8.2 the emission factor used are presented and in Table 8.3 the reported emissions of Hg, dioxin and PAH-4 from landfill fires are presented.

Table 8.2. Emission factors used for estimation of Hg, dioxin and PAH emissions from landfill fires.

Fire category	Hg g/hour	Dioxin g/hour	PAH benzo(a) pyrene g/hour	benzo(b) fluoranthene g/hour	benzo(k) fluoranthene g/hour	Indeno(1,2,3-cd)-pyrene g/hour
Surface	1.30	200×10^{-6}	0.15	0.24	NE	0.09
Underground	0.031	12.6×10^{-6}	------	------	------	------

Table 8.3. Number of hours of landfill fires and estimated Hg, dioxin and PAH emissions in Sweden 1996 – 2010.

Year	Surface fire, no. of hours	Underground fire, no. of hours	Hg emissions, kg	Dioxin emissions, g	Total PAH emissions, kg
1996	1284	966	1.7	0.27	0.62
1997	1108	1772	1.5	0.24	0.53
1998	654	1174	0.9	0.15	0.31
1999	733	2563	1.0	0.18	0.35
2000	969	717	1.3	0.20	0.46
2001	660	10023	1.2	0.26	0.32
2002	714	1892	1.0	0.17	0.34
2003	809	1024	1.1	0.17	0.39
2004	476	1131	0.7	0.11	0.23
2005	1771	1692	2.4	0.38	0.85
2006	1898	3255	2.6	0.42	0.91
2007	1696	3795	2.3	0.39	0.81
2008	1766	3220	2.4	0.39	0.85
2009	1522	1262	2.0	0.32	0.73
2010	1050	1866	1.4	0.23	0.50

[169] The Swedish Civil Contingencies Agency, personal communication
[170] Pettersson et al., 1996.

8.5.2.2 EMISSIONS FROM PETS

The estimates of emissions of ammonia from cats and dogs are based on a calculation made in the beginning of the nineties and the same value (0.5 Gg NH_3) has been used for the whole time period from 1990[171]. The calculation is based on data on the number of cats and dogs and an estimated value on the amount of emissions from cats and dog relative to emissions from humans.

8.5.2.3 EMISSIONS FROM COMPOST PRODUCTION FROM WASTE

There is a Tier 2 emission factor for NH_3 (0.24 kg/Mg organic waste) presented in EMEP/EEA emission inventory guidebook 2009, which has not been used for any calculations yet.

8.5.3 Recalculations

Emissions from landfill fires have been recalculated due to updated information on number of hours of surface and underground fires 2001, 2005-2009. In 2008 and 2009 emissions of Hg, Dioxin and PAH-4 decreased about 10-25 % compared to previous submission.

8.6 Coming improvements

No major improvements are planned for the next submission.

8.7 QC for NFR 6

8.7.1 Quality assurance

Experts at the Swedish EPA conduct a review of the inventory estimates, methodologies and emissions factors used. The experts also identify areas of improvement, which constitute part of the basis for improvements in coming submissions.

8.7.2 Quality control

All quality procedures according to the Swedish QA/QC plan (Manual for SMED:s Quality System in the Air Emission Inventories) have been implemented during the work with this sub-mission.

All Tier 1 general inventory level QC procedures and some specific Tier 2 QC procedures, listed in Good Practice Guidance section 8, have been performed and are documented in check-lists.

The time series for all revised data have been studied carefully in search for outliers and to make sure that levels are reasonable.

Data have, when possible, been compared with information in legal environmental reports and/or other independent sources.

Remarks in reports from the UNFCCC and CLRTAP/NEC reviews have been carefully read and taken into account.

[171] Statistics Sweden, MI 37 SM 0901. Emissions of ammonia to air in Sweden in 2007.

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