2000/1 | Rapporter | Reports

Ketil Flugsrud, Eilev Gjerald, Gisle Haakonsen, Sigurd Holtskog, Henning Høie, Kristin Rypdal, Bente Tornsjø and Fredrik Weidemann

The Norwegian Emission Inventory

Documentation of methodology and data for estimating emissions of greenhouse gases and long-range transboundary air pollutants

Statens forurensningstilsyn • Norwegian Pollution Control Authority
Oslo

Statistisk sentralbyrå • Statistics Norway
Oslo–Kongsvinger

Rapporter	I denne serien publiseres statistiske analyser, metode- og modellbeskrivelser fra de enkelte forsknings- og statistikkområder. Også resultater av ulike enkeltundersøkelser publiseres her, oftest med utfyllende kommentarer og analyser.
Reports	This series contains statistical analyses and method and model descriptions from the different research and statistics areas. Results of various single surveys are also published here, usually with supplementary comments and analyses.

ISBN 82-537-4770-5
ISSN 0806-2056

Emnegruppe
01.90 Metoder, modeller, dokumentasjon

Design: Enzo Finger Design
Trykk: Statistisk sentralbyrå

Standardtegn i tabeller	Symbols in tables	Symbol
Tall kan ikke forekomme	Category not applicable	.
Oppgave mangler	Data not available	..
Oppgave mangler foreløpig	Data not yet available	...
Tall kan ikke offentliggjøres	Not for publication	:
Null	Nil	-
Mindre enn 0,5 av den brukte enheten	Less than 0.5 of unit employed	0
Mindre enn 0,05 av den brukte enheten	Less than 0.05 of unit employed	0.0
Foreløpige tall	Provisional or preliminary figure	*
Brudd i den loddrette serien	Break in the homogeneity of a vertical series	—
Brudd i den vannrette serien	Break in the homogeneity of a horizontal series	|
Rettet siden forrige utgave	Revised since the previous issue	r

Abstract

Ketil Flugsrud, Eilev Gjerald, Sigurd Holtskog, Henning Høie, Gisle Haakonsen, Kristin Rypdal, Bente Tornsjø and Fredrik Weidemann

The Norwegian Emission Inventory
Documentation of methodology and data for estimating emissions of greenhouse gases and long-range transboundary air pollutants

Reports 2000/1 • Statistics Norway 2000

Emissions of pollutants to air cause damage to the environment, to parts of the infrastructure and to human health. To combat the effects of such emissions, Norway has in addition to its domestic environmental policy, signed the protocols on long-range transboundary air pollution (LRTAP) as well as the Climate Change Convention (UNFCCC) and the Kyoto Protocol. Both the domestic policy and international agreements put a need for the control and monitoring of the emissions.

The purpose of this documentation is to provide information on and make transparent the emission estimation methodologies used in Norway and the origin of emission factors and activity data that are used in the estimates.

The Norwegian emission inventory is a joint undertaking between the Norwegian Pollution Control Authority and Statistics Norway. The Pollution Control Authority is responsible for the emission factors and for providing data from specific industries and sources, while Statistics Norway is responsible for developing the emission models, for the collection and development of activity data, and for the calculations.

Emission estimates are made using the national emission inventory model "Kuben" (the "Cube"). Emissions from some sources are calculated in separate models (road traffic, landfills, HFCs, SF_6, PFCs, ammonia in agriculture, and solvents) and entered into "Kuben". The national emission model estimates emissions of each pollutant by technical source (a total of 34 sources), emission carrier (a total of 32 emission carriers), economic sector (131 sectors), and municipality (443 municipalities and regions outside the mainland). Emissions may be listed by the parameters above, or by combinations of them.

The emission inventory covers the greenhouse gases CO_2, CH_4 and N_2O, the traditional long-range air pollutants SO_2, NO_x, NMVOC and NH_3 (LRTAP), the heavy metals lead and cadmium, and particulate matter and CO. Only the greenhouse gases and the LRTAP gases are covered in this report. The report replaces the two previous documentations of the emission inventory, Rypdal (1993) and Rypdal (1995a).

The SO_2 and NO_x emission inventories were started in 1983, NMVOC emissions in 1987 and NH_3 in 1991. The first CO_2 emission estimate was produced in 1987. Methodologies for other greenhouse gases have been developed gradually. All methodologies have been revised since the first estimates. Complete input data for the national emission model exist for the years 1980, 1987 and 1989-1998, and national aggregated estimates since 1973. The whole time series of emissions is always recalculated whenever methodologies or emission factors are changed.

Contents

List of figures

List of tables

Appendices

1. Introduction

Emissions of pollutants to air may have local, regional or global effects. Local effects are seen in limited areas where emissions are high, e.g. towns and built-up areas, and the impact of emissions on human health is of particular importance here. The most important components of such emissions in Norway are nitrogen oxides, particulate matter and certain volatile organic compounds. The major regional problems are acidification of water and soils and damage to vegetation, and the most important pollutants involved are sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia. The global effects are depletion of the ozone layer and climate change. Compounds containing chlorine and bromine have the greatest impact on the ozone layer, and carbon dioxide, methane and nitrous oxide are the most important greenhouse gases.

Norway has signed the protocols on long-range transboundary air pollution (LRTAP) as well as the Climate Change Convention (UNFCCC) and the Kyoto Protocol, which set limits on emissions of several pollutants. Emission estimates are reported annually to the UNFCCC and the economic Commission for Europe (UNECE). Outside the framework of the protocols, emission figures are also reported to the OECD and Eurostat. However, emission figures are reported at a rather aggregated level and details of the sources included and how the estimates have been made are not provided. The purpose of this documentation is to provide information on the emission estimation methodologies used in Norway and the origin of emission factors and activity data that are used in the estimates. For many sources, the information given will make it possible for an external party to reconstruct the inventory. However, in some cases information has been aggregated to satisfy requirements for confidentiality or because too much detail will be confusing rather than clarifying the situation (e.g. details of energy consumption in manufacturing industries). The report also describes changes in emissions from individual sources over time, and gives explanations of these changes.

The Norwegian emission inventory is the result of cooperation between the Norwegian Pollution Control Authority and Statistics Norway. The Pollution Control Authority is responsible for developing the emission factors and providing data reported by industrial plants and specific industries. Statistics Norway is responsible for developing the emission models, for the collection and development of activity data, and for the calculations.

The first Norwegian inventories of SO_2 and NO_X emissions were made in 1983. NMVOC emissions were first estimated in 1987 and NH_3 emissions in 1991. The first CO_2 emission estimate was produced in 1987. Since then, methodologies for other greenhouse gases have been developed gradually, first for methane and nitrous oxide, and later for SF_6, PFC and HFCs. All methodologies have been revised since the first estimates. Methodologies and emission factors are frequently revised in connection with emission reduction plans. Complete input data for the national emission model have been stored and give emission figures for the years 1980, 1987 and 1989-1998. In addition, national aggregated estimates are available for all pollutants and years since 1973. The whole time series of emissions is always recalculated whenever methodologies or emission factors are changed.

The emission inventory covers the greenhouse gases CO_2, CH_4 and N_2O, the traditional long-range air pollutants SO_2, NO_X, NMVOC and NH_3, the heavy metals lead and cadmium, and particulate matter and CO. In this report, however, we only discuss the greenhouse gases and traditional long-range air pollutants. Emissions of the greenhouse gases PFCs, HFCs and SF_6 are estimated outside the main emission model due to the nature of the sources, but are discussed in this report. The reports replaces the two previous documentations of the emission inventory, Rypdal (1993) and Rypdal (1995a).

The report has been edited by Henning Høie, while Kristin Rypdal has been responsible for the scientific contents.

2. Summary

2.1. The national emission inventory

Emission estimates are made using the national emission inventory model "Kuben" (the "Cube"). Emissions from some sources are calculated in separate models (road traffic, landfills, HFCs, SF_6, PFCs, ammonia in agriculture, and solvents) and loaded into “Kuben”. Emissions of the main pollutants from large industrial plants are reported by the Norwegian Pollution Control Authority and fed directly into the model, after a quality control. The national emission model estimates emissions of each pollutant by

- *Technical source* (a total of 34 sources, including direct-fired furnaces, small stoves, passenger cars, bio-processes, extraction processes, etc.).
- *Emission carrier* (a total of 32 emission carriers, including coal, natural gas, gasoline, nitrogen compounds, waste, etc.).
- *Economic sector* (131 sectors according to the sector classification in the National Accounts).
- *Municipality.*

Emissions may be listed by the parameters above, or by combinations of them. This allows flexible reporting for national needs and reporting by SNAP sources (Selected Nomenclature of Air Pollution) for international purposes, for example to the UNECE, Corinair or the UNFCCC (list of abbreviations, see appendix A).

The first preliminary estimates of national emissions are made a few months after the end of the inventory year, based on the previous year's estimate and any new relevant statistics available. An update of the preliminary estimate is made about one year after the end of the inventory year. A final estimate that also includes emissions by municipality is completed a year later. However, all final estimates are updated whenever methodologies and emission factors are revised, in order to obtain consistent time series.

2.1.1. Methodologies and sources of data

The emission estimates are based mainly on internationally recommended methodologies. The Intergovernmental Panel on Climate Change (IPCC) and Corinair/EEA/UNECE (IPCC 1997a,b, EEA 1996) (list of abbreviations, see appendix A) have developed guidelines for emission estimation for all main emission sources. Their manuals are updated regularly. However, in some cases methodologies have been adjusted to take account of Norwegian conditions. In addition, more detailed studies have been undertaken in certain cases.

- Activity data are mostly taken from official statistical sources and other material available at Statistics Norway. Where activity data are not available, research reports are used or extrapolations are made from expert judgements.

- Emissions of the main pollutants from large industrial plants are based on the figures reported to the Norwegian Pollution Control Authority by the plants (based on measurements or calculations at the plants).

- Emission factors for the main emission sources are taken from reports on Norwegian conditions. International default data are used in cases where the emission factors are highly uncertain (e.g. nitrous oxide from agriculture).

- For smaller emission sources, or when national data are difficult to obtain, international data are used. The use of recommended international default data is considered to reduce the uncertainty of the national inventory in these cases.

The emissions estimation methodologies are being developed continuously. Statistics Norway and Norwegian Pollution Control Authority have initiated several studies of emissions, e.g. emissions from road, sea, and air transport, HFCs, SF_6, and landfills. Usually, such studies are connected to an evaluation of emission reduction measures. Statistics Norway is also working to increase the environmental relevance of the statistical system. As far as possible, data collection relevant to the emission inventories is integrated into other surveys and statistics.

2.1.2. Uncertainties

Uncertainty is an important aspect of inventory quality. The sources of uncertainty in the emission estimates include sampling errors, poor relevance of emission factors or activity data, and gross errors (SFT 1999e).

The emission estimates for the pollutants in the Norwegian inventory may be ranked roughly in order of increasing uncertainty as follows:

Greenhouse gases:
$CO_2 \approx SF_6 < HFC < CF_4/C_2F_6 \approx CH_4 < N_2O$

Long range air pollutants:
$SO_2 < NO_X < NH_3 \approx NMVOC$

Making an emission inventory is a laborious process involving several steps. There are two main ways of reducing uncertainties:

- Reducing the number of gross errors.
- Obtaining better scientific information, including improved input data.

An emission inventory is never final. When better input data become available, emissions are updated for all years so that a consistent time series is maintained.

2.1.3. Applications of the inventory

The inventory uses one methodology for integrated multipollutant emission estimation. The inventory is used for several purposes.

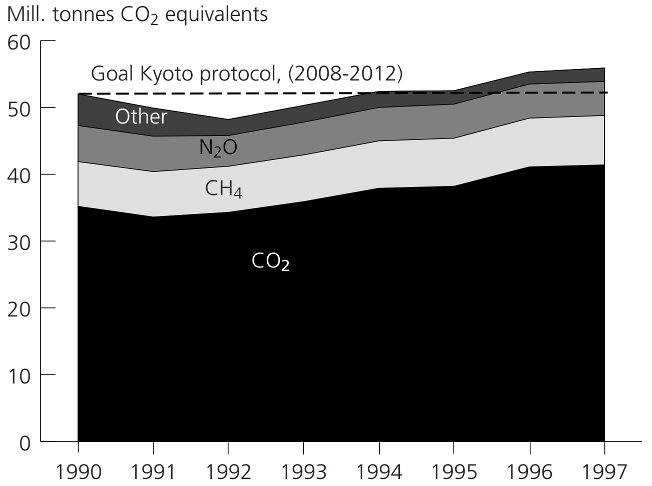
- Reporting to international protocols (UNFCCC and UNECE/EMEP).
- As a basis for reporting to the Corinair exercise.
- Reporting to Eurostat and the OECD.
- As input to the national accounts via the NOREEA matrix, which combines environmental and economic data (Norwegian Economic and Environmental Accounts) (Hass and Sørensen 1999).
- As input to air quality models for estimation and projection of local air pollution and evaluation of reduction measures.
- As a basis for government evaluation of mitigation measures, including technical regulation, taxes and possible future emission trading systems.
- As a basis for projections of emissions in the future.

2.2. Inventory results

2.2.1. Emissions of greenhouse gases (GHG)

Pollutants other than CO_2 constitute 26 per cent of total emissions, weighted by GWP values. Nearly 60 per cent of GHG emissions in Norway originate from fuel combustion. Industrial processes (especially ammonia and fertiliser production and metal production) account for around 20 per cent of the total. Agriculture and waste management emit 9 and 8 per cent of the total, respectively.

Figure 2.1. Greenhouse gas emissions in Norway. 1990-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Total greenhouse gas emissions in Norway have risen by 7.5 per cent from 1990 to 1997 (figure 2.1). CO_2 emissions have increased by 18 per cent, whereas total emissions of other greenhouse gases have decreased. In particular, emissions of PFCs from aluminium production and SF_6 from metal production have been substantially reduced since 1990. CO_2 emissions have risen in several sectors, with a particularly large rise in oil and gas production, parts of the manufacturing industries, metal production, and transport. According to its commitment under the Kyoto Protocol, Norway's greenhouse gas emissions may not rise by more than 1 per cent from the 1990 level by the period 2008-2012 (figure 2.1).

2.2.2. Emissions of long-range transboundary air pollutants

NO_X is the most important acidifying gas emitted in Norway, and accounts for about two thirds of total national emissions of acidifying substances. The largest source of NO_X emissions is national sea traffic. This is explained by the long coastline, the volume of transport between mainland and the offshore oil and gas facilities, the large fishing fleet, and the fact that no technical measures have been implemented to reduce emissions.

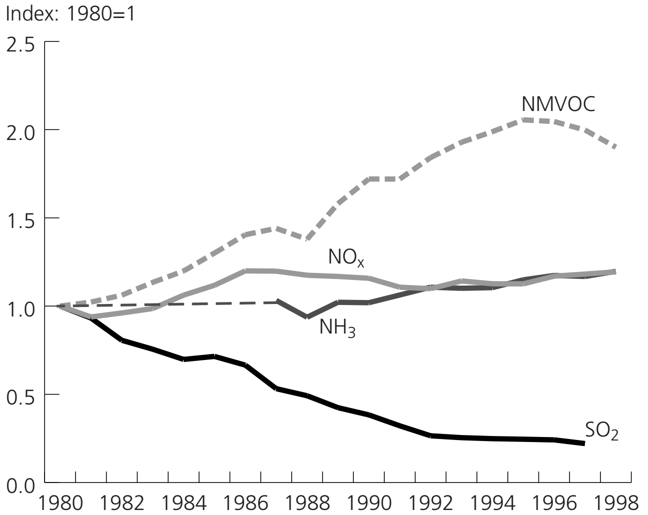
The main source of SO_2 emissions in Norway today is metal production, where coal and coke are used as reducing agents. In contrast to the situation in many other countries, electricity production in Norway is based on hydropower, and electricity is also widely used for heating.

Agriculture (use of synthetic fertiliser and manure) is the most important source of ammonia emissions.

Emissions of NMVOC in Norway are high compared to those in other European countries because of emissions from the oil production industry. More than half of all NMVOC emissions in Norway originate from this industry (particularly from loading oil onto ships).

Relative trends in emissions of long-range air pollutants since 1980 are shown in figure 2.2.

Figure 2.2. Trends in emissions of acidifying gases and NMVOC. 1980-1998



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 2.1. Emissions compared to commitments to restrict emissions. Valid until the new LRTAP protocol was signed[1]

Pollutant	Base year	Target	By year	Achieved (base year-1998[2])
SO_2	1980	76 per cent decrease	2000	-78 per cent
NO_x	1987	Stabilisation	1994	-1 per cent
NO_x	1986	30 per cent decrease	1998	-0.5 per cent
NMVOC	1989	30 per cent decrease	1999	+20 per cent
NH_3	1990	-	1990	+17 per cent

[1] The new LRTAP protocol is to be signed in late 1999. See table 2.2.

[2] SO_2: 1997.

Source: Proposition No. 1 (1998-99) to the Storting, and the emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 2.2. Emissions compared to commitments to restrict emissions in the LRTAP protocol

Pollutant	Base year	Target	By year	Achieved (base year-1998)
SO_2	1990	22 ktonnes (-58 per cent)	2010	-44 per cent
NO_x	1990	156 ktonnes (-28 per cent)	2010	+3 per cent
NMVOC	1990	195 (-37 per cent)	2010	+17 per cent
NH_3	1990	23 ktonnes (0 per cent)	2010	+10 per cent

Source: Proposition No. 1 (1999-2000) to the Storting, and the emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

3. Data for estimation of emissions

3.1. Emissions from combustion

Emissions from combustion are estimated by multiplying fuel consumption by fuel- and technology-specific emission factors (appendix E). Emissions from large plants (especially SO_2) are based on measurements or estimates at the plants reported to the Norwegian Pollution Control Authority. The inventory model is described in more detail in chapter 5.

3.1.1. Energy data

Data sources

Statistics Norway has two ways of presenting official energy data. The *energy balance* presents energy production, conversion, import, export and use in Norway, and the classification of energy use by purpose is aggregated. The energy balance follows international guidelines and is reported to the OECD and the UN. In the *energy accounts*, energy use is much more disaggregated by economic sector. The accounts are based on the energy balance, but the figures are corrected for Norwegian energy use abroad and foreign energy use in Norway, i.e. they are intended to include all Norwegian economic activity. The only differences are in the sectors for transport and fishing. The energy balance and energy accounts for 1997 are shown in appendix C. Box below explains the energy accounts and the energy balance in more detail.

The reported figures for emissions to air are based on the energy accounts. Hence, the calculated emissions cover all Norwegian economic activity. However, the calculated emissions are corrected where necessary to correspond to international guidelines as laid down by the ECE and the UNFCCC (see list of abbreviations, appendix A and list of sectors, appendix D). For example, emissions from consumption of bunker fuel in international sea traffic or in air transport abroad are calculated, but are subtracted from the reported figures. The energy accounts also include fuel consumed as raw materials or reducing agents. This consumption is subtracted before combustion emissions are calculated. Emissions from fuels used as raw materials or reducing agents are treated as non-combustion emissions.

The energy balance and energy accounts use several data sources. Statistics Norway prepares official sales statistics for liquid commercial fuels for the Norwegian Petroleum Industry Association. These statistics are the main data source for the energy accounts.

The quality of the energy data varies between main sectors. Energy use in the largest manufacturing industries is reported annually to Statistics Norway and the reliability of these figures can be considered to be high, whereas much uncertainty is connected to the calculation of energy use in public and private services.

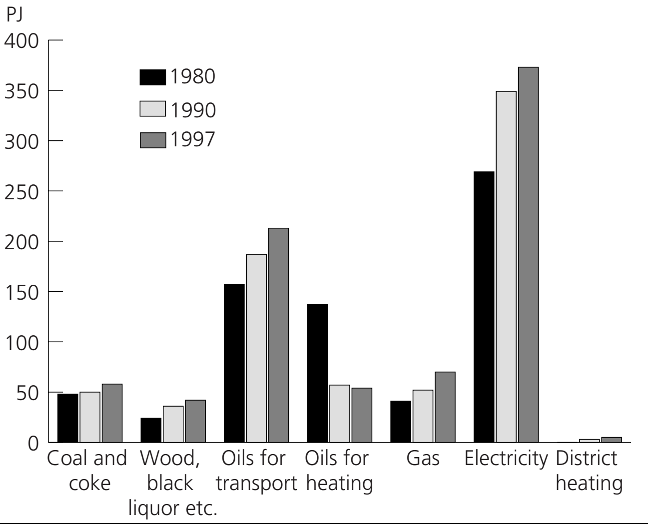
General energy use

Total energy use in Norway, excluding international sea traffic, was 1 038 petajoules (PJ) in 1998. About 18 per cent of this was used in the energy sectors (sectors generating energy commodities, primarily oil and gas production, petroleum refineries and hydroelectric plants) (see appendix C).

The energy accounts and the energy balance

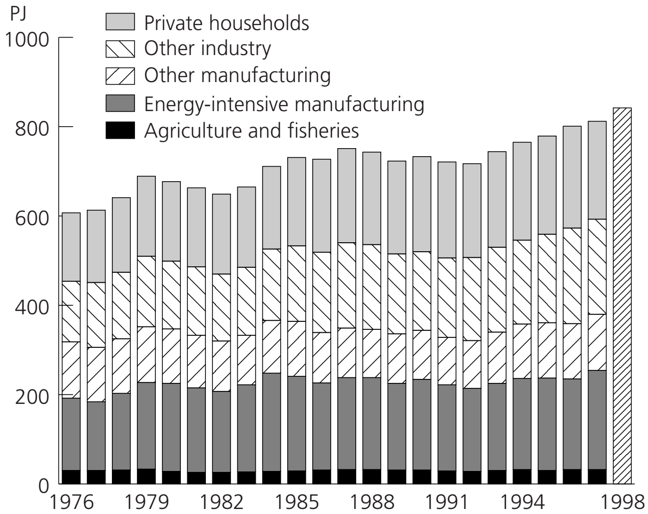
The energy accounts and the energy balance are two different ways of presenting the supply and use of energy. The energy accounts are set up on the pattern of the national accounts, and follow energy use in Norwegian economic activities. The energy balance follows the flow of energy within Norway. This means that the figures include only energy sold in Norway, regardless of the users' nationality. In the energy accounts all energy used by Norwegian enterprises and households is included, even if the energy is bought abroad. This leads to different figures for international sea traffic and aviation. The energy balance separates out energy used for transport, whereas the energy accounts place all energy use under the relevant consumer sector, regardless of whether it is used for transport or heating. Apart from coal and coke, energy carriers used as raw materials are segregated in the energy balance, but allocated to industry and fuel consumption in the energy accounts.

Figure 3.1. Energy use[1] in Norway, by energy commodity



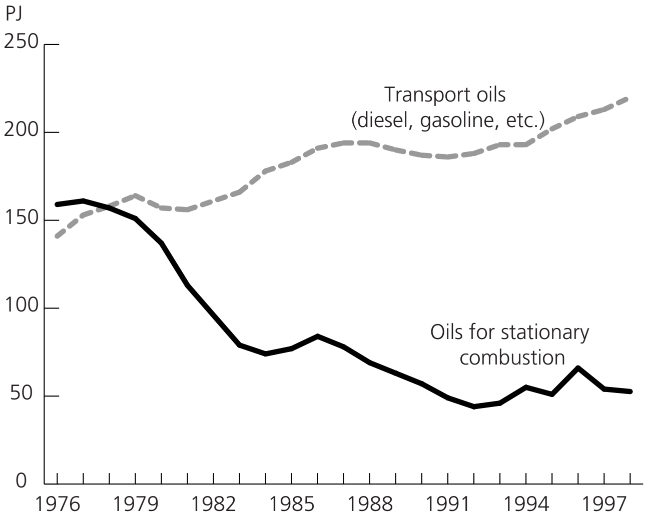
[1] Excluding the energy sectors and international sea traffic, including energy used as raw materials.
Source: Energy Statistics from Statistics Norway.

Figure 3.2. Energy use[1] by consumer group. 1976-1998



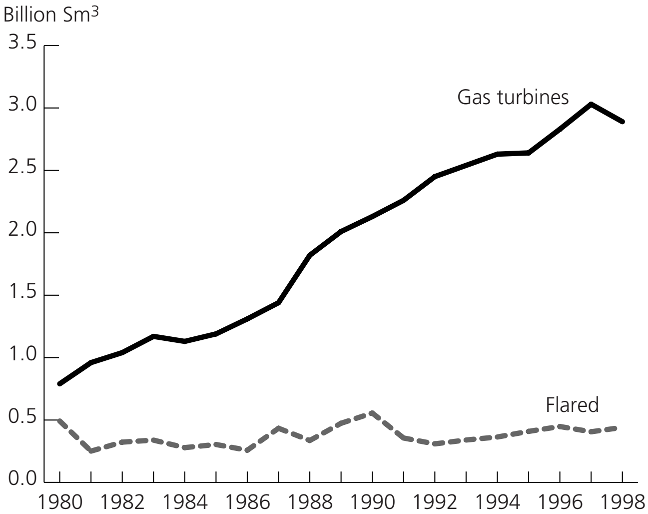
[1] Excluding the energy sectors and international sea traffic.
Source: Energy Statistics from Statistics Norway.

Figure 3.3. Consumption[1] of oil products. 1976-1998



[1] Excluding the energy sectors and international sea traffic
Source: Energy Statistics from Statistics Norway.

Figure 3.4. Combustion of natural gas in petroleum extraction. Gas turbines and flaring. 1980-1998



Source: Norwegian Petroleum Directorate.

Domestic energy consumption, i.e. consumption excluding the energy sectors and international sea traffic, was 676 PJ in 1980, 733 PJ in 1990 and 846 PJ in 1998. This gives an average annual increase of 1.1 per cent from 1980 to 1997 and 1.5 per cent from 1990 to 1997. From 1997 to 1998, consumption increased by 4 per cent. Consumption of the various energy commodities used in Norway in 1980, 1990 and 1997 is shown in figure 3.1. About half the energy consumed in Norway is hydroelectricity.

Total domestic energy use has increased by about 20 per cent in the last 17 years, and by about 10 per cent since 1990 (figure 3.2). In the 1980s in particular, electricity was substituted for oil for heating purposes. Consumption of heating oils dropped by more than 60 per cent in the period 1980-1998, but by only 7 per cent from 1990 to 1998. Gasoline consumption has shown an overall decrease in the period 1990-1998, but increased slightly from 1997 to 1998. Diesel consumption increased steadily from 1980 to 1998.

As a result of the increase in the level of activity in the North Sea, energy use in the energy sectors has risen strongly, from 66 PJ in 1980 to 192 PJ in 1998. Natural gas accounted for 30 PJ of this in 1980 and 148 PJ in 1998. Combustion of natural gas in the extraction of crude oil and natural gas has nearly tripled (figure 3.4). However, there was a reduction from 1997 to 1998, mainly because production of crude oil dropped. Before this reduction, natural gas combustion had increased continuously since 1980.

The gas is mainly used for energy purposes, but some is flared. The quantity of natural gas flared has been relatively stable since 1980. Even though overall energy use in the extraction of oil and gas is higher now than in 1980, energy use per unit of production has been reduced by the introduction of more modern production technology. Diesel is also used in petroleum extraction, in diesel engines and in turbines.

Use of fuels split by emission source

Emissions of a given pollutant from combustion usually depend on the combustion technology and amount of fuel consumed. Therefore, in order to calculate emissions of technology-dependent pollutants, we need to differentiate between the technical sources where combustion takes place. Within each economic sector, consumption of each fuel is split between the sources available in the emission model (see chapter 5). Consumption is allocated on the basis of information on activities in each sector or, if necessary, on special calculations or surveys.

The fuels gasoline, auto diesel and marine gas oil/diesel oil are generally used for transport. Marine diesel is also used on drilling and extraction platforms (stationary combustion). Calculations are carried out in order to split the consumption of gasoline and auto diesel between different kinds of road traffic and other uses (e.g. motorised equipment). Heavy fuel oil is mainly used in ships in the transport sector, but small quantities are also used in the fishing and extraction sectors. Solid fuels and kerosene are burnt in small stoves in private households. Coal, coke and heavy fuel oil are used in direct-fired furnaces in certain industries, e.g. metal and cement production. Light fuel oil is generally combusted in boilers of various sizes.

The fuels that give rise to emissions, their total consumption in 1997 and their theoretical specific energy content are listed in table 3.1.

Solid fuels

Coal-, gas- and oil-fired power plants are of little importance in Norway. Coal and coke are used mainly in the production of mineral products, above all in direct-fired furnaces in cement production. In addition, small amounts are used in greenhouses and private households. The largest share, however, is used as reducing agents in metal production and as raw materials in the production of carbides. The consumption figures are based on annual reports from industrial plants and on trade data.

Wood is an important source of energy in Norway. It is mainly used in households and in the wood-processing industry. Industrial consumption is determined using a combination of figures from branch organisations, figures reported directly to Statistics Norway and in some cases projections of reported figures for earlier years. Consumption in private households is more uncertain. The estimate is based on Statistics Norway's yearly Survey of Expenditure, and shows that about 10 per cent of the energy used in private households is wood. Nearly three quarters of Norwegian households have a wood fuel stove or an open fireplace (Bøeng and Nesbakken 1999).

Combustion of waste in combined heat and power plants (plants that produce both electricity and district heating) and district heating plants is included in the energy balance and accounts. Waste combustion figures are reported yearly to the Norwegian Pollution Control Authority and Statistics Norway, and are included in the energy balance and accounts. Consumption of solid fuels outside the energy sectors and excluding the use of energy as a raw material has increased by 72 per cent from 1980 to 1997, mainly due to a rise in the use of biofuels.

Table 3.1. Fuel consumption figures used to calculate emissions to air from combustion. Energy content of fuels. 1997

Fuel	Consumption[1]	Unit	Energy content	Unit
Coal[2]	252	ktonnes	28.1	TJ/ktonnes
Coal coke	15	ktonnes	28.5	TJ/ktonnes
Petrol coke	7	ktonnes	35	TJ/ktonnes
Wood etc.	2591	ktonnes		
- Fuel wood	1343	ktonnes	16.8	TJ/ktonnes[3]
- Black liquor (dry matter)	595	ktonnes	14	TJ/ktonnes[3]
- Wood waste	653	ktonnes	16.8	TJ/ktonnes[3]
Waste	459	ktonnes	10.5	TJ/ktonnes
Gasoline, cars	1664	ktonnes	43.9	TJ/ktonnes
Gasoline, aviation	2	ktonnes	43.9	TJ/ktonnes
Kerosene, heating	168	ktonnes	43.1	TJ/ktonnes
Kerosene, jet, all aviation in Norway[4]	623	ktonnes	43.1	TJ/ktonnes
-of this, domestic aviation	391	ktonnes	43.1	TJ/ktonnes
Auto diesel	1490	ktonnes	43.1	TJ/ktonnes
Marine fuel	1317	ktonnes	43.1	TJ/ktonnes
Heating oils, light	637	ktonnes	43.1	TJ/ktonnes
Special distillates	214	ktonnes	43.1	TJ/ktonnes
Heavy fuel oil	342	ktonnes	40.6	TJ/ktonnes
Waste oil, paint, varnish	57	ktonnes	40.6	Tj/ktonnes
Crude oil	35	ktonnes	42.3	TJ/ktonnes
Refinery gas	655	ktonnes	48.6	TJ/ktonnes
Refinery gas (flaring)	63	ktonnes	48.6	TJ/ktonnes
LPG	94	ktonnes	46.1	TJ/ktonnes
Excess gas	235	ktonnes	50	TJ/ktonnes
Natural gas	3441	MSm^3	40.8[5]	TJ/MSm^3
Natural gas (flaring)	467	MSm^3	40.8[5]	TJ/MSm^3
Methane (landfill gas)	17	ktonnes	50.2	TJ/ktonnes

[1] Combustion only. Excluding international sea traffic.
[2] Hard coal.
[3] Dry solid fuel.
[4] Foreign airlines included.
[5] Factor for 1997. The average differs from one year to another.
Source: Energy Statistics from Statistics Norway.

Gaseous fuels
Combustion of natural gas takes place mainly in the oil and gas extraction sector, where most of it is used for energy purposes and some is flared. The Norwegian Petroleum Directorate reports consumption figures for all platforms on the Norwegian part of the continental shelf, the Norwegian economic part of platforms shared with the UK and consumption at the two onshore gas terminals. From the mid-1990s, a small but increasing amount of natural gas has also been utilised in some manufacturing industries, and this consumption is reported to Statistics Norway by the enterprises. Refinery gas is combusted at the oil refineries and is partly used for energy purposes and partly flared. Some large industrial plants use an excess petrochemical gas which is composed mainly of methane and hydrogen. A large quantity of methane is emitted from landfills. A small proportion of this is extracted and partly used for energy purposes and partly flared (see section 3.2.14 Landfills). Liquefied petroleum gas (LPG) is mainly used as a raw material for the manufacture of plastics and ammonia. There is also some combustion in the manufacturing industries, in addition to a small quantity used in private households. Total consumption of gaseous fuels outside the energy sectors has increased from 4 PJ in 1980 to 22 PJ in 1997 excluding use as raw material.

Liquid fuels
Oils for non-transport purposes accounted for about 7 per cent of domestic energy use in 1997, and transport oils accounted for a quarter of energy use (see figure 3.1). The largest fraction of this was gasoline for road traffic, followed by diesel for road traffic and marine fuels (mainly used in ships and fishing vessels).

The sales statistics for petroleum products, derived from reports on sales figures from the oil companies, constitute the basis for annual figures on the use of different oil products in Norway. These are the basis for the calculation of Norwegian emission figures by economic sectors.

The major manufacturing plants report their use of all forms of energy directly to Statistics Norway each year (manufacturing statistics). Energy used as fuel and energy used as raw materials or reducing agents are reported separately. Energy use in smaller plants is estimated. The figures on use of the middle distillates in the manufacturing industries may be somewhat uncertain, as the calculated figures (reported and estimated) usually differ from the sales statistics. The consumption figures for diesel, marine fuel and heating oils are redistributed to agree with the sales figures.

The sales statistics give more aggregated data than the energy accounts. There is substantial uncertainty connected to the allocation of consumption to sectors where little information relevant to fuel consumption is available, such as public and private services. In some sectors, occasional surveys are used as a basis for allocating consumption.

Industrial use of spill oil, paint and varnish as a fuel is reported by the Norwegian Resource Centre for Waste and Recycling (Norsas).

Transport fuels
Aviation
Both kerosene-type jet fuel and gasoline-type aircraft fuel are used in aircraft. Gasoline is used in small aircraft only. Use of aircraft gasoline is allocated to sectors in the energy accounts according to the petroleum statistics.

The airlines have reported domestic consumption of jet kerosene to Statistics Norway since 1993. The survey is annual, but data from the surveys for 1993 and 1994 have not been used here as one of the largest airlines in Norway was not included. Domestic consumption prior to 1995 is estimated by extrapolation on the basis of domestic kilometres flown.

Consumption of bunker fuel[1] in Norway, which is reported to the UNFCCC, is estimated as the difference between total purchases of jet kerosene in Norway for civil aviation (Petroleum Statistics) and reported domestic consumption, given by the survey mentioned above. The quantities of fuel bought abroad by Norwegian airlines are reported directly to Statistics Norway by the airlines.

Emission and energy data are needed for the following purposes:

- Consumption of jet kerosene in the LTO cycle of all Norwegian and international flights is needed for reporting to the ECE, where emissions from all LTOs (landing-and-take-off) in Norway are included irrespective of the destination of the aircraft.
- The UNFCCC needs figures for emissions from domestic aviation and bunker fuel.
- NOREEA needs emissions from all Norwegian activity, domestic and international flights.

Consumption of fuel by Norwegian international flights is calculated as follows:

Norwegian purchases in Norway - domestic consumption + Norwegian purchases abroad

Emissions from Norwegian international flights inside Norway are calculated by assuming that 50 per cent of this fuel consumption takes place in Norway and 50 per cent outside Norway.

[1] All fuels sold in Norway used for international traffic.

Table 3.2. Fuel consumption in national sea traffic. 1993. ktonnes

	Total	Diesel/ gas oil	Special distil-lates	Heavy fuel oil
Total	1058	903	76	78
Fishing vessels	385	366	17	1
Coastal traffic	403	312	51	40
- Freighters	177	132	5	40
- Ferries and passenger ships	226	181	46	-
Oil related vessels	189	164	8	17
- Supply/standby ships	105	97	8	-
- Crude oil shuttle tankers	17	1	-	16
- Mobile drilling rigs	65	65	-	-
- Other	1	-	-	1
Other vessels	81	61	-	21
- Rescue vessels	2	2	-	-
- Military vessels	32	32	-	-
- Vessels owned by the coastal authorities	5	5	-	-
- Other[1]	42	22	-	21

[1]Very crude estimate.
Source: Flugsrud and Rypdal (1996).

Sea traffic
For fuel consumption in national sea traffic we use figures from Statistics Norway's sales statistics for petroleum products (Petroleum Statistics). Consumption in Norwegian international sea traffic is based on an estimate of expenditure, prices and an approximate allocation to Norwegian and international consumption. The Petroleum Statistics give figures for international bunker fuel. Flugsrud and Rypdal (1996) have calculated fuel consumption and emissions to air from national sea traffic directly. For cargo vessels, consumption is known from surveys. Other fuel data are collected directly from the shipowners (e.g, the Norwegian Defence Forces). Table 3.2 shows fuel consumption as calculated by Flugsrud and Rypdal (1996).

Fuel consumption for fishing vessels is calculated from data on expenditure (Flugsrud and Rypdal 1996). The expenditure is known from an annual survey that covers all ships larger than 8 metres. The data are uncertain due to incomplete responses and uncertainties in prices.

3.1.2. Emission factors
Emissions from combustion are split into two groups by source; stationary and mobile combustion. Stationary combustion includes emissions from all combustion of energy commodities in various types of stationary equipment. The most important of these are direct-fired furnaces where combustion of energy commodities provides heat for a particular industrial process, boilers where energy commodities are used to heat water, e.g. to form steam, small stoves that use oil or wood to heat housing, and flaring (combustion of fuels without using the energy).

Mobile combustion includes emissions from all combustion of fuels in various modes of transport and mobile motorised equipment.

Stationary combustion
As described in chapter 5, emissions from combustion are calculated by multiplying the activity data (e.g. tonnes fuel) by an emission factor (e.g. in tonnes CO_2 per tonne fuel). This chapter describes the emission factors for the various pollutants originating from stationary combustion used in the Norwegian emission model.

CO_2
In 1997, oil and gas extraction accounted for 50 per cent of stationary CO_2 emissions, and most of these originated from the combustion of natural gas. The rest of the manufacturing industry and the gas terminals accounted for 38 per cent of the stationary CO_2 emissions (appendix B). For liquid fuels, coal and coke we generally use emission factors reflecting the average carbon content of Norwegian fuels (SFT 1990 and Norwegian Petroleum Industry Association). The emission factor for CO_2 from flaring of natural gas is from a study by the Norwegian Oil Industry Association (OLF 1994). We do not consider net CO_2 emissions from wood/biomass burning in the inventory, because the amount of CO_2 released during burning is the same as that absorbed by the plant/tree during growth. However, emissions from wood and biomass will be calculated here for comparison. For the same reason, the CO_2 emission factors used in the inventory for combustion of methane from landfills include only the fossil part of the emissions (estimated at 7.5 per cent). The emission factor for combustion of waste (also fossil part only) was calculated by SFT (1996). Carbon emitted in compounds other than CO_2, e.g. as CO, CH_4 and NMVOC, is included in the CO_2 emission estimates. This intentional double counting of carbon is in accordance with the IPCC guidelines (IPCC 1997b). The emission factors are shown in table 3.3.

CH_4 and N_2O
In 1997, private households accounted for 63 and 32 per cent respectively of stationary emissions of CH_4 and N_2O. Only about 3 and 2 per cent respectively of total CH_4 and N_2O emissions originate from stationary combustion.

Emission factors for CH_4 and N_2O, unlike those for CO_2, depend on the source of the emissions and the sector where the emissions take place. Information about these emission factors is unfortunately limited. The emission inventory mostly uses default factors from the IPCC (1997b) (see tables 3.4 and 3.5). Some factors used for the oil and gas sectors and waste combustion are from Norwegian sources (OLF 1994 and SFT 1996). The emission factor for methane from fuel wood is taken from SINTEF (1995). Because of the lack of data, some emission factors are used for sector/source combinations other than those they have been estimated for.

Table 3.3. Emission factors for CO_2 from combustion of various energy commodities. Tonnes per unit weight, volume and energy content

	Tonnes CO_2/tonne	CO_2 /kSm[3]	Tonnes CO_2/TJ
Coal[1]	2.42		86.1
Coal coke	3.19		111.9
Petrol coke	3.59		102.6
Wood etc.	0.0 (1.8[2])		0.0 (96[2])
Waste	0.25		23.8
Natural gas	2.75	2.34	57.3
Natural gas (flaring)	2.86	2.43	-
Refinery gas	2.80		57.6
Excess gas	2.50		50.0
Landfill gas[3]	0.275		
LPG	3.00		65.1
Gasoline (cars)	3.13		71.3
Gasoline (aviation)	3.13		71.3
Kerosene (heating)	3.15		73.1
Kerosene (aviation) (jet fuel)	3.15		73.1
Diesel (road transport)	3.17		73.5
Marine diesel/gas oil	3.17		73.5
Light fuel oil	3.17		73.5
Heavy fuel oil	3.20		78.8
Waste oil	3.20		78.8

[1]Individual emission factors for two factories are used for coal.
[2]Non-fossil emissions not included in the inventory.
[3]Only fossil carbon is taken into account (plastic, rubber, PVC, polyethylene etc.).
Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

SO_2

In 1997, the manufacturing sectors accounted for 75 per cent of stationary SO_2 emissions. The oil and gas industry was only responsible for 3 per cent, while households accounted for 12 per cent of the emissions.

The emission factors used in 1997 are shown in appendix E. The Norwegian Petroleum Industry Association contributes figures for the sulphur content of liquid fuels. All values are updated annually. The sulphur content of most fuels has been reduced since 1980 (table 3.6). For solid fuels (coal, coke or black liquor) used in major large industrial plants, annual plant-specific averages are used. Eight waste incineration plants report emission figures based on measurements to the Norwegian Pollution Control Authority. We use these emission data directly in the emission model. For other uses of solid fuels we use the values in appendix E every year. Gases and liquefied gases have no significant sulphur content.

It is assumed that 100 per cent of the sulphur content is emitted, except in the case of the largest industrial plants and the combustion of coal and coke generally. In these cases, emissions may be reduced by the retention of sulphur in ash or products, or by cleansing. It is assumed that 98 per cent of the sulphur is retained in cement production, and 30 per cent in the production

Table 3.4. Emission factors for CH_4 from stationary combustion of various fuels

Fuel	Source	Sector	Emission factor (kg/tonne fuel)	Reference
Coal	Direct-fired furnaces	Cement and structural clay	0.028	2
Natural gas/other gas	Direct-fired furnaces	General	0.054	2
Marine diesel	Direct-fired furnaces	General	0.16	6
Light/heavy fuel oil and waste oil	Direct-fired furnaces	General	0.04	1
Natural gas	Turbines	General	1.07	3
Other gas	Turbines	General	0.05	1
Marine diesel	Turbines	Oil and gas extraction	0	3
Natural gas/other gas	Flaring	General	0.28	3
Other gas	Flaring	Refuse disposal	0.37	4
Coal	Boilers	Manufacturing - energy	0.03	1
Coal	Boilers	General/manufacturing - except energy	0.28	1
Coal coke and petrol coke	Boilers	General/manufacturing	0.28	1
Wood etc.	Boilers	General/manufacturing	0.25	2
Natural gas	Boilers	Manufacturing - energy	0.05	1
Natural gas	Boilers	Manufacturing - except energy	0.24	1
Other gas	Boilers	General/manufacturing	0.24	1
LPG/kerosene	Boilers	General/manufacturing	0.17	1
Fuel oil	Boilers	Manufacturing	0.1	1
Fuel oil	Boilers	General	0.4	1
Coal/coal coke	Small stoves	General/private	8.4	1
Wood	Small stoves	General/private	5.3	5
LPG	Small stoves	General/private	0.24	1
Kerosene (heating)	Small stoves	General/private	0.3	1
Light fuel oil	Small stoves	General/private	0.4	1

Source: 1: IPCC (1997b), Tier 1. 2: IPCC (1997b), Tier 2. 3: OLF (1994). 4: SFT (1996). 5: SINTEF (1995). 6: SFT/SSB (1999).

Table 3.5. Emission factors for N_2O from stationary combustion of various fuels

Fuel	Source	Sector	Emission factor (kg/tonne fuel)	Reference
Natural gas/other gas	Direct-fired furnaces	General	0.024	2
Marine diesel/fuel oil	Direct-fired furnaces	General	0.03	1
Waste oil	Direct-fired furnaces	General	0.03	1
Natural gas	Turbines	General	0.022	2
Marine diesel/natural gas	Turbines	Oil and gas extraction	0.024	2
Other gas	Flaring	Refuse disposal	0.0015	3
Marine diesel	Flaring	General	0.024	2
Coal/coal coke/petrol coke	Boilers	General/manufacturing	0.04	1
Wood etc.	Boilers	General/manufacturing	0.07	1
Natural gas/other gas	Boilers	General/manufacturing	0.005	1
LPG	Boilers	General/manufacturing	0.03	1
Kerosene (heating)	Boilers	General/manufacturing/private	0.03	1
Diesel (road transport)	Boilers	General/manufacturing	0.03	1
Marine diesel/fuel oil	Boilers	General/manufacturing	0.03	1
Coal/coal coke	Small stoves	Private	0.04	1
Wood	Small stoves	Private	0.07	1
LPG	Small stoves	Private	0.03	1
Kerosene (heating)	Small stoves	General/private	0.03	1
Light fuel oil	Small stoves	General	0.03	1

Source: 1: IPCC (1997b), Tier 1. 2: OLF (1994). 3: SFT (1996).

Table 3.6. Average sulphur content[1] of different oil products. Per cent S

	Gasoline	Kerosene	Middle distillates	Heavy fuel oil <1 per cent sulphur	Heavy fuel oil >1 per cent sulphur
1980	0.05	0.01	0.33	0.95	2.30
1981	0.05	0.02	0.36	0.95	2.30
1982	0.05	0.01	0.32	0.95	2.30
1983	0.05	0.02	0.35	1.00	2.30
1984	0.05	0.01	0.22	0.85	2.25
1985	0.035	0.02	0.22	0.97	2.30
1986	0.035	0.02	0.22	0.97	2.20
1987	0.035	0.02	0.22	0.95	2.20
1988	0.035	0.02	0.20	0.95	2.20
1989	0.03	0.02	0.17	0.91	2.00
1990	0.03	0.015	0.16	0.85	1.97
1991	0.03	0.019	0.14	0.84	2.18
1992	0.03	0.016	0.13	0.82	2.13
1993	0.03	0.021	0.11	0.81	2.29
1994	0.03	0.018	0.07	0.71	2.24
1995	0.012	0.023	0.07	0.59	2.17
1996	0.011	0.025	0.06	0.63	2.33
1997	0.008	0.023	0.06	0.63	2.36

[1] It is possible to calculate figures in kg SO_2/tonnes of oil by multiplying the S percentages by 20.

Source: Norwegian Petroleum Industry Association.

of concrete pumice stone. For use of coal and coke generally (except for manufacture of cement and concrete pumice stone) 3 per cent retention in ash is normally assumed (Rosland 1987). Emissions are controlled through abatement measures at some of the large plants, e.g. pulp and paper plants and refineries. In these cases emission estimates are based on measurements and not on emission factors.

NO_X and NMVOC

The emission factors for NO_X and NMVOC also depend on the source/sector combination. The emission factors used in the year 1997 are shown in appendix E. With few exceptions they are taken from Rosland (1987). Stationary combustion accounts for approximately 21 and 3.5 per cent respectively of total NO_X and NMVOC emissions. The most important sources are discussed in the following paragraphs.

Oil and gas extraction and drilling

Emissions from extraction of oil and gas contributed 67 per cent of Norwegian stationary NO_X emissions in 1997. Emission factors have been derived from measurements coordinated by the Norwegian Oil Industry Association (OLF 1994). The sources considered are combustion of natural gas in gas turbines and flares and combustion of diesel in gas turbines and diesel engines. Diesel is used on drilling (mobile) platforms and on production platforms if it is not feasible to use natural gas. Gas is flared on production platforms. In well testing, the collected oil and gas is flared due to lack of transport facilities.

Residential fuelwood combustion

The most important stationary NMVOC source is residential fuelwood combustion in private households, which accounts for 70 per cent of stationary emissions. The emission factor for NMVOC from residential fuel wood combustion, 6.9 kg NMVOC/tonne wood, is derived from a study carried out by the Norwegian Institute for Air Research (Braathen et al. 1991). Formaldehyde is not included in this emission factor. The emission factors for all sources are given in appendix E.

Waste combustion

For emissions from waste combustion, NO_X emissions as reported to the Norwegian Pollution Control Authority by the plants are used in the model. For NMVOC, emissions are calculated using an emission factor of 0.7 kg/tonne (SFT 1996).

Mobile sources

Road traffic

Emissions from road traffic are an important part of total national emissions, especially for CO_2 (21 per cent in 1997), NO_X (27 per cent), and NMVOC (16 per cent). They contribute an even higher proportion of CO emissions (61 per cent), which are not covered in this report.

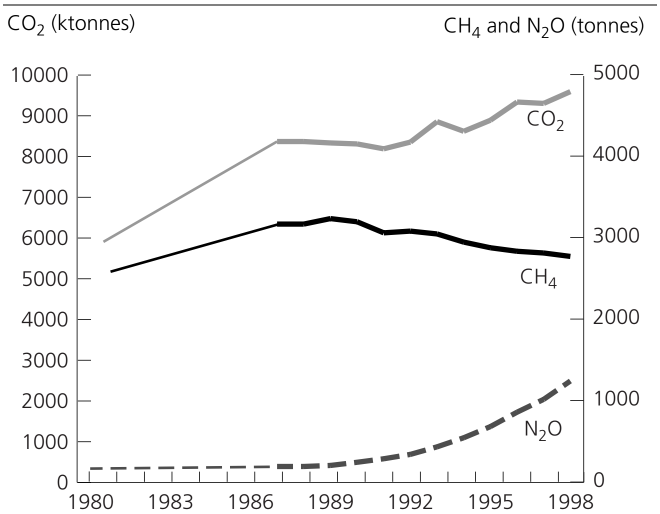
A model for estimating emissions from road traffic was developed in 1993 (SFT 1993) and revised in 1998 (SFT/SSB 1999). The model is described in more detail in chapter 5.4. The results (as average emission factors) from this model are used as input to the general emission model.

The model is fuel-based, since total national fuel consumption is assumed to be more certain than mileage data. Activity data such as vehicle numbers and mileages are used to allocate fuel consumption to usage classes. For several pollutants (CO_2, SO_2, heavy metals), we can use general emission factors that depend only on the fuel type, and the calculation is straightforward. For other pollutants, the factors depend on vehicle type and size, fuel type, technology, age, and driving pattern.

The factors are derived from driving cycle measurements made in Norway and other countries. The most important sources, besides Norwegian measurements reported in SFT (1993), are data from Corinair/Copert (Eggleston et al. 1991, EEA 1997) and the German Umweltbundesamt (Hassel et al. 1994). Emissions from warm engines and additional emissions from evaporation and cold starts are calculated separately. Evaporative emissions are estimated by the method described in the Corinair Guidebook (EEA 1996). Cold start emissions are calculated using factors from Copert and Sérié and Joumard (1996), taking into account detailed driving patterns and regional temperature data. NMVOC and methane factors are derived from VOC data, applying results from measurements of NMVOC to methane ratios. Ageing of vehicles has been taken into account by introducing ageing factors per 10 000 km. A simplified method is used for motorcycles and mopeds. The average factors for 1997 are shown in table 3.7. More detailed factors and factors in g/km are given in appendix E.

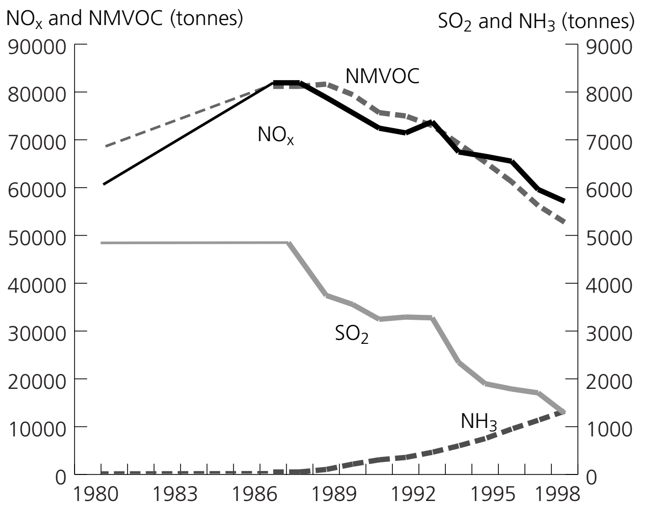
Trends in greenhouse gas emissions from road traffic are shown in figure 3.5.

Figure 3.5. Emissions of greenhouse gases from road traffic in Norway. 1980-1998



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.6. Emissions of SO_2, NO_x, NMVOC and NH_3 from road traffic in Norway. 1980-1998



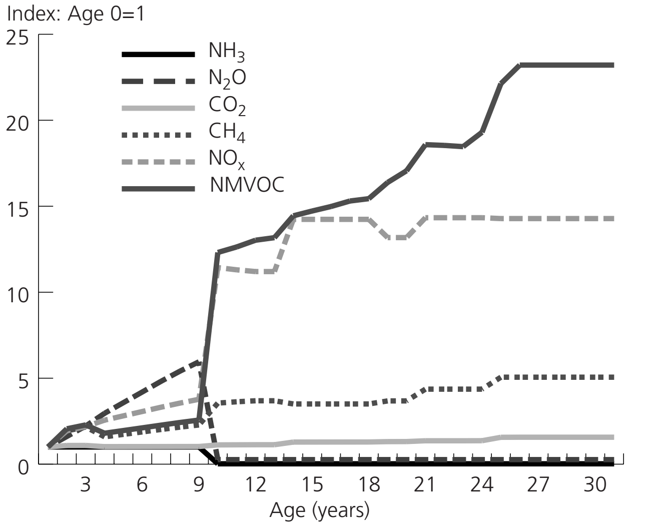
Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.7. Average emission factors for road traffic, including cold start and evaporation. 1997. kg/tonne fuel, except CO_2: tonnes/tonne fuel

Vehicle type	Fuel	CO_2	CH_4	N_2O	SO_2	NO_X	NMVOC	NH_3	CO	PM_{10}
Passenger	Gasoline	3.13	1.58	0.61	0.16	17.9	31.2	0.77	241	0.28
Other light duty	Gasoline	3.13	1.05	0.28	0.16	15.1	23.1	0.35	195	0.21
Heavy duty	Gasoline	3.13	2.39	0.04	0.16	55.1	50.3	0.00	279	0.10
Passenger	Diesel	3.17	0.09	0.16	1.20	8.1	2.9	0.02	11	3.47
Other light duty	Diesel	3.17	0.14	0.19	1.20	8.4	3.4	0.01	13	3.06
Heavy duty	Diesel	3.17	0.15	0.03	1.20	34.5	3.6	0.00	14	2.45
Mopeds	Gasoline	3.13	5.85	0.06	0.16	2.7	367.5	0.05	700	0.14
Motorcycles	Gasoline	3.13	4.94	0.05	0.16	7.1	118.8	0.05	708	0.15

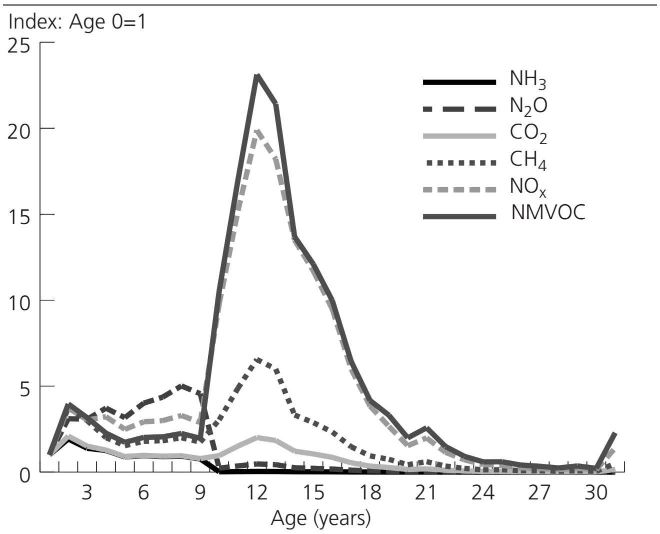
Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.7. Average emissions per km by vehicle age. Gasoline passenger cars. 1997



Source: SFT/SSB (1999).

Figure 3.8. Total emissions by vehicle age. Gasoline passenger cars. 1997

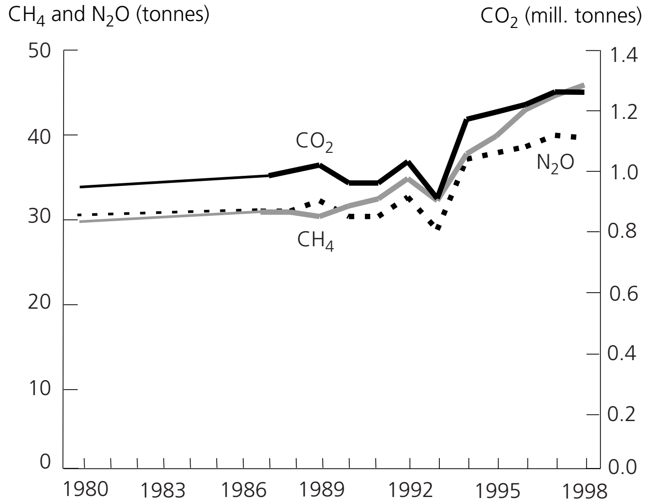


Source: SFT/SSB (1999).

CO_2 emissions from road traffic have doubled in the period from 1973 to 1998. Total annual mileage has increased even more, but the average specific fuel consumption has decreased slightly. Growth was strongest during the 1970s and early 1980s. CH_4 emissions increased until around 1990, but have been decreasing since then due to the introduction of emission controls. N_2O emissions have been increasing rapidly since 1989, when catalytic converters were introduced.

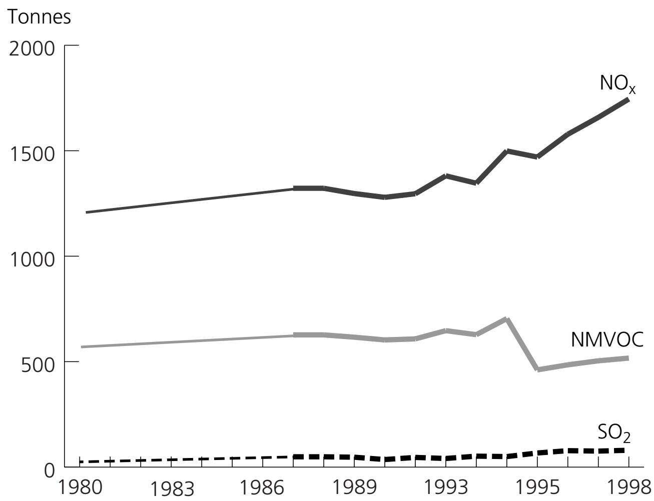
The relationship between emissions and vehicle age is shown in figures 3.7 and 3.8. Figure 3.7 shows average emissions per km from gasoline passenger cars by vehicle age. The trends are a result of technological changes and ageing. NMVOC and CO show the largest reductions in specific emissions in newer vehicles.

Figure 3.9. Emissions of greenhouse gases from domestic aviation in Norway. 1980-1998



Source: Rypdal and Tornsjø (1997) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.10. Emissions of NO_x, NMVOC and SO_2 from domestic and foreign aviation in Norway under 1 000 m (LTO cycle). 1980-1998



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

The relation between total emissions and vehicle age is shown in figure 3.8. In addition to the differences in specific emissions, this figure also takes into account variations in vehicle numbers and annual mileage. The large peak around a vehicle age of 12 years is explained by high car sales in the years immediately before the introduction of catalytic converters in 1989.

Aviation

Emissions of CO_2 from domestic aviation account for about 3 per cent of total CO_2 emissions in Norway. Aviation is a minor source of emissions of methane and nitrous oxide in Norway (less than 0.5 per cent of the total in both cases). There is little data on emissions of CH_4 and N_2O from aviation.

Table 3.8. Emission factors for CH_4 and N_2O in aviation. kg/tonne fuel

	CH_4 Domestic	CH_4 Foreign	N_2O Domestic and foreign
Jet fuel, LTO	0.35	0.6	0.1
Gasoline (aviation), LTO	1.4[1]	1.4[1]	0.1
Cruise	0	0	0.1

[1]Derived from factor for VOC (Knudsen and Strømsøe 1990), based on the assumption that the relationship between emissions of CH_4 and VOC from civilian air traffic is the same as for small aircraft (Rypdal and Tornsjø 1997).

Source: IPCC (1997a,b).

Emissions of CO_2 and N_2O from domestic aviation in Norway have increased by 31 per cent from 1990 to 1997, while CH_4 emissions have increased by about 40 per cent (figure 3.9). Domestic consumption of jet fuel in Norway increased by 31 per cent in the period 1990-1997, including fuel for military aircraft. In 1993, the amount of jet fuel used for military aircraft was lower than the previous year, but in 1994 it rose to almost twice the 1993 figure.

Emissions of CO_2 depend on the type of fuel. Two types of fuel are used, jet fuel (kerosene) and gasoline (aviation). The latter is used only in small aircraft. Emission factors for CO_2 from combustion are 3.15 tonnes CO_2/tonne jet fuel and 3.13 tonnes CO_2/tonne gasoline (Norwegian Petroleum Industry Association). The emission factors for N_2O and CH_4 are uncertain. Default emission factors from the IPCC are used for jet fuel, while factors for CH_4 for gasoline are derived from VOC data (table 3.80) and the IPCC (cruise). The methodology used is based on the IPCC Tier 2 method (IPCC 1997a,b).

Emissions of SO_2 depend on the sulphur content of the fuel used. The sulphur content is given in section 3.1.2.

Consumption of jet fuel in Norway increased by 20 per cent in the period 1987-1997, including fuel for military aircraft and fuel used for foreign aviation in Norway. Emissions of NO_X from domestic and foreign aircraft under 1000 m increased by 25 per cent from 1987 to 1997, while emissions of SO_2 increased from 49 to 76 tonnes during the same period. However, NMVOC emissions were reduced by 18 per cent in the period 1989 to 1997. The reduction was largest from 1994 to 1995, due to changes in the aircraft fleet. The emission inventory does not consider emissions of NH_3 from aviation, due to lack of data, but these are probably insignificant.

The reporting requirements make it necessary to distinguish between emissions over and under 1000 m when calculating national emissions from aviation. A landing and take off, including idling and taxiing at the airport, is called a "Landing Take Off" (LTO) cycle. All movements under 1000 m are included in the LTO.

Table 3.9. Emission factors[1] for NO_x and NMVOC for charter/ scheduled flights including helicopters, used for 1994 and earlier years. kg/tonne fuel

	NO_x	NMVOC
LTO	10.7	4.9
Cruise	8.5	2.1

[1]Apply to both domestic and foreign flights. There is no division of the factors between domestic and foreign flights because of lack of data. Such data are available from 1995 onwards.

Source: Rypdal and Tornsjø (1997).

Table 3.10. Emission factors for NO_x and NMVOC for charter/ scheduled flights including helicopters, used from 1995. kg/tonne fuel

	NO_x	NMVOC
LTO		
-Domestic	9.6	3.5
-Foreign	11.1	0.9
Cruise		
-Domestic	8.1	2.4
-Foreign	9.5	0.8

Source: Rypdal and Tornsjø (1997).

Table 3.11. Emission factors for NO_x and NMVOC for small aircraft and military aircraft. kg/tonne fuel

	NO_x	NMVOC
Small aircraft		
-LTO	2.9	12.7
-Cruise	4.4	11.1
Military aircraft		
-LTO	13.4	7.4
-Cruise	11.7	4.3

Source: Rypdal and Tornsjø (1997).

Movements over 1000 m are included in the cruise phase.

Emissions of NO_X and NMVOC from aviation depend on the type of aircraft. Emission factors are derived from studies performed by the Norwegian Institute of Air Research (Knudsen and Strømsøe 1990) and Statistics Norway (Rypdal and Tornsjø 1997). Emissions per unit of fuel are calculated for landing/take off (LTO, emissions below 1000 m) and cruise (above 1000 m). Emissions below 100 m are of interest for the calculation of emissions by municipality, so these figures are also calculated. The fractions of fuels (jet kerosene) used for LTO are derived from the same studies.

Emission factors have been derived from the composition of the aircraft fleet. Some of the emission factors used for civil aircraft are different for the years before 1995 and from 1995 onwards because of improvements in the aircraft fleet. In earlier inventories, the same average emission factors were used for charter/scheduled flights (both domestic and foreign), small aircraft and military aircraft, and helicopters were not included. Now, specific factors have been calculated for small aircraft and military aircraft (table 3.11). For 1994 and earlier years, the average factors from the earlier inventories are used, corrected for helicopters (table 3.9).

From 1995 there are different emission factors for domestic and foreign charter/scheduled flights, and helicopters are included (table 3.10). The figures for the proportion of fuel used in the LTO cycle for each type of aircraft are the same every year.

Each of the factors for the LTO cycle in tables 3.9-3.11 is split into one factor for 0-100 m and one for 100-1000 m when the emission model is run.

Ships
In 1997, Norwegian national sea traffic accounted for 10 per cent of total CO_2 emissions. The corresponding values for NO_X and SO_2 were 40 and 8 per cent respectively. Marintek, the Norwegian Oil Industry Association and the IPCC have determined emission factors for ships (Flugsrud and Rypdal 1996) that apply to ships both in transit and in port. Average emission factors have been aggregated from individual factors for specific ships. According to Marintek there is no basis for using separate emission factors for ships in port. The factors for NO_X and NMVOC are in good agreement with Lloyd's Register (1995).

Other mobile sources
Emissions of greenhouse gases have increased by 34 per cent due to an increase in energy use. Energy used by motorised equipment, snowmobiles and trains has increased most, while it is assumed that energy use by small boats has been stable.

Table 3.12. Emission factors for ships. kg/tonne fuel except CO_2 in tonnes/tonne fuel

Source	Marine fuels	Light fuel oil	Special distillate	Heavy fuel oil
Greenhouse gases:				
CO_2				
General	3.17	3.17	3.17	3.2
CH_4				
General	0.23	0.23	0.23	0.23
Oil drilling	0.8			1.9
N_2O				
General	0.08	0.08	0.08	0.08
Oil drilling	0.02			
Other gases:				
SO_2				
General	1.2	1.2	3.8	12.6
Fishing	1.2		3.8	44.7
National sea traffic	1.2		3.8	26
International sea traffic	1.2		3.8	38.3
Foreign activity in Norway	1.2		3.8	38.3
Oil and gas extraction	1.2		3.8	47.2
NO_x				
General	65.2	65.2	65.2	65.2
Fishing	71.1	71.1	71.1	71.1
Oil drilling	70	70	70	70
Oil and gas extraction	74.6	74.6	74.6	74.6
Military activity	63.1	63.1	63.1	63.1
NMVOC				
General	2.4	2.4	2.4	2.4
Fishing	1.5	1.5	1.5	1.5
Oil drilling	5		6.4	6.4
Oil and gas extraction	2.3	2.3	2.3	2.3
Military activity	2.2	2.2	2.2	2.2

Source: Flugsrud and Rypdal (1996), OLF (1994) and IPCC (1997b).

Table 3.13. Emission factors for boats, snowmobiles, motorised equipment and diesel locomotives. 1997

	Unit (emission/fuel consumption)	Snow-mobiles	Boats, 2-stroke	Boats, 4-stroke	Motorised equipment, 2-stroke	Motorised equipment, 4-stroke	Diesel locomotives
Gasoline							
CO_2	Tonnes/tonne	3.13	3.13	3.13	3.13	3.13	.
CH_4	kg/tonne	5.85	5.1	1.7	6-8.1	2.2-5.5	.
N_2O	kg/tonne	0.059	0.02	0.08	0.02	0.07-0.08	.
SO_2	kg/tonne	0.16	0.16	0.16	0.16	0.16	.
NO_x	kg/tonne	2.74	6	12	2	10	.
NH_3	kg/tonne	0.053	-	-	-	-	.
NMVOC	kg/tonne	368	240	40	500	110	.
CO	kg/tonne	700	415	1000	700	1200	.
PM_{10}	kg/tonne	0.14	8	1	8	1	.
Pb	g/tonne	1.4	1.4	1.4	1.4	1.4	.
Cd	g/tonne	-	-	-	-	-	.
Diesel and light fuel oil							
CO_2	Tonnes/tonne	.	.	3.17	.	3.17	3.17
CH_4	kg/tonne	.	.	0.18	.	0.17-0.18	0.18
N_2O	kg/tonne	.	.	0.03	.	1.3	1.2
SO_2	kg/tonne	.	.	1.2	.	1.2	1.2
NO_x	kg/tonne	.	.	54	.	46-54	47
NH_3	kg/tonne	.	.	-	.	0.005	-
NMVOC	kg/tonne	.	.	27	.	3.8-7.2	4
CO	kg/tonne	.	.	25	.	11-25	11
PM_{10}	kg/tonne	.	.	4	.	3.8-7.1	3.8
Pb	g/tonne	.	.	0.12	.	0.12	0.12
Cd	g/tonne	.	.	0.007	.	0.007	0.007

Source: SFT (1993) and IPCC (1997b).

The sulphur content in both gasoline and diesel declined from 1980 to 1998 and SO_2 emissions in this period dropped by 83 per cent. However, the growth in energy use led to an increase in emissions of other acidic substances (such as NO_X), so despite the reduction in sulphur content, total emissions of acid equivalents increased almost 20 per cent.

The emission factors are taken from SFT (1993) and the IPCC (1997b), except for SO_2 where figures are supplied by the Norwegian Petroleum Industry Association. The factors are based on the fuel type used. The factors are given in table 3.13.

The emission factors for CH_4 and N_2O have been revised so that they have the same values as in the IPCC Tier 2 method (IPCC 1997b), except for snowmobiles.

The emission factors for snowmobiles have been revised in accordance with Statistics Norway's revision of the national model for emissions from road traffic. The emission factors set for snowmobiles are the same as those for mopeds.

Emissions are estimated on the basis of the emission factors and consumption of the various fuels. Fuel consumption figures for boats, snowmobiles and motorised equipment are based on:

- Sample surveys.
- Estimates based on activity level.
- Qualified assumptions.

The fuel consumption of diesel locomotives is based on sales statistics.

3.2. Non-combustion emissions

In addition to emissions from stationary and mobile combustion, there are non-combustion emissions, for instance fugitive emissions of methane and NMVOC from oil loading and emissions that occur as a part of a production process (e.g. CO_2 generated by oxidation of coal and coke used in metal production). In the emission inventory, the non-combustion emissions of each pollutant are calculated source by source. Non-combustion processes are particularly important for emissions of CH_4, NH_3 and N_2O. For these pollutants, non-combustion emissions account for 96, 96 and 89 per cent of the total, respectively. Non-combustion SO_2 emissions make up 62 per cent of the total emissions of this component, while the corresponding value for NO_X is only 4 per cent.

3.2.1. Oil and gas extraction and drilling

Extraction of crude oil and natural gas is the most important source of NMVOC emissions and an important source of methane emissions. The main activities in this sector that result in emissions of CH_4 and NMVOC are test drilling (pre-production), oil and gas production and transport of oil and gas.

Emissions of CH_4 and NMVOC are generated by the use of turbines and diesel engines, flaring, well-testing, loading of crude oil, low pressure venting of hydrocarbons and diffuse emissions from process systems.

Methane and NMVOC emissions from turbines and flaring are defined as stationary combustion and calculated as described in 3.1.2. Emissions of CH_4 and NMVOC are oxidised to CO_2 in the atmosphere and counted as indirect CO_2 emissions.

Direct emissions of hydrocarbons (VOC)

Direct emissions of hydrocarbons (NMVOC and CH_4) include diffuse and cold vent emissions. Diffuse emissions are small, uncontrolled leakages from many sources. Cold venting is the controlled emission of CH_4 and NMVOC from known point sources. Emissions of these gases represent both lost sales and a high risk of explosion. The oil companies therefore try to minimise these emissions.

The Norwegian Oil Industry Association has made a study of emissions from oil and gas extraction including direct emissions (OLF 1993). The study was based on data from the oil companies. Figures for cold venting and diffuse emissions are based on information collected from the field operators. From 1997, more detailed data have been collected, and it is assumed that the quality of the emission estimates has improved. To make a more consistent time series of the emissions, the emissions have been recalculated for earlier years. The parameters used in the recalculation are platform age and production data for each field. It is assumed that platforms that are less than 15 years old emit 50 per cent less than older platforms (OLF 1993).

Table 3.14 shows estimated diffuse and cold vent emissions of CH_4 and NMVOC in the years 1989, 1994 and 1998. Despite the fact that extraction of oil and gas has almost doubled, NMVOC emissions were only 11 per cent higher in 1998 than in 1989. CH_4 emissions have decreased by 7 per cent in the same period. Both these changes are due to improved management of the installations.

Table 3.14. Direct emissions of NMVOC and CH_4 from production of oil and gas. Tonnes

	1989	1994	1998
NMVOC	3600	3565	3983
CH_4	8755	8670	8173

Source: Norwegian Petroleum Directorate.

Table 3.15. Emission factors for diffuse emissions of CH_4 and NMVOC from gas terminals. Tonnes/million Sm^3 natural gas. 1997

NMVOC	79.4
CH_4	22.7

Source: Norwegian Pollution Control Authority and Foreign Trade Statistics from Statistics Norway.

Table 3.16. Emissions factors for VOCs and CH_4 from oil loading offshore. 1989-1997. Per cent of oil throughput[1]

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Gullfaks									
VOC emitted	0.14	0.15	0.14	0.19	0.23	0.21	0.21	0.22	0.24
Methane content of VOC	20.0	19.1	18.2	17.3	16.4	15.5	14.6	14.0	17.0
Statfjord									
VOC emitted	0.255	0.311	0.297	0.298	0.330	0.300	0.340	0.340	0.320
Methane content of VOC	2.0	2.6	3.2	4.0	4.4	5.0	5.0	5.0	5.4
Draugen									
VOC emitted					0.12	0.12	0.12	0.12	0.12
Methane content of VOC					5	5	5	5	5
Heidrun									
VOC emitted							0.12	0.12	0.12
Methane content of VOC							5	5	8
Yme, Norne, Balder and Njord									
VOC emitted									0.12
Methane content of VOC									5

[1] No values indicate fields not in production.

Source: Norwegian Petroleum Directorate and the emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

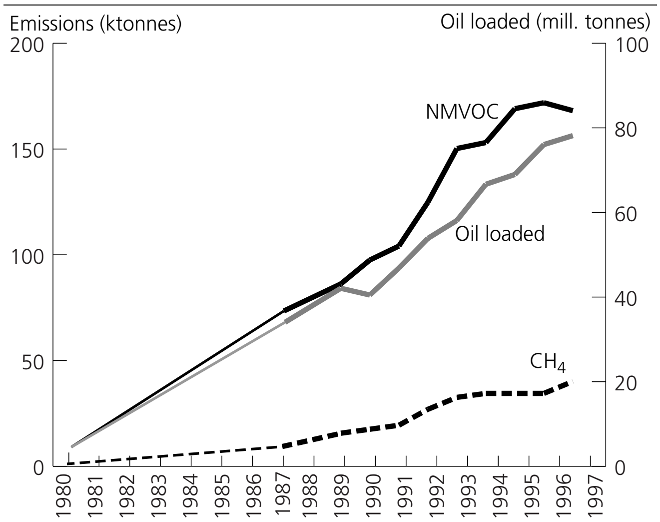
The proportion of the diffuse emissions originating from the transport of natural gas is mainly generated at the two existing gas terminals in Norway. In 1997, emissions totalled 1266 and 2263 tonnes respectively of CH_4 and NMVOC. Table 3.15 shows emissions of CH_4 and NMVOC per MSm^3 gas throughput.

Loading of crude oil offshore and onshore

The emissions of CH_4 and NMVOC from loading of crude oil are calculated on the basis of the amount of crude oil loaded on to shuttle tankers (Norwegian Petroleum Directorate) and on field specific emission factors. Only the Norwegian part of oil production at fields with oil loading is included. The evaporation rate varies from field to field and over time, and the emission factors are dependent on the composition of the crude oil as indicated by density and Reid vapour pressure (RVP). The emission factor for a field rises as oil production falls and the amount of gas in the field increases. The VOC evaporation emission factors are obtained from measurements, which include emissions from loading and washing of shuttle tankers. For some fields the emission factors are not measured, only estimated. The CH_4 content of VOC evaporated is also measured so that total emissions of VOC are split between CH_4 and NMVOC.

A similar method is used for calculating emissions from loading of crude oil at the two oil terminals onshore. The emission factor is considerably lower at one terminal than at the other because the oil is transported by ship to the terminal and therefore the lightest fractions have already evaporated. At the other terminal the oil is delivered by pipeline. This terminal has installed vapour recovery units (VRU), which may reduce NMVOC emissions from loading of ships at the terminal by about 90 per cent. In 1997, NMVOC emissions at this terminal were 23 per cent lower than they would have been without VRU. However, VRU technology is not designed to reduce methane and ethane emissions.

Figure 3.11. Emissions of NMVOC and CH_4 from oil loading offshore and volumes of oil loaded. 1980-1997



Source: Norwegian Petroleum Directorate and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

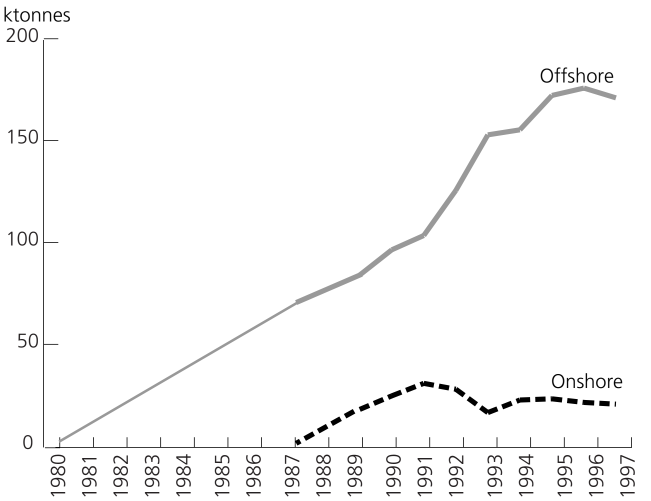
Table 3.17. Amounts of oil loaded and emissions of NMVOC and CH_4 from oil loading onshore. 1997

Oil field	Oil through-put (Million tonnes)	VOC emis-sions (Per cent of oil through-put)	NMVOC emis-sions (ktonnes)	CH_4 emis-sions (ktonnes)
Total			21	0.082
Mongstad (from Troll)	10.1	0.020	2	0.025
Mongstad (from other fields)	18.0	0.025	4	0
Sture	32.2		15[1]	0.058

[1] Value reported to the Norwegian Pollution Control Authority by the terminal.

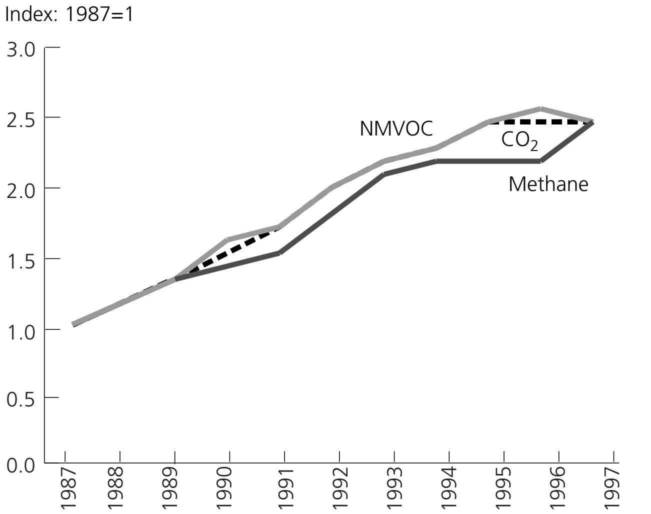
Source: Norwegian Pollution Control Authority and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.12. Emissions of NMVOC from oil loading. Onshore and offshore. 1980-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.13. Emissions of CH_4, NMVOC and CO_2 from oil and gas extraction activities. 1987-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.18. Production of coal, emission factor and emissions of CH_4 from coal extraction. 1997

Production (tonnes)	Emission factor (tonnes/tonne produced)	Emissions (tonnes)
386440	0.014	5410

Source: Manufacturing Statistics from Statistics Norway, IPCC (1997b) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Trends in CH_4, NMVOC and CO_2 emissions from oil and gas extraction activities are shown in figure 3.13.

3.2.2. Extraction of coal

Norway produces coal on Svalbard. Exact figures for methane emissions from mining processes are not available due to the lack of relevant measurements. The IPCC (1997b) recommends (in the Tier 1 method) calculating emissions from underground mines using the equation:

Emissions (Gg CH_4) = emission factor (m^3 CH_4/tonne) • tonnes of coal produced • conversion factor (Gg/$10^6 m^3$)

We have chosen to use this method in the Norwegian emission inventory. The IPCC Tier 1 Global Average Method for underground mines recommended using CH_4 emission factors of between 10 and 25 m^3/tonne coal extracted. For post-mining activities IPCC recommends an emission factor between 0.9 and 4.0 m^3/tonne. The total emissions for underground mines and post-mining activities should therefore lie between 10.9 and 29 m^3/tonne. Statistics Norway/Norwegian Pollution Control Authority use the average of the interval which given in tonnes CH_4/tonne coal extracted is 0.014. This gave CH_4 emissions of 5400 tonnes in 1997 (table 3.18).

Both Norway and Russia extract coal on Svalbard, but only the Norwegian emissions are included in our estimates.

3.2.3. Food production

Production of bread and beer (and other similar yeast products) involves fermentation processes that lead to emissions of NMVOC (ethanol). The emission factors are taken from the EEA (1996). The production volume is reported to Statistics Norway. Figures for the mass production of bread are relatively uncertain. The calculated figures for 1997 are shown in table 3.19.

3.2.4. Metal mines

The treatment of ore generates emissions of SO_2. Norway's last metal mine reporting non-combustion emissions was closed in 1996. Before 1987, emissions from smelting at Sulitjelma (copper mine) were relatively high (figure 3.14). This plant was closed in 1987. In 1980, metal mines accounted for 18 ktonnes of SO_2.

3.2.5. Carbide production

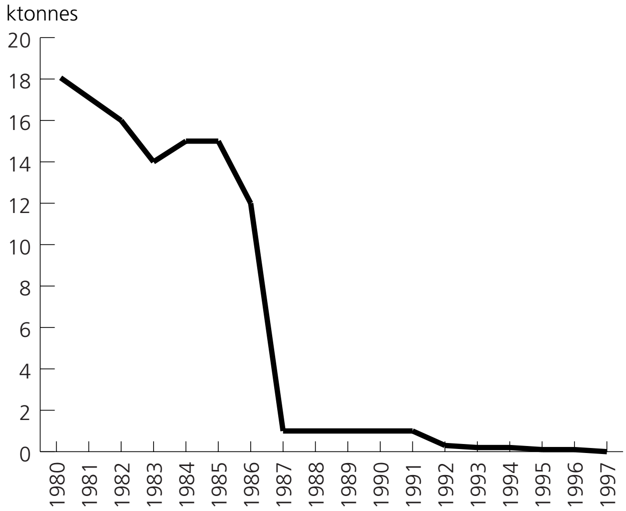
Silicon carbide and calcium carbide are produced in Norway. The most important emissions from carbide production are CO_2 emissions, but during production of silicon carbide SO_2 is also emitted.

Table 3.19. Production of bread and beer, emissions and emission factors for NMVOC in these types of production

	Production	Emission factor	Emissions (tonnes)
Total			867
Bread	273 ktonnes	3 kg/tonne	819
Beer	240 mill. litres	0.2 kg/m^3	48

Source: Manufacturing Statistics from Statistics Norway, EEA (1996) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

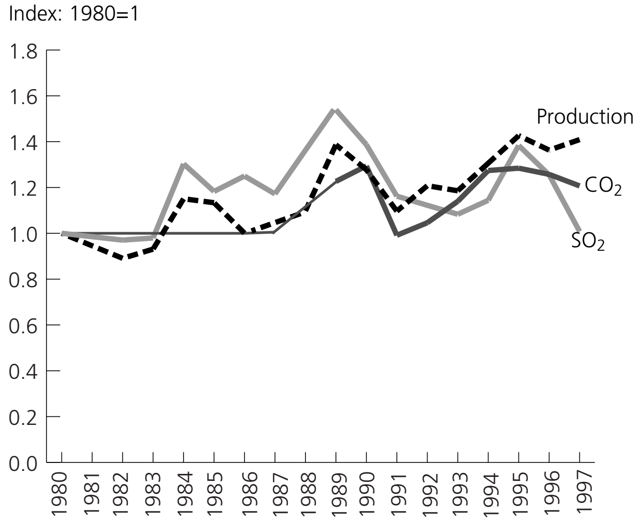
Figure 3.14. Emissions of SO_2 from metal mines[1]. 1980-1997



[1] We have emission data for only one of the companies in the period 1982-1986. The figures are therefore too low for this period.

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.15. Production of silicon carbide and emissions of CO_2 and SO_2. 1980-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Silicon carbide

Three factories in Norway manufacture silicon carbide (SiC). SiC is produced by reduction of quartz (SiO_2) with petrol coke as a reducing agent.

$$SiO_2 + 3C \rightarrow SiC + 2CO$$
$$CO \xrightarrow{O_2} CO_2$$

The activity data used here is the consumption of petrol coke as reported to Statistics Norway; in other words, the CO_2 emissions are calculated from the consumption of petrol coke. This is in accordance with the IPCC Guidelines (IPCC 1997b). The IPCC recommends using an emission factor of 2.3 tonnes CO_2/tonne petrol coke. Our emission inventory uses a factor of 2.51 tonnes CO_2/tonne petrol coke, as recommended by SINTEF (1998e). The reason for the discrepancy between the SINTEF and IPCC values is that different assumptions are made about the percentage of sequestered carbon in produced silicon carbide. The IPCC assumes that 35 per cent is sequestered, which means 0.376 tonnes C/tonne SiC. Based on an analysis by the Norwegian manufacturers, SINTEF has calculated the value of sequestered carbon in SiC to be 0.308 tonnes C/tonne SiC.

CO_2 emissions have been calculated on the basis of production data reported annually to Statistics Norway and the emission factor above. CO_2 emissions were calculated to be 234 ktonnes in 1997 and 251 ktonnes in 1990.

In addition, methane (CH_4) may be emitted from petrol coke during parts of the process. The emission factor used for calculation of methane emissions is 10 kg/tonne, which is the factor recommended by the IPCC (1997b).

This gives estimated CH_4 emissions of 932 tonnes in 1997, a reduction of about 70 tonnes since 1990. A drop in petrol coke consumption caused this reduction.

All sulphur in the petrol coke is assumed to be emitted to air as SO_2. Thus, the emissions are calculated from the sulphur content of coke as reported annually to the Norwegian Pollution Control Authority and the consumption of petrol coke as reported to Statistics Norway. An estimated 3200 tonnes were emitted in 1997, which is almost the same as in 1980 (see figure 3.15).

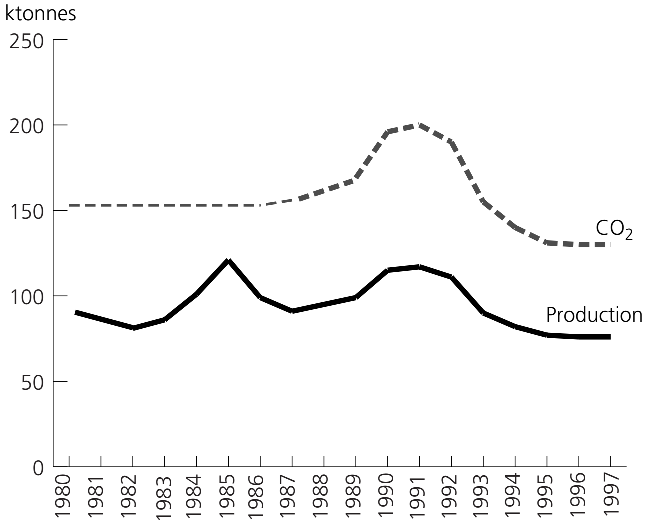
Calcium carbide

Two stages in the calcium carbide (CaC_2) manufacturing process generate CO_2 emissions:

1. The reaction
   $CaCO_3 \rightarrow CaO + CO_2$
   which takes place when limestone (calcium carbonate) is heated.
2. The reactions
   $CaO + C \text{ (petrol coke)} \rightarrow CaC_2 + CO$
   $CO \xrightarrow{O_2} CO_2$
   where petrol coke is used as a reducing agent to reduce the CaO to calcium carbide.

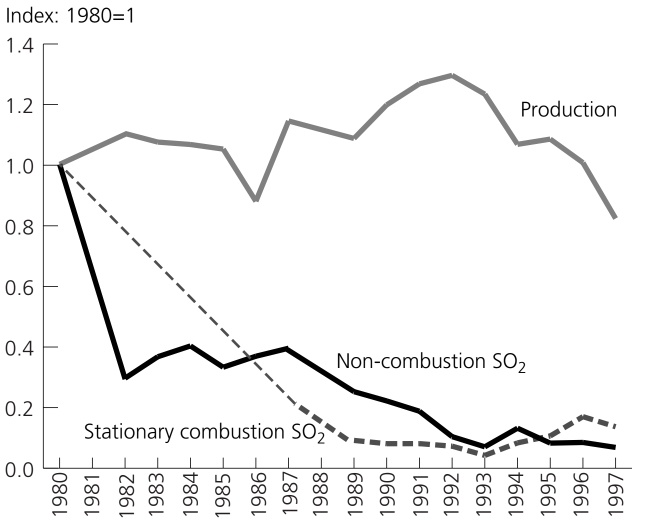
Some of the carbon from petrol coke will be sequestered in the product, but not permanently. Thus, this carbon is included in the emission estimate. Emission estimates are based on the amount of calcium carbide produced each year. Production figures are reported to Statistics Norway. The emission factor has been estimated by SINTEF (1998e) to be 1.71 tonnes/tonne. The default IPCC factor is 1.8 tonnes/tonne. SINTEF (1998e) concludes that the one reason for the difference between the factors is that the IPCC assumes that all calcium carbonate is calcinated.

Figure 3.16. Production of calcium carbide and CO_2 emissions. 1980-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.17. Production of pulp and emissions of SO_2. Non-combustion emissions and emissions from stationary combustion. 1980-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Sulphur in coke is a potential source of SO_2. However, no SO_2 is emitted, since practically all of the sulphur in the petrol coke will be sequestered in the product.

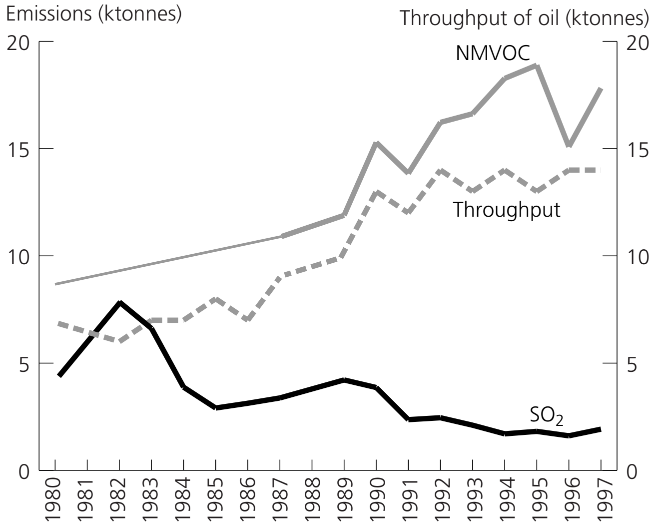
3.2.6. Manufacture of other inorganic chemicals

The production of inorganic chemicals led to non-combustion SO_2 emissions of 389 tonnes in 1997. One tonne of NO_X was also emitted in the same year.

Sulphuric acid

Emissions from production of sulphuric acid are reported to the Norwegian Pollution Control Authority. Based on measurements, SO_2 emissions were estimated at 324 tonnes in 1997, down from 1500 tonnes in 1980.

Figure 3.18. Throughput of oil and emissions of SO_2 and NMVOC from oil refineries. 1980-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Titanium dioxide

The SO_2 emission figures from production of titanium dioxide are based on calculations, and a figure of 65 tonnes was reported to the Norwegian Pollution Control Authority for 1997. This is a reduction from 400 tonnes in 1980.

Explosives (NO_X)

The production of explosives leads to emissions of NO_X. These totalled 1 tonne in 1997, down from 16 tonnes in 1987.

3.2.7. Pulp and paper industries

All SO_2 emissions from producers of chemical pulp are measured continuously. Emission estimates are made from these measurements, and total emissions in 1997 were estimated at 577 tonnes. Emissions from this source have been reduced considerably since the early 1980s by the development of control technologies and new production technology. In 1980, non-combustion SO_2 emissions from this source were 8400 tonnes.

3.2.8. Refineries

The most important non-combustion emissions from oil refineries are NMVOC (both from production and from various fugitive sources) and SO_2 (from the production process). These emissions make up 4 and 5 per cent respectively of national emissions. There are currently (1999) three refineries in Norway.

SO_2 emissions are measured and reported to the Norwegian Pollution Control Authority annually, and totalled 1900 tonnes in 1997. Emissions have been reduced in the last 10 years despite a rise in production, by the installation of more equipment to control emissions.

The refineries also report NMVOC emissions to the Norwegian Pollution Control Authority. The emissions are estimated on the basis of measurements. In 1997, emissions totalled 18 ktonnes, an increase from 12 ktonnes in 1989. These figures include fugitive emissions from the production process, storage and handling, except those during stage 1 at the refineries, which includes the loading of trucks and trains. Crude oil and light distillates are stored in floating roof tanks. The NMVOC emissions vary with the production level.

3.2.9. Distribution of gasoline

Distribution of gasoline has contributed slightly less than 2 per cent of national totals of NMVOC emissions over the last few years. NMVOC are emitted when gasoline evaporates during loading and unloading of tanker trucks, trains and ships at refineries, gasoline depots and filling stations, and when cars etc. fill gasoline at filling stations.

These NMVOC emissions were estimated at 7000 tonnes in 1997 and 8200 tonnes in 1989. This reduction is explained both by reduced gasoline sales (6.6 per cent) and reduced emissions per unit gasoline sold (9 per cent). The reduction per unit gasoline sold is due to installation of more vapour recovery units (VRU) at depots and refineries. Table 3.20 shows emissions of NMVOC from gasoline distribution in 1989 and 1997, split between stage I (loading and unloading of tanker trucks, ships and trains) and stage II (filling gasoline at filling stations).

Today all tanker trucks are bottom-filled and many tanks at gasoline depots and refineries have floating roofs. A growing number of filling stations are equipped with VRU. The emission factors for loading of bottom-filled tanker trucks are 0.055 per cent by weight and 0.16 per cent by weight respectively (TI 1991) for unloading gasoline at filling stations which are not equipped for vapour collection and for VRU at depots. With a vapour collection system at filling stations and VRU at the depots, emissions are reduced by about 95 per cent. We use an emission factor of 0.00148 tonnes NMVOC per tonne gasoline for filling gasoline at filling stations. For spillage, an emission factor of 0.000008 tonnes NMVOC per tonne gasoline is used (EEA 1996).

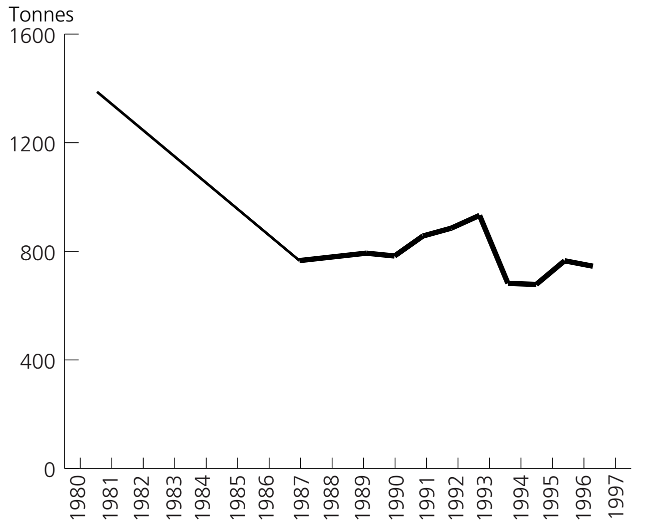
Table 3.20. Gasoline sold and NMVOC emissions from distribution of gasoline. 1989 and 1997. ktonnes

	1989	1997
Gasoline sold	1783	1664
Total emissions	8.2	7.0
-Emissions stage 1 (loading and unloading of ships, trucks and trains[1])	5.4	4.5
-Emissions stage 2 (filling cars at filling stations)	2.8	2.5

[1] Includes emissions from storage tanks during unloading of ships at depots.

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.19. Emissions of NMVOC from the petrochemical industry. 1980-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

3.2.10. Other petrochemical industry

Natural gas liquids (NGL) are the raw material for production of propene and ethene at Norsk Hydro's plant at Rafnes. Plastic is produced from these gases at the Statoil plant at Bamble, and methanol is produced at Statoil's Tjeldbergodden plant. NMVOC is emitted from all three plants. According to reports to the Norwegian Pollution Control Authority, 763 tonnes of NMVOC were emitted from these plants in 1997. The emissions have decreased from 1410 tonnes in 1980. In 1990, which is the base year for the NMVOC agreement, the emissions were 810 tonnes. The emission reductions have been achieved through control and maintenance. Leakage is detected by routine controls and a program of maintenance is followed. Controlled emissions are avoided as far as possible.

3.2.11. Mineral production

Cement production

Production of cement gives rise to both non-combustion and combustion emissions of CO_2. The non-combustion emissions originate mainly from the calcination of the raw material calcium carbonate ($CaCO_3$):

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$$

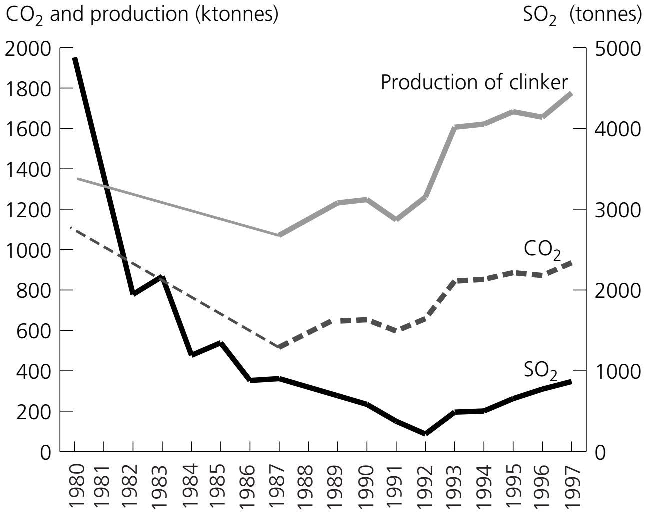
The CaO is heated to form clinker, and then crushed to produce cement. The IPCC (1997b) recommends an emission factor of 0.5071 tonne CO_2/tonne clinker. In the emission inventory, we have chosen emission factors calculated specifically for the two Norwegian factories by SINTEF (1998a) based on the actual composition of the raw materials. Production data are reported annually from the plants. Production, emission factors and estimated emissions for 1997 are shown in table 3.21.

Table 3.21. Production of clinker, emission factors and estimated emissions of CO_2. 1997

Production of clinker (ktonnes)	Emission factors (tonnes/tonne produced)	Emission (ktonnes)
1776	0.520/0.541	935

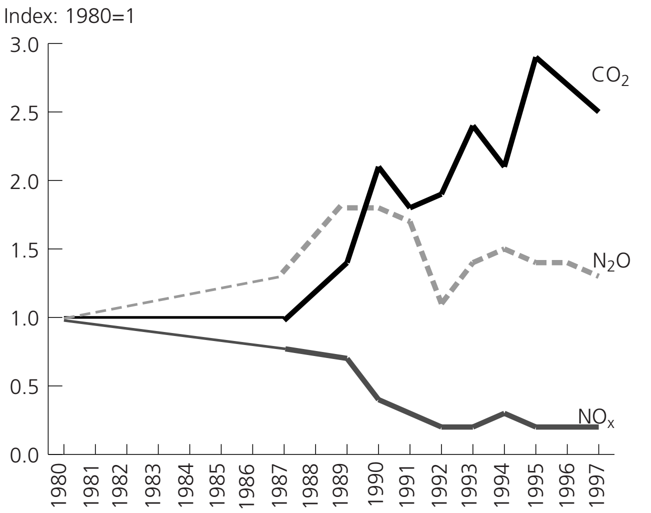
Source: Norcem, SINTEF (1998a) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.20. Production of clinker and emissions of CO_2 and SO_2 from cement production. 1980-1997



Source: Norcem and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.21. Emissions of CO_2, N_2O and NO_X from production of fertilisers. 1980-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

The SO_2 emissions from cement manufacture are estimated from measurements at two plants and reported to the Norwegian Pollution Control Authority. In 1997, emissions totalled 900 tonnes SO_2, as compared with 4900 tonnes in 1980. The reduction is explained by the closure of one factory and the replacement of petrol coke and oil with a high sulphur content by organic waste.

Concrete pumice stone

Non-combustion emissions of SO_2 originate from the clay used in the production process. In 1997, emissions of 200 tonnes were reported to the Norwegian Pollution Control Authority, based on measurements at the two manufacturing plants. Emissions have been stable since 1980.

3.2.12. Production of fertilisers

Both ammonia and nitric acid are formed as steps during fertiliser production, and this leads to emissions of CO_2, N_2O and NO_X.

Production of ammonia

Hydrogen for ammonia production is produced from hydrocarbon gases (LPG), and CO_2 is emitted. All consumption of hydrocarbon gases in this production process is considered to be non-energy use. The total amount of gas consumed is reported by the plants to

Statistics Norway. However, the chemical composition of the gases is variable. We have chosen to use an emission factor of 3 tonnes CO_2/tonne LPG. This is recommended by the IPCC (1997b) and is calculated from the carbon content of LPG. The calculations have been compared to the plants' own reports of emissions and are in good agreement with these.

Manufacture of nitric acid

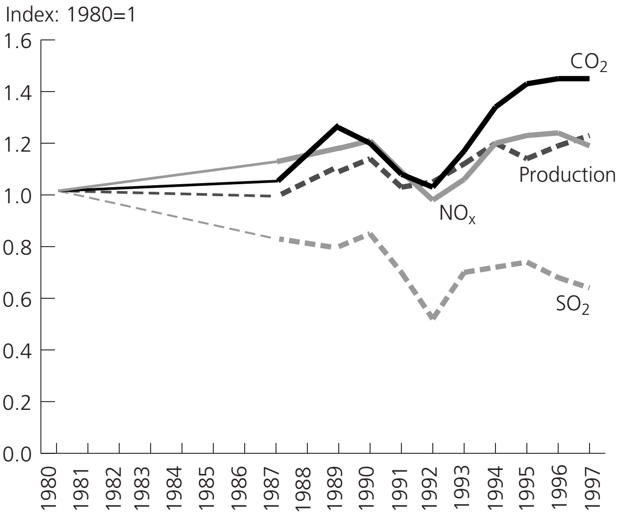
N_2O emissions were reported to be 4800 tonnes in 1997, down from 6650 tonnes in 1990. The reduction is due to technological improvements at one of the plants. At one plant, emissions are measured continuously, whereas at the other the figures are calculated from monthly measurements of N_2O.

3.2.13. Metal production

Norway produces ferroalloys, aluminium, nickel, zinc and magnesium. These production processes lead to emissions of CO_2, SO_2, NO_X and NMVOC. For the calculation of CO_2 emissions there are at least two appropriate types of activity data: the amount of reducing agents consumed and the production volume. The IPCC's Tier 1 method recommends using consumption of coal, coke, petrol coke, prebaked anodes and coal electrodes as activity data for calculating CO_2 emissions (IPCC 1997b). Norway has relatively good activity data for production volumes, consumption of coal and coke as reducing agents and the use of prebaked anodes based on annual reports from the plants.

In 1997, total CO_2 emissions from metal production were 5500 tonnes, up from 4800 tonnes in 1990. The rise is explained by an increase in production.

Figure 3.22. Production of ferroalloys and emissions of CO_2, NO_x and SO_2 from these productions. 1980-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

SO_2 emissions originate from sulphur in reducing agents and ores. In addition, depending on the process conditions, NO_X and NMVOC may be emitted.

Ferroalloys

There are 15 plants that produce ferroalloys in Norway. The emission inventory uses a method recommended by the IPCC for estimating the CO_2 emissions, but the emission factors are from Norwegian sources, based on the actual composition of the raw materials used. Table 3.22 shows the Norwegian emission factors and emissions per reducing agent.

The SO_2 emissions are estimated from the amounts of reducing agents used and their sulphur content, as reported to the Norwegian Pollution Control Authority by each plant. Some of the sulphur is trapped in the product. For production of ferro manganese and silicon manganese, 98-99 per cent of the sulphur is trapped, while for other ferroalloys it is assumed that about 5 per cent is trapped. In 1997, emissions totalled 9000 tonnes SO_2, as compared with about 7500 tonnes in 1980.

Emissions of NO_X originate from production of ferro silicon and silicon metal. The production volume as reported to Statistics Norway is taken as the activity basis. The applied emission factor of 11.7 kg NO_X/ tonne ferroalloy has been estimated from measurements at two Norwegian ferroalloy plants. However, this figure is rather uncertain. An estimated 6300 tonnes of NO_X were emitted in 1997. In 1987, the figure was 5300 tonnes.

NMVOC emissions originate from the use of coal and coke in the production processes. The emissions are estimated from the consumption of reducing agents as reported to Statistics Norway. An emission factor of 1.7 kg NMVOC/tonne coal or coke has been applied (EPA 1986). In 1997, 1800 tonnes of NMVOC were emitted, as compared with 1300 tonnes in 1989.

Table 3.22. Emission factors for CO_2 from production of ferroalloys. Tonnes CO_2/tonne reducing agent or electrode

	Coal	Coke	Electrodes
Ferro silicon	3.1	3.36	3.36
Silicon metal	3.1	3.36	3.54
Ferro chromium	-	3.22	3.51
Silicon manganese	-	3.24	3.51
Ferro manganese	-	3.24	3.51

Source: SINTEF (1998b, 1998c, 1998d and 1998e) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.23. Production, emission factors and emissions of NO_x from production of ferroalloys. 1997

	Production (ktonnes)	Emission factor (tonnes/tonne ferroalloy)	NO_x emissions (tonnes)
Total			6543
Ferro silicon	439	0.0117	5134
Silicon metal	120	0.0117	1410

Source: Norwegian Pollution Control Authority, Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.24. Consumption of reducing agents, emission factors and emissions of NMVOC from production of ferroalloys. 1997

	Consumption (ktonnes)	Emission factor (Tonnes/tonne reducing agent)	Emissions (Tonnes)
Total			1784
Coal	530	0.0017	900
Coal coke	506	0.0017	860
Petrol coke	14	0.0017	24

Source: Energy Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.25. Consumption of reducing agents, emission factors and emissions of CO_2 from production of iron. 1997

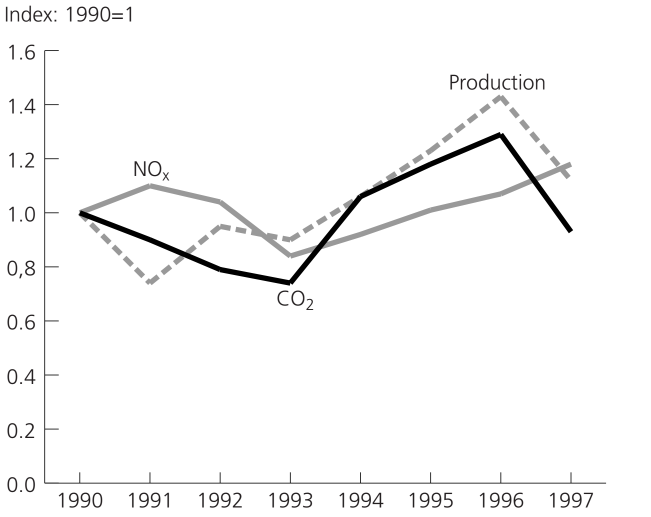
	Consumption (Tonnes)	Emission factor (Tonnes/tonne reducing agent)	Emission (ktonnes)
Total			158.0
Coal	65100	2.42	157.5
Petrol coke	100	3.59	0.4

Source: Energy Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Iron and steel

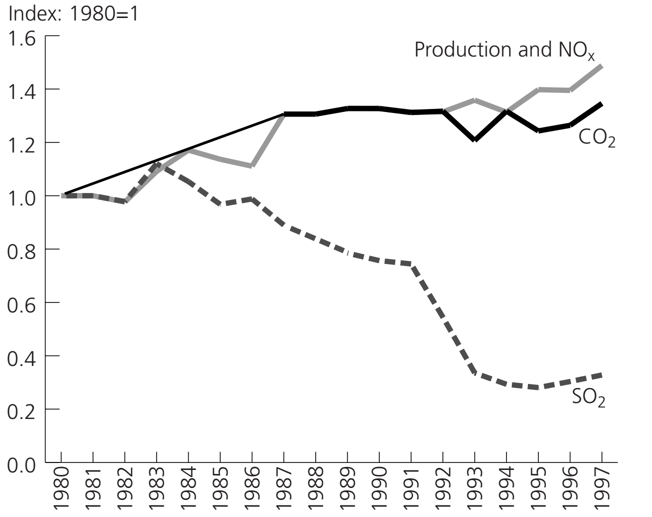
CO_2 emissions from non-combustion processes in iron and steel production are estimated from the use of coal and coke as reported to Statistics Norway. The calculated emissions for 1997 are shown in table 3.25.

Figure 3.23. Production of iron and emissions of CO_2 and NO_x. 1990-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.24. Production of aluminium and emissions of CO_2, NO_x and SO_2 from aluminium production. 1980-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.26. Consumption of reducing agents, emission factors and emissions of CO_2 in aluminium production

	Consump-tion (Tonnes)	Emission factor (Tonnes/tonne reducing agents)	Emissions (ktonnes)
Total			1584
Petrol coke	41643	3.59	150
Prebaked anodes	122808	3.59	441
Coal electrodes	276593	3.59	993

Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

SO_2 and NO_X emissions are estimated from measurements. In Norway, iron is produced from ilmenite and coal. In 1997, total emissions were estimated to be 13 tonnes of SO_2 and 246 tonnes of NO_X.

In 1988, one of the SO_2-emitting plants was closed. SO_2 emissions from this plant were reduced in the years before it closed.

Aluminium

The aluminium production process leads to emissions of CO_2, SO_2, NO_X and perfluorocarbons (PFCs). There are 7 plants that produce aluminium in Norway. Both the prebaked anode and the Søderberg production methods are used.

For aluminium manufacturing, the actual consumption of raw materials as reported to Statistics Norway is used as activity data. This method is in accordance with the IPCC's recommendations. Statistics Norway and the Norwegian Pollution Control Authority use an emission factor of 3.59 tonnes CO_2/tonne reducing agent. The IPCC (1997b) recommends a factor of 3.6.

The SO_2 emissions are estimated from measurements at each plant as reported to the Norwegian Pollution Control Authority. They totalled 1 800 tonnes in 1997. Figure 3.24 shows that SO_2 emissions have decreased steadily despite increased production. This reduction has been achieved by scrubbing the exhaust gas with seawater.

The NO_X emissions are estimated from the level of production as reported to Statistics Norway. An emission factor of 0.71 kg NO_X per tonne aluminium produced has been derived from measurements at two Norwegian aluminium plants. However, this figure is rather uncertain. An estimated 700 tonnes of NO_X were emitted in 1997.

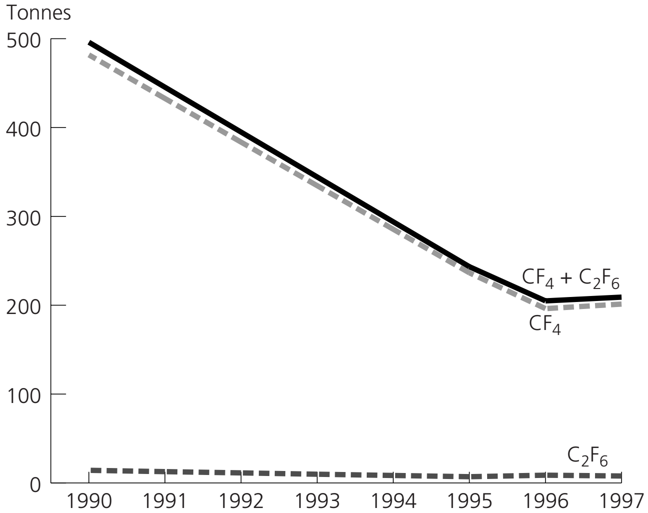
Perfluorocarbons (PFCs)

Perfluorinated hydrocarbons (PFCs), e.g. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), are produced during aluminium production during anode effects (AE), when the voltage of the cells increases from the normal 4-5V to 25-40V. During normal production, PFCs are not produced. Starting new smelters generates additional PFC emissions. The fluorine in the PFCs produced during anode effects originates from cryolite. Molten cryolite is necessary as a solvent for alumina in the production process.

Emissions of PFCs from a pot line (or from smelters) are dependent on the number of anode effects (AE) and their intensity and duration. Estimates of PFC emissions from production of aluminium are based on plant-specific information and are dependent on the technology used.

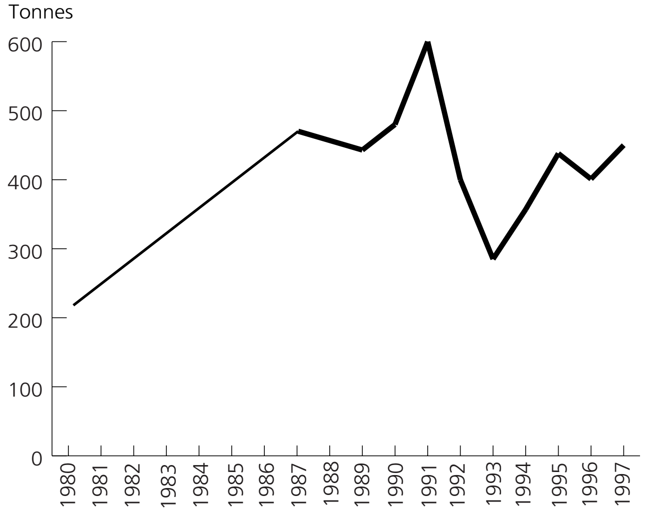
In 1992 and 1996-1997, the aluminium industry measured emissions of PFCs from the smelters. The measurements in production cells were carried out using a photoacoustic gas monitor.

Figure 3.25. Emissions of PFCs from production of aluminium. 1990-1997



Source: Norwegian Pollution Control Authority.

Figure 3.26. Emissions of SO_2 from manufacture of prebaked anodes. 1980-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.27. Emissions of PFCs from production of aluminium. 1997. kg/tonne aluminium

	Emission intervals		Average emissions	
	CF_4	C_2F_6	CF_4	C_2F_6
Søderberg	0.285-0.810	0.009-0.34	0.451	0.017
Prebaked	0.020-0.100	0.001-0.004	0.068	0.003

Source: Norwegian Pollution Control Authority.

The formula for calculating CF_4 and C_2F_6 emissions from aluminium production is as follows:

$$Q=1.01 \cdot [A \cdot B \cdot C \cdot D \cdot E + (F \cdot G)],$$

where Q is the total yearly emissions of CF_4 and C_2F_6 per cell.

Variables to be reported each year:
B: number of anode effects per cell per day
D: average annual amperage in kA
E: number of cells in production multiplied by number of production days
G: number of "newly started" cells

Constants:
A: average measured emissions per anode effect minute per kA per cell
C: duration of anode effect in minutes
F: average emissions per new start of a cell
1.01: to include non-measured C_2F_6, the measured amount of $CF_4 + C_2F_6$ is multiplied by 1.01, see explanation below.

Measurements from 1992 showed that the content of C_2F_6 in anode gas was 1 to 10 per cent, and 3 per cent on average. The measured emissions of CF, that is $CF_4 + C_2F_6$, include all CF_4, but only about 70 per cent of the C_2F_6 emissions. This means that 1 per cent of the total emissions of $CF_4 + C_2F_6$ was not measured. The measured total figure for $CF_4 + C_2F_6$ is therefore multiplied by a factor of 1.01 to include non-measured C_2F_6. The total amount of C_2F_6 in the total estimated $CF_4 + C_2F_6$ emissions (Q) is then 4 per cent. These results are confirmed by the measurements made in 1996-97.

Emissions of PFCs have been reduced by about 60 per cent in the period 1990-97. This reduction has been achieved by improving the efficiency of the production process and installing point feeders. Table 3.27 shows calculated emissions of CF_4 and C_2F_6 in 1997 per production unit of aluminium with Søderberg and prebaked technology.

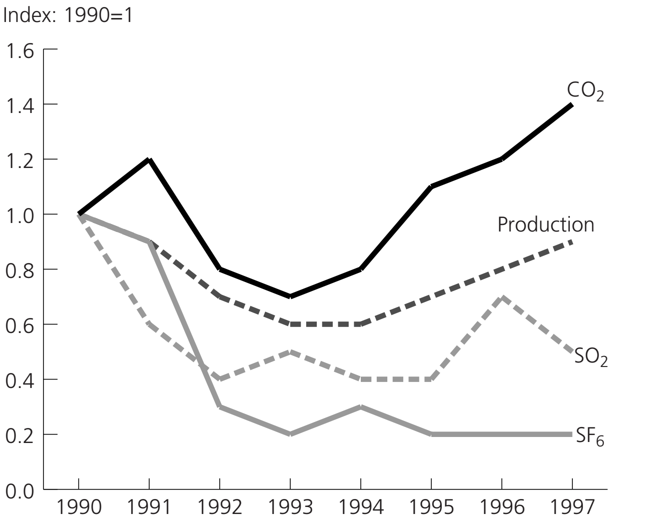
Sulphur hexafluoride (SF_6)
SF_6 used as cover gas in the aluminium industry is assumed to be inert, and SF_6 emissions are therefore assumed to be equal to consumption. At one plant SF_6 was used as cover gas in the production of a specific quality of aluminium from 1992 to 1996. The aluminium plant no longer produces this quality, which means that SF_6 emissions have stopped.

Manufacture of prebaked anodes

Prebaked anodes and coal electrodes are an alternative to the use of coal and coke as reducing agents in the production processes for aluminium and ferroalloys. The anodes and coal electrodes are produced from coal and coke. The production of anodes and coal electrodes leads to emissions of SO_2.

Two plants produce prebaked anodes and coal electrodes in Norway. Emissions totalled 450 tonnes in 1997 (partly estimated from measurements). They have varied to some extent over the last ten years, and in 1980 and 1990, emissions were 224 and 480 tonnes respectively.

Figure 3.27. Production of magnesium and emissions of CO_2 and SO_2 from this production. 1990-1997



Source: Manufacturing Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Magnesium

Production of magnesium leads to non-combustion CO_2 emissions. Dolomite ($MgCa(CO_3)_2$) is the raw material, and coke is used as an anode in the production process. Carbon and carbonate in coke is emitted as

CO_2. The IPCC (1997b) recommends using the consumption of reducing agent as the activity data for estimating emissions. SINTEF (1998f), on the other hand, recommends using production volume in the calculations. The Norwegian emission inventory uses production volumes as activity data. From the mid-1970s, both the magnesium chloride brine process and the chlorination process were used for magnesium production in Norway. Since 1991, only the chlorination process has been in use. In 1997, CO_2 emissions were estimated at 176 ktonnes.

SO_2 emissions are estimated from the consumption of coke. The emissions reported to the Norwegian Pollution Control Authority by magnesium producers were 167 tonnes in 1997 and 306 tonnes in 1990.

Emissions of SF_6 from magnesium production have decreased by 80 per cent from 1990 to 1997, see figure 3.27. In 1997, SF_6 consumption was 0.538 kg SF_6/ tonne cast magnesium. The producer of magnesium intends to replace SF_6 with SO_2 as cover gas.

The Norwegian producer of cast magnesium has assessed whether SF_6 used as cover gas reacts with other components in the furnace. The results so far indicate that it is relatively inert, and it is therefore assumed that all SF_6 used as cover gas is emitted to air. The consumption figures are used as the emission estimates in accordance with the IPCC Guidelines (IPCC 1997a,b).

Other metals

In addition to the metals mentioned in the chapters above, nickel and zinc are also produced in Norway.

The SO_2 emissions from the only nickel plant are estimated from continuous measurements. They totalled 158 tonnes in 1997, an increase from 115 tonnes in 1980.

12 tonnes of SO_2 were emitted from the only zinc plant in 1997. This is a reduction from 65 tonnes in 1980. The emissions are estimated from infrequent measurements combined with calculations.

3.2.14. Landfills

CH_4 and CO_2 are emitted during biological decomposition of waste. This transformation of organic matter takes place in several steps. During the first weeks or months, decomposition is aerobic, and the main decomposition product is CO_2. This form of decomposition continues until all the oxygen is consumed. When there is no more oxygen left, the decomposition becomes anaerobic, and methane emissions start to rise. After a year or more, CH_4 emissions become stable. This stage can last for several decades before the emissions start to fall again until all organic parts of the waste are chemically stable.

The Norwegian Pollution Control Authority (SFT) has developed a new model for calculating methane emissions from landfills (SFT 1999a). This model, which is based on the IPCC theoretical first order kinetics methodologies (IPCC 1997b), takes into account the fact that methane is emitted from a waste deposit for several years. Improved waste statistics have become available in the last few years, giving better data on waste volumes and waste composition (Statistics Norway 1998). The model therefore now gives a better estimate of methane emissions from municipal waste and private industrial landfills. The effect of weather conditions is also taken into account. The amount of methane generated in the year of calculation by waste deposited in year *x* is given by the equation:

$$Q_{T,x} = k \cdot M_x \cdot F \cdot MCF \cdot L_0 \cdot e^{-k(T-x)} \cdot v/1000,$$

where

$Q_{T,x}$: Amount of methane generated in the year of calculation (T) from the waste volume deposited in year x.

k: Generation rate of methane ($k=\ln(2)/t_{1/2}$)

M_x: Waste volume deposited

F: The fraction of methane in the gas generated (55 per cent)

MCF: Methane correction factor

L_0: Landfill gas potential

T: The year of calculation

x: Base year

v: Density of methane (0.7168 kg/m^3)

Table 3.28. Variables used in the calculations of CH_4 from landfills. Values not listed in the text

Variables	Type of waste		
	Household	Commercial/Institutional	Manufacturing
$t_{1/2}$ (half life)	9.5 years	11 years	11 years
Landfill gas potential (L_0)	370 Nm^3/tonne	355 Nm^3/tonne	425 Nm^3/tonne
Correction factor (1997[1]) (MCF)	1.00	0.80	0.80
Oxidation effect	10 per cent	10 per cent	10 per cent

[1] Different correction factors for different years.

Source: SFT (1999a).

Table 3.29. Burning of CH_4 from landfills. 1990-1997

Year	Tonnes CH_4 burned	Per cent of total CH_4 generated
1990	1075	1
1991	3584	2
1992	8602	4
1993	9318	5
1994	10752	5
1995	11827	6
1996	13619	7
1997	16845	8

Source: SFT (1999a).

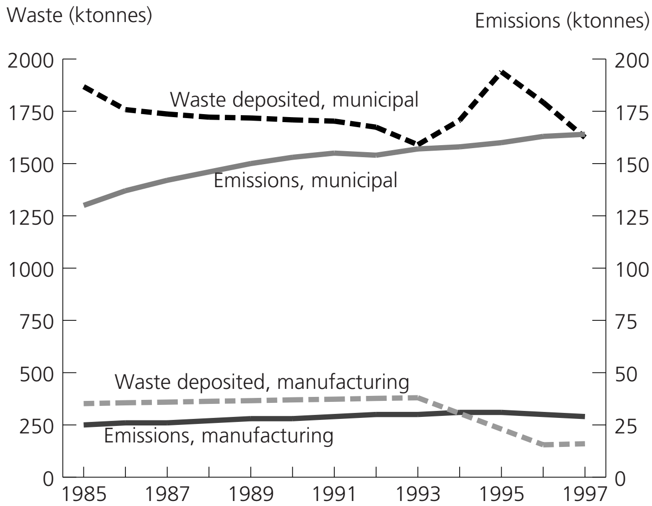
Table 3.30. Estimation factors and emissions of CH_4 from sewage. 1997

Human population	kg BOD[1]/ capita/day	kg CH_4/kg BOD[1]	Anaerobic part (per cent)	Emissions (Tonnes)
4393000	0.05	0.25	2	401

[1] Biological oxygen demand.

Source: Statistics Norway, Norwegian Pollution Control Authority and IPCC (1997a,b).

Figure 3.28. Municipal and manufacturing waste deposited and emissions of methane from landfills. 1985-1997



Source: Waste Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

The amount of methane emitted to the atmosphere in the year of calculation based on waste deposited in all years from 1945 onwards is given by the equation:

$$CH_4\ emissions = (Q_T - R) \cdot (1\text{-}Ox)$$

where

Q_T: Amount of methane generated in the year of calculation (tonnes/year)

R: Amount of methane combusted (tonnes/year)

Ox: Fraction of the methane that is oxidised.

Table 3.28 shows other variables used in the calculations.

Burning the gas will of course reduce methane emissions. In 1997 approximately 17 ktonnes was extracted and burnt. Emissions of CH_4 from landfills in 1997 were estimated at 193 ktonnes.

Estimated CO_2 emissions from landfills in 1997 were 40 ktonnes. This figure includes both direct emissions from the landfills and indirect emissions from oxidation of methane in the atmosphere. It is estimated that 7.5 per cent of the waste is fossil carbon. The rest of the carbon in the waste is non-fossil and is by definition not included in the CO_2 emission inventory.

Emissions have increased substantially in recent decades with the increasing amount of waste landfilled (figure 3.28). However, in 1997 emissions fell from 194 ktonnes to 193 ktonnes as a result of an increase in the amount of methane burnt and a reduction in the amount of waste landfilled. The decrease in emissions is expected to continue.

3.2.15. Sewage and waste water treatment

Methane and N_2O are formed during the degradation of sewage. The quantities are calculated in accordance with IPCC methodology and factors suggested by the IPPC have been used, except for the estimation of nitrogen in sewage (table 3.31). This is based on waste water data from Statistics Norway and a specific nitrogen factor provided by the Norwegian Pollution Control Authority. The same estimate of nitrogen is used every year due to lack of data, but new estimates for the years 1992-1997 will be available soon. The factor for the anaerobic part of the CH_4 calculation (table 3.30) is from Statistics Norway (waste water statistics). All emission factors are from the IPCC (1997a,b). It is estimated that 401 tonnes of CH_4 (table 3.30) and 362 tonnes of N_2O (table 3.31) are formed. N_2O is also formed as a by-product in biological nitrogen-removal plants. It is assumed that 2 per cent of the nitrogen removed will form N_2O. Calculations show that 57 tonnes of N_2O is formed in these plants.

Table 3.31. Estimation factor and emissions of N_2O from sewage. 1997

Amount nitrogen supplied (Tonnes)	N_2O-N/supplied N (per cent)	Emissions (Tonnes)
23000	1	362

Source: Statistics Norway, Norwegian Pollution Control Authority and IPCC (1997a,b).

Table 3.32. Emission factors for HFCs from products and lifetime of products

Application category	Lifetime of products (years)	Emissions during lifetime (per cent of initial charge)
Refrigeration and air conditioning		
Household refrigerators and freezers	15	1.5
Commercial and industrial applications	15	3.5
Refrigerated transport	15	15
Air conditioning aggregates and heat pumps	15	4
Water/liquid refrigerating aggregates, water-based heat pumps	15	5
Mobile air conditioners	12	10
Foam		
Polyurethane with diffusion barrier	40	1
Polyurethane without diffusion barrier	20	5
Extruded polystyrene	30	3
Fire extinguishers	15	5
Solvents	2	50
Aerosol propellants	2	50

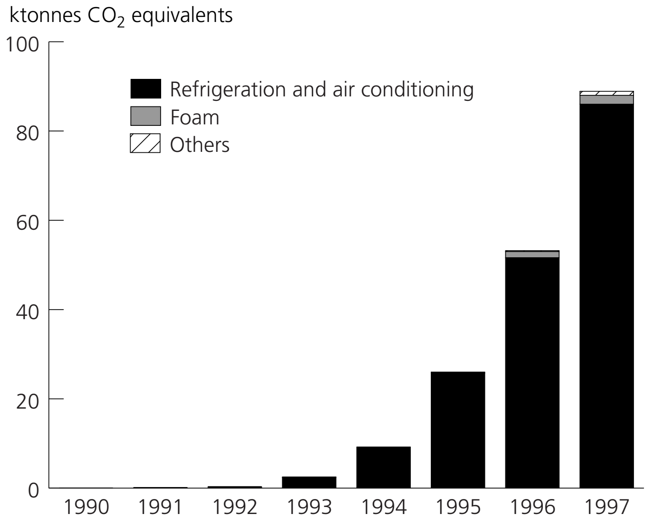
Source: SFT (1999d).

3.2.16. Emissions of HFCs and PFCs from products and processes

HFCs and PFCs are used in refrigeration and air conditioning, foam blowing, fire extinguishers, aerosol propellants and solvents. The HFCs and PFCs registered for use in Norway are HFC-23, HFC-32, HFC-134a, HFC-143a, HFC-152a, HFC-227ea and PFC218.

Emissions of HFCs and PFCs from products are calculated using IPCC's Tier 2 methodology, and the figures are for actual emissions of the substances (IPCC 1997b). The emissions are estimated on the basis of consumption and emission characteristics related to various processes and equipment. Routines for servicing equipment and for recovering the chemicals are also taken into account. Moreover, the time lag between consumption and emission is considered in this method. The time lag results from the fact that chemicals are charged into new products and then slowly leak out over time. For instance, a household refrigerator gradually emits small fractions of the initial charge of refrigerant through leakage and service operations.

Figure 3.29. Emissions of HFCs and PFCs. 1990-1997. ktonnes CO_2 equivalents



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Routines for the collection of information on imports of chemicals in bulk were established in 1990. The reporting system covers CFCs, HCFCs, HFCs and PFCs. Importers of bulk chemicals are contacted yearly, and are required to provide information on the types, amounts and application categories of the chemicals they import. A reporting system for imports and exports of equipment containing HFCs and PFCs has also been established. The amounts of HFCs and PFCs imported in products are determined using the "bottom-up approach", which means that we have counted imported units and multiplied them by the amount of chemical per unit. Emission characteristics for the different categories of equipment and products are defined by expert judgement (SFT 1999d).

Emissions of HFCs and PFCs from products in Norway in 1997 totalled 89 ktonnes or expressed in CO_2 equivalents, about 0.16 per cent of total emissions of greenhouse gases. Emissions of HFCs/PFCs increased by a factor of magnitude from 1990 to 1997. This is because HFCs have replaced CFCs and to some extent HCFCs as refrigerants and in other application areas. The application category "refrigeration and air conditioning" contributed about 97 per cent of these emissions, see figure 3.29.

3.2.17. Emissions of SF_6 from products and processes

In 1997, SF_6 emitted from products and processes, excluding emissions from production of primary aluminium and magnesium, was estimated at 91 ktonnes, measured as CO_2 equivalents. This is 0.2 per cent of total emissions of greenhouse gases in Norway.

In 1999, the method of estimating SF_6 emissions has been revised (SFT 1999c). The new method is largely in accordance with the Tier 2 methodology in the IPPC guidelines for emission inventories (IPCC 1997a,b). Data is collected from direct consultations with importers and exporters of bulk chemicals and products containing SF_6, and from companies that use SF_6 in various processes. The inventory can easily be updated annually by consulting about 20 different users and companies. These consultations will provide input data that cover about 90 per cent of total yearly emissions of SF_6.

During the work on the new methodology, historical data have been recalculated, emission factors from different sources have been established and the bank of SF_6 in existing installations has been estimated. The inventory covers emissions from products and processes. Emissions from production of aluminium and magnesium are described in detail in chapter 3.2.13. New sources that have been included in this inventory are the use of SF_6 as a tracer gas, in medical surgery, in the production of semiconductors and in sound-insulating windows, and emissions of SF_6 from electrical transformers, footwear and sound insulating of windows. Some other minor sources are also included.

The emissions reported in the inventory take into account imports, exports, recycling, banking, technical lifetimes of products, and different rates of leakage from processes, products and production processes. Leakage rates and product lifetimes are shown in tables 3.33 and 3.34.

Table 3.33. Yearly rate of leakage of SF_6 from different processes

Process emission source	Leakage rate (per cent of input of SF_6)
Secondary aluminium foundries	50
Secondary magnesium foundries	100
Tracer gas in the offshore sector	0
Tracer gas in scientific experiments	100
Production of semiconductors	50
Medical use	100
Production of sound-insulating windows	2
Other minor sources	100

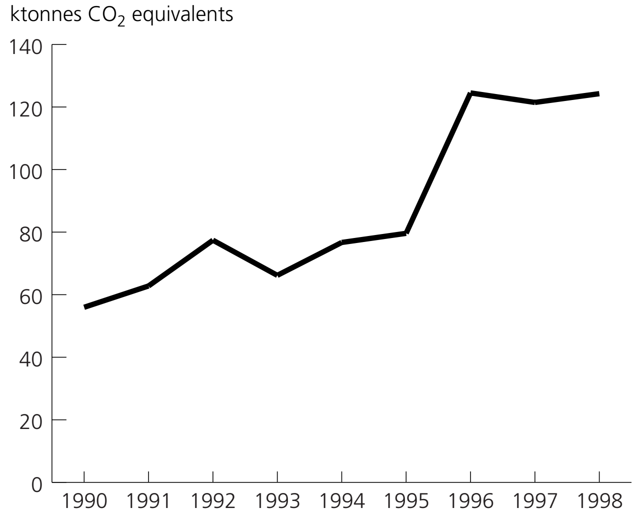
Source: SFT (1999c).

Table 3.34. Product lifetimes and leakage rates from products containing SF_6

Product emission source	Yearly rate of leakage (per cent of remaining content)	Product lifetime (years)
Gas-insulated switchgear (GIS)	1	30
Electrical transformers for measurements	1	30
Sound-insulating windows	1	30
Footwear (trainers)	25	9
Other minor sources	..	..

Source: SFT (1999c).

Figure 3.30. Emissions of SF_6 from products and processes excluding primary magnesium and aluminium production. 1990-1998



Source: SFT (1999c).

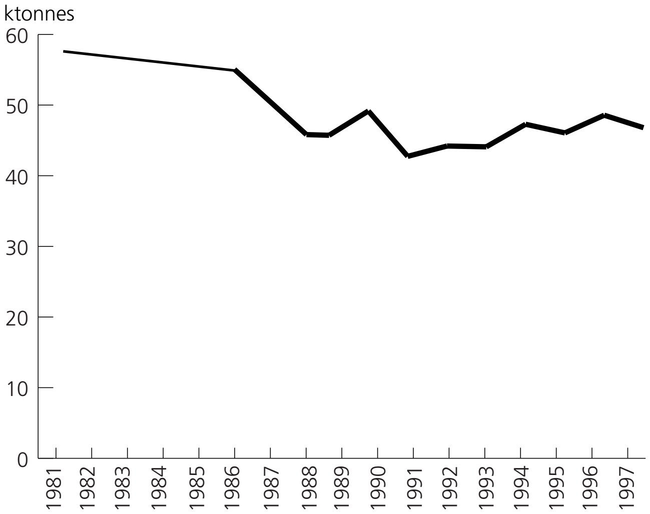
Figure 3.30 shows total emissions from products and processes. The upward trend in total emissions may largely be explained by changes in two of the major emission sources. The largest product emission source is gas-insulated switchgear, GIS. Emissions from GIS increased slightly from 1990 to 1998, but the increase was more pronounced between 1990 and 1992 than between 1993 and 1998. The rise in emissions is directly related to the increase in the amount of SF_6 banked in Gas-Insulated Switchgear (GIS) equipment, where the actual emissions from the bank are calculated by multiplying the amount of SF_6 banked by a specific emission factor which is kept constant from 1990 to 1998.

The largest process emission source is the use of SF_6 as a tracer gas in scientific experiments. In the inventory no emissions from this source were registered before 1994. The emission factor for SF_6 used for this purpose is considered to be 100 per cent. There was a relatively large increase in these emissions from 1993 to 1996, but they declined slightly from 1997 to 1998.

3.2.18. Solvent losses (NMVOC)

The methodology used to estimate emissions from use of solvents and products containing solvents is based on a solvent balance approach (Rypdal 1995). Solvents are both imported to and produced in Norway. Most of the solvents used will sooner or later evaporate to air. Solvents not emitted within the country are either exported, used as raw material, incinerated or broken down in water. The solvent balance follows the flow of solvents from production, import and export, via transformation, to incineration or consumption. This methodology gives independent emission estimates for each year of inventory and in principle covers all fugitive sources.

Figure 3.31. Solvent losses (NMVOC) 1981-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

The equation applied for the solvent balance is:

Emissions = (Production + Import - Export - Destruction – Raw material use) · Solvent content · Fraction emitted + Emissions from certain industrial processes

The solvent balance is based on the commodities in the foreign trade and production statistics that are either pure solvents or contain solvents. The equation is applied to each commodity and total emissions are given by the sum of emissions from all commodities.

In the following, data of major importance for the solvent balance are described.

- *Imports and exports* of the various commodities are determined by Statistics Norway in collaboration with the customs authorities.
- *Production* of the commodities in Norway is based on the manufacturing statistics from Statistics Norway, which cover all main manufacturers annually.
- *Destruction* of solvent waste and paint is given by official statistics on waste delivered and incinerated (Norsas). In addition, the Norwegian Pollution Control Authority has information about incineration in licensed plants.
- *Raw materials* used in industrial processes: data are gathered by Statistics Norway (Manufacturing Statistics). However, these data are not collected annually, but at roughly five-year intervals. These data thus make a large contribution to the uncertainty in the emission figures.
- The *solvent content* is determined using several sources, the most important of which is the Norwegian Product Register. The average solvent content is determined from the average chemical composition of the product category. The solvent contents of the remaining commodities are, with few exceptions, taken from investigations in other countries.
- *Fraction emitted* to air: a figure is assumed for each commodity. Generally, the fraction is higher for products that are not water soluble than for those that are.
- In certain *industrial processes* where solvents are used as raw materials, fractions of the solvents may evaporate to air. Emissions from these plants have been added to the solvent balance where data are available. The emission estimates or emission factors are provided by the Norwegian Pollution Control Authority. However, figures have not been delivered every year and are not available for the most recent years for several plants.

Of the data listed above, the amount of *raw materials* used in industrial processes and the *fraction emitted* to air will probably be the most uncertain figures and contribute most to the uncertainty in the figures for total emissions of solvents.

Total emissions are allocated to main sectors on the basis of the type of commodity, manufacturing statistics from Statistics Norway, data from the Product Register and data on expenditure from the National Accounts.

Total emissions have increased from 45 ktonnes in 1989 to 46 ktonnes in 1997. Figure 3.31 shows there was an overall reduction of about 27 per cent, or 15 ktonnes, from 1981 to 1991. The main reason for this is a reduction in the consumption of white spirit, aromatic compounds, mixed thinners and insecticides and herbicides. From 1991 to 1997, emissions have risen by about 10 per cent, with little fluctuation from one year to another in the period. The main reason for this is increased use of white spirit, aldehydes and glue.

Use of white spirit and paint are the most important sources of solvent emissions in Norway. Each of these sources accounted for about 20 per cent of the total in 1997. Other important sources are ink, ethers and household products. Previously, use of paint was the most important source and use of white spirit second in importance. In addition, the use of aromatic compounds and insecticides, herbicides etc. were among the important sources in 1981.

For some commodities, consumption has changed as a result of environmental concerns or regulations. There has been a small overall reduction in total paint use in the period 1981 to 1997. However, the use of water-based paints has risen in recent years. Emissions from use of chlorinated solvents have been reduced from about 3 000 tonnes in 1981 to about 300 tonnes in 1997. In the last few years there has been an increase in the amount of registered solvents and solvent-containing products incinerated or regenerated.

About 40 per cent of solvent emissions in Norway are from manufacturing industries, and the main sectors are printing and publishing and the chemical industry. The construction industry is also an important emitter in Norway. A quarter of the emissions originate from this sector. The household sector contributes 17 per cent of total emissions. Use of household products is the main source.

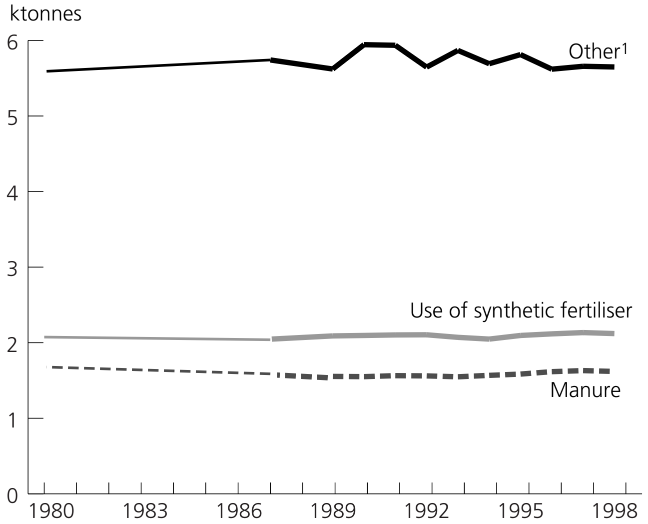
3.2.19. CO_2 from liming of industrial waste

Sulphuric acid waste from a specific plant is neutralised with limestone. An emission factor of 0.45 tonnes CO_2/tonne sulphuric acid has been calculated from the reaction equation. Emissions from liming of industrial waste totalled 21 ktonnes CO_2 in 1997.

3.2.20. Agriculture

Agricultural activities contribute to process emissions of CO_2, CH_4, N_2O and NH_3. The processes involved are related to domestic animals, manure management and cultivation and liming of agricultural soils.

Figure 3.32. Emissions of N_2O from agriculture in Norway. 1980-1998



[1] Includes emissions from biological nitrogen fixation, crop residues, cultivation of soils with a high organic content, N losses by volatilisation, leaching and runoff.

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

N_2O

More than 50 per cent of total N_2O emissions in Norway are from agricultural sources. About half of these are generated by the use of synthetic fertiliser and leaching/runoff from agricultural land. Figure 3.32 shows N_2O emissions from agriculture in Norway.

Microbiological processes in soil lead to emissions of N_2O. Three sources of N_2O are distinguished in the IPCC methodology:

1. direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta, nitrogen used as fertiliser, biological nitrogen fixation, crop residues and cultivation of soils with a high organic content)
2. direct soil emissions from animal production (emissions from droppings on pastures)
3. N_2O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff, and sewage production).

Emissions of nitrous oxide from agriculture are calculated according to the IPCC (1997a,b), but national factors are used where they are available and where they are evaluated to give better results under Norwegian conditions than the default factors from the IPCC (1997a,b).

Agricultural soils

Synthetic fertiliser

Consumption of synthetic fertilisers in Norway is calculated by the Norwegian Agricultural Inspection Service. Annual consumption has been about 110 ktonnes N for the last few years. When calculating direct emissions of N_2O from the use of synthetic fertiliser, an emission factor of 0.0125 kg N_2O-N/kg N is used, as recommended by the IPCC. The factor is temperature-dependent. The emissions are corrected for ammonia that volatilises during application (see 3.2.20 on ammonia). Emissions of N_2O have increased from 2087 tonnes in 1980 to 2120 tonnes in 1997 as a result of a rise in fertiliser consumption, and have remained in the interval 2000-2100 tonnes/year throughout the period.

Manure

This section covers emissions of animal waste used as manure and emissions from grazing animals. In Norway, all animal excreta which is not deposited during grazing is used as manure. Further, it is assumed that animals do not emit N_2O themselves, and emissions of N_2O before manure application on fields are not taken into account (Aakra and Bleken 1997). The amount of manure is estimated from the number of animals (Agricultural Statistics) and factors for each kind of animal, see table 3.35. Total manure in 1997 (preliminary figure) has been estimated at about 83 ktonnes N using national emission factors. The uncertainty connected to this estimate is higher than the figure for synthetic fertiliser used. There is significant uncertainty connected to the allocation of manure between what is used as fertiliser and droppings on pastures. The split was estimated in 1994 (Aakra and Bleken 1997), and the same fractions are used every year. Emissions of N_2O from manure used as fertiliser are calculated using the emission factor from the IPCC, 0.0125 kg N_2O-N/kg N, while emissions of N_2O from animals on pastures are calculated using the IPCC factor of 0.02 kg N_2O-N/kg N (IPCC 1997a,b). Temperature influences both factors. The N_2O emissions are corrected for ammonia that volatilises during application and from pastures. Total N_2O emissions from manure have varied from 1500 to 1600 tonnes in the

Table 3.35. N in excreta from different animals

	kg/animal/year[2]
Dairy cattle	89.8
Non-dairy cattle > 1year	38.5
Non-dairy cattle < 1year	30.3
Horses	52.3
Sheep	9.6
Dairy goats	14.0
Pigs for breeding	24.3
Pigs for slaughtering[1]	4.0
Hens	0.8
Chicks bred for laying hens[1]	0.16
Chicks for slaughtering[1]	0.058
Ducks, turkey[1]	0.37
Mink, females	4.7
Foxes, females	11.9

[1] Per stalled animal.

[2] Includes pasture.

Source: Sundstøl and Mroz (1988).

period 1990-1997, with a maximum in 1997. In 1997, manure used as fertiliser and droppings on pastures accounted for 900 tonnes N_2O and 600 tonnes N_2O respectively.

Biological nitrogen fixation

Another source of nitrous oxide emissions is connected to biological nitrogen fixation. The most important N-fixing crop in Norway is clover. The amount of nitrogen fixed by a crop is very uncertain, and it is difficult to assign a conversion factor for N_2O emissions derived from nitrogen fixation (IPCC 1997a,b). Biological N-fixation is estimated at around 8000 tonnes N/year (Aakra and Bleken 1997). Using the IPCC default emission factor of 0.0125 kg N_2O-N/kg N gives emissions of 160 tonnes N_2O per year.

Crop residues

There is only limited information concerning re-utilisation of nitrogen from crop residues. Nitrous oxide emissions associated with crop residue decomposition are calculated by estimating the amount of nitrogen entering soils as crop residue, as recommended by the IPCC (1997a,b). The amount of nitrogen in crop residues returned to soils is assumed to be equal to that in the harvest (Aakra and Bleken 1997). The IPCC factor of 0.0125 kg N_2O-N/kg N has been used and gives N_2O emissions from crop residues of 1500 tonnes in 1997. In the period 1980 to 1997, the emissions varied from 1500 to 1900 tonnes, with a maximum in 1990.

Cultivation of soils with a high organic content

Large N_2O emissions occur as a result of cultivation of organic soils (histosols) due to enhanced mineralisation of old, N-rich organic matter (IPCC 1997a,b). The area of cultivated organic soil in Norway is approximately 1.8×10^5 ha (Aakra and Bleken 1997).

Using the IPCC default emission factor of 5 kg N_2O-N/ha per year, N_2O emissions are estimated at 1400 tonnes per year.

N losses by volatilisation

Atmospheric deposition of nitrogen compounds fertilises soils and surface waters, and enhances biogenic N_2O formation. Climate and fertiliser type influence ammonia volatilisation. We calculate emissions of N_2O from ammonia volatilised during use of manure in Norway, and assumed to be subsequently deposited in Norway, according to the method described by the IPCC (1997a,b). Deposition of ammonia corresponds to the amount of NH_3 which volatilises during use of synthetic fertiliser and manure. N_2O emissions from the use of synthetic fertiliser and manure are corrected for these amounts (see 3.2.20, ammonia). The IPCC default emission factor of 0.01 kg N_2O-N/kg NH_3-N is used. N_2O emissions from deposition have been relatively stable, around 300 tonnes per year in the period 1980 to 1997.

Leaching and runoff

A considerable amount of fertiliser nitrogen is lost from agricultural soils through leaching and runoff. Fertiliser nitrogen in ground water and surface waters enhances biogenic production of N_2O as the nitrogen undergoes nitrification and denitrification. The fraction of the fertiliser and manure nitrogen lost to leaching and surface runoff may range from 10 to 80 per cent. The IPCC (1997a,b) proposes a default value of 30 per cent. However, this value will not be used in future, since a national factor of 18 per cent is believed to give better results under Norwegian conditions (JORDFORSK 1998). The value has been estimated from a runoff model. Using the IPCC default emission factor of 0.025 kg N_2O-N/kg N leaching/runoff gives emissions of 2300 tonnes N_2O in 1997. Emissions have increased by about 4 per cent in the period 1990 to 1997.

CO_2 from liming

Process emissions of CO_2 from agriculture derive from liming. Lakes and agricultural soils are limed in Norway to reduce the damage from acidification and unbalanced soils. Application of calcium carbonate ($CaCO_3$) gives rise to emissions of CO_2. The emission factor used is 0.44 tonne CO_2/tonne calcium carbonate applied (SFT 1990). It is however uncertain whether all of this should be considered as a net emission source.

The Norwegian Pollution Control Authority has estimated the consumption of lime in agriculture to be approximately 400 ktonnes/year, which gives estimated emissions of 170 ktonnes CO_2/year. This corresponds to less than 0.5 per cent of total CO_2 emissions in Norway. This is the only source of CO_2 emissions from agricultural processes.

In 1990 about 20 ktonnes of calcium carbonate was used to lime lakes (Directorate for Nature Management), but from 1992 the figure has been about 30 ktonnes a year. This gives total emissions of 183 ktonnes CO_2 each year from liming.

CH_4

Domestic animals are the major source of CH_4 emisions from agriculture, accounting for 31 per cent of total CH_4 emissions in 1997. Both enteric fermentation and manure management contribute to emissions of methane.

Enteric fermentation

The production of CH_4 by enteric fermentation in animals varies with digestive system and feed intake. Ruminants such as cattle and sheep produce most methane. However, enteric fermentation in pseudo-ruminants (e.g. horses) and monogastric animals (e.g. pigs) is also of significance. We use the number of each kind of domestic animal and average emission factors for each kind to calculate emissions, in accordance with the IPCC Tier 1 method (IPCC 1997a,b).

Although the emissions depend on several factors and therefore vary between different individuals of one kind of animal, we have chosen to apply average emission factors for each kind. Default emission factors from the IPCC (1997a,b) are used. The emission factor for reindeer has been estimated by scaling the emission factors for goats and sheep according to carcass weight.

The numbers of the various kinds of animals are taken from Statistics Norway's livestock statistics. These are based on the register of production holders applying for governmental grants. Almost 100 per cent of all livestock are registered here.

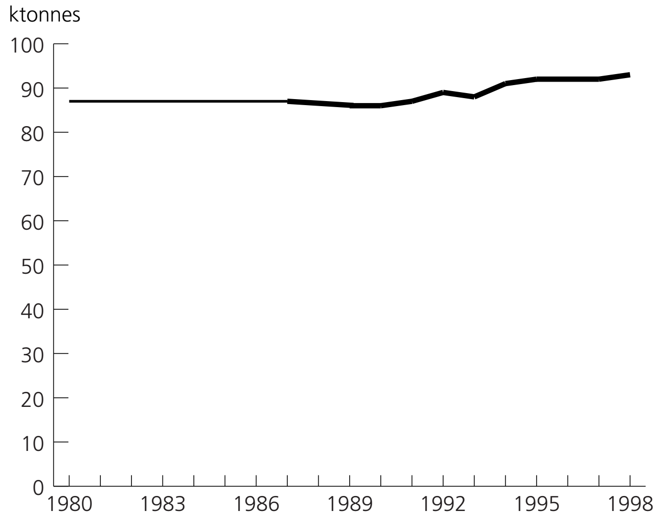
The composition of the population of domestic animals has changed since 1990, which explains why emissions have increased although the total number of animals has decreased (figure 3.33).

Table 3.36. Emissions of CH_4 from enteric fermentation. Emission factors and number of animals. 1997

Animal	No. of animals	Emission factor (Tonnes/ animal/year)	Emissions (Tonnes)
Total 1990			86106
Total 1997			93115
Dairy cattle	343721	0.1	34372
Non-dairy cattle	671643	0.048	32239
Sheep, incl. lambs	2651195	0.008	21210
Goats	78565	0.005	393
Reindeer	177196	0.011	1949
Horses	45000	0.018	810
Pigs	627061	0.0015	941
Hens	3400896	0.00002	68
Turkeys	13674	0.00002	0.3

Source: IPCC (1997a,b), Agricultural Statistics from Statistics Norway and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 3.33. Emissions of CH_4 from enteric fermentation in domestic animals. 1980-1998



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.37. Emissions of CH_4 from manure management. Emission factors and numbers of animals. 1997

	No. of animals	Production (kg/ animal/day)	VS (per cent)	B_0 (m^3/kg-VS)	MCF (per cent)	Emission (tonnes)
Total						15893
Horses	45000	25.5	16.4	0.21	8	764
Non-dairy cattle	671643	15-35	9.2	0.21	8	5714
Dairy cattle	343721	45	9.2	0.18	8	4951
Sheep	2651195	1-2	19.5	0.19	5	1668
Goats	78565	1-1.8	23	0.19	5	64
Pigs	627061	4.5-9	9.5	0.21	8	1243
Poultry	11383953	0.085-0.7	15.6-19.4	0.25	8	1051
Fur-bearing animals	1081500	0.175-0.56	16	0.25	8	375
Reindeer	177196	2	19.5	0.19	2	63

Source: Agricultural Statistics from Statistics Norway, Agricultural University of Norway[3], IPCC (1997a,b) and the emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table 3.38. Parameters included in the estimation of NH_3 emissions from manure and manure management

Input	Sources
Number of animals	Statistics Norway, Norwegian Grain Administration
Percentage of manure dropped into fields during grazing	ECETOC (1994)
Cultivation	Norwegian Grain Administration
Emissions from storage of manure	Morken (1994)
Area where manure is spread, split by cultivation practice and time of spreading	Statistics Norway (Sample Survey of Agriculture)
Emissions to air during spreading of manure	Claesson and Steinbeck (1991), Morken (1994)

Manure management
Organic material in manure is transformed to methane in an anaerobic environment by microbiological processes. Emissions from cattle are most important in Norway. The emissions from manure depend on several factors; type of animal, feeding, manure management system and weather conditions (temperature and humidity).

Emissions of methane from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997a,b):

$$E_i = \frac{N_i \cdot M_i \cdot VS_i \cdot B_{0_i} \cdot MCF_i}{1000}$$

E: Emissions of methane
N: Population of animals
M: Production of manure (kg/animal/year)
VS: Volatile solids (per cent)[2]
B_0: Maximum methane-producing capacity (m^3/kg-VS)
MCF: Methane conversion factor
$_i$: Species

The factors M, VS, B_0 and MCF are average factors meant to represent the whole country. The factor B_0 represents the maximum potential production of methane under optimum conditions. MCF is a correction of B_0 according to how the manure is handled. The factors are estimated jointly by Statistics Norway and the Agricultural University of Norway[3].

NH_3
In 1997, 94 per cent of NH_3 emissions in Norway originated from three agricultural sources:

1. manure and manure management
2. straw treated with NH_3 to be utilised as fodder
3. use of fertiliser

Of these, manure management accounts for two thirds of the NH_3 emissions from agriculture.

Manure management
Emissions of NH_3 from manure depend on several factors, e.g. type of animal, nitrogen content in fodder, manure management, climate, time of spreading of manure, cultivation practices and characteristics of the soil. The parameters included are shown in table 3.38.

The emission sources are split into manure in storage, droppings on pastures, manure during and after spreading, and emissions from reindeer.

Use of fertiliser
Calculations of NH_3 emissions from use of fertiliser are based on the amounts of nitrogen supplied and factors for the percentage of nitrogen emitted during spreading. The emission factors vary from one type of fertiliser to another. ECETOC (1994) estimated emission factors, see table 3.40.

Treatment of straw
Emissions of NH_3 from treatment of straw depend only on the amount of NH_3 used. It is estimated that 67 per cent of the ammonia applied is not integrated with the straw, and is therefore emitted after the treatment. The amount of NH_3 used per year is obtained from Norsk Hydro and the Norwegian Agricultural Supply Cooperative. The emission factor is estimated by the Department of Animal Science at the Agricultural University of Norway.

Table 3.39. Nitrogen excreted in manure and urine. kg/animal/year

	Total nitrogen excreted	NH_3-N
Horses	50.5	18.9
Cattle	19.6-85.7	7.1-37.6
Sheep	8.61	5.6
Goats	12.3	5.5
Pigs	3.96-20.24	2.8-13.9
Poultry	0.03-0.61	0.01-0.3
Fur-bearing animals	1.2-2.38	0.5-1.0

Source: Bleken (1996) and Morken (1994).

Table 3.40. Emission factors for different fertilisers. Per cent of applied N

Fertiliser	Emission factor
Urea	15
Ammonium sulphate	5
Ammonium nitrate	5
Other	1

Source: ECETOC (1994) and Norsk Hydro.

[2] Volatile solids (VS) are the degradable organic material in livestock manure (IPCC 1997a,b).
[3] Institute of Chemistry and Biotechnology, Section for Microbiology.

4. Results of the inventory

This chapter presents the main results of the Norwegian emission inventory at national level. Appendix B gives a more detailed overview of Norwegian emissions.

The data sources on which the emission figures are based are presented in chapter 3: *Data for estimation of emissions*. The inventory model itself is described in chapter 5. Emission factors are shown in tables throughout chapter 3 and in appendix E. Table 4.2 lists Norway's international commitments as regards emissions to air.

4.1. Greenhouse gases (GHGs)

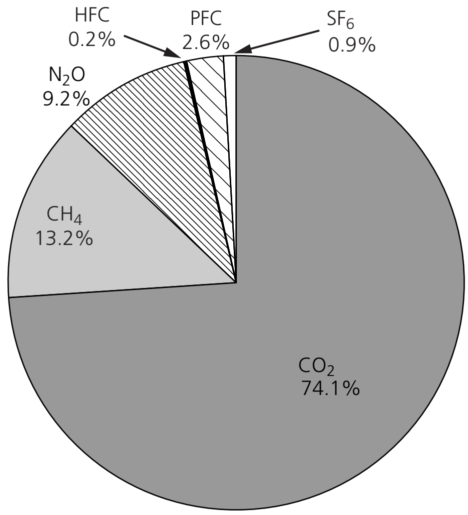
The atmosphere contains many different gases, some of which have the ability to absorb radiation, thus raising the global temperature. This is called the greenhouse effect. The average temperature on earth is +15 °C, whereas without the greenhouse effect it would have been –18 °C. In recent centuries, human activity has increased the concentration of these gases, and this is believed to be causing a further rise in the global mean temperature - the "enhanced greenhouse effect". The most important greenhouse gases are carbon dioxide (CO_2), water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Table 4.1. Emissions of greenhouse gases in Norway by IPCC category. 1997. Million tonnes CO_2 equivalents

	Total	CO_2	CH_4	N_2O	Others
Total national emissions	55.9	41.4	7.4	5.1	2.0
1 Energy sectorial approach	35.1	33.5	1.0	0.5	0.0
A Fuel combustion	32.4	31.6	0.3	0.5	0.0
B Fugitive emissions from fuels	2.6	1.9	0.7	0.0	0.0
2 Industrial processes	11.3	7.7	0.0	1.5	2.0
3 Solvent and other product use	0.1	0.1	0.0	0.0	0.0
4 Agriculture	5.2	0.0	2.3	2.9	0.0
5 Land-use change and forestry	0.0	0.0	0.0	0.0	0.0
6 Waste	4.2	0.0	4.1	0.1	0.0
7 Other	0.0	0.0	0.0	0.0	0.0

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 4.1. Composition of greenhouse gas emissions in Norway. Weighted by GWP values (100 years). 1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

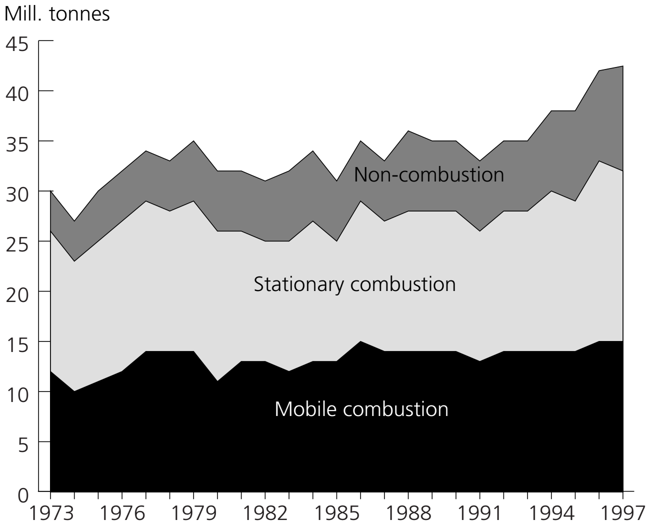
The composition of Norwegian GHG emissions in 1997 is shown in figure 4.1. Pollutants other than CO_2 constitute 26 per cent of total emissions, weighted by GWP values. Nearly 60 per cent of GHG emissions in Norway originate from fuel combustion (table 4.1). Industrial processes (especially ammonia and fertiliser production and metal production) account for around 20 per cent of the total. Agriculture and waste management emit 9 and 8 per cent of the total, respectively.

4.1.1. Carbon dioxide (CO_2)

In 1997, Norwegian CO_2 emissions totalled 41.4 million tonnes. This is an 18 per cent increase from the 1990 level (figure 4.2), half of which is due to an increase in stationary combustion.

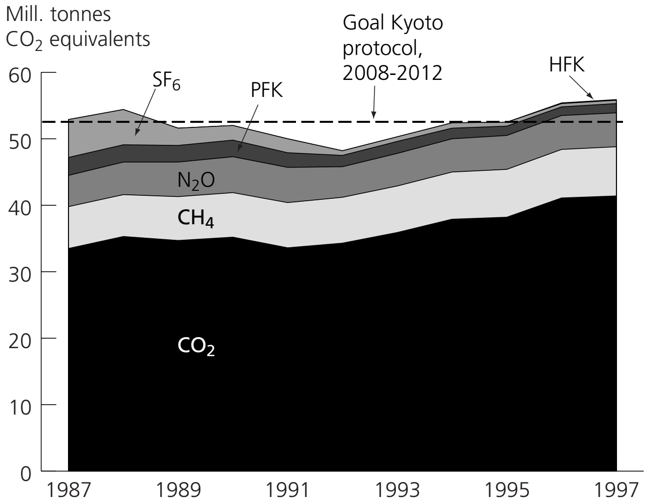
Of these emissions, 42 per cent originated from stationary combustion, 37 per cent from mobile combustion and 21 per cent from non-combustion sources. Oil and gas extraction alone accounted for 23 per cent of the CO_2 emissions while road transport accounted for 21 per cent and national sea traffic for 10 per cent of the total.

Figure 4.2. Emissions of CO_2 by source. 1973-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 4.3. Emissions of greenhouse gases. 1987-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

4.1.2. Methane (CH_4)

In 1997, CH_4 emissions were estimated at 350 ktonnes. This is a 10 per cent increase since 1990. Emissions from landfills have increased by 6 per cent, and emissions from animals and animal manure by 7 per cent. Non-combustion emissions from oil and gas industries have risen by 80 per cent and account for 12 ktonnes of the total rise of 33 ktonnes in methane emissions.

Non-combustion sources accounted for 96 per cent of emissions in 1997. Most important was methane generated from anaerobic degradation of waste, which alone accounted for 55 per cent of the total emissions, while 31 per cent were related to domestic animals and animal manure. Thus, combustion sources accounted for only 4 per cent of the emissions. Households, road traffic and oil and gas activities accounted for 2, 1 and 1 per cent respectively.

4.1.3. Nitrous oxide (N_2O)

In 1997, 16 ktonnes of N_2O were emitted in Norway. This means that there has been a 7 per cent reduction in the period 1990-1997, mainly due to a reduction in emissions from the production of nitric acid (used in fertiliser production).

In 1997, non-combustion sources accounted for 89 per cent of total emissions, mobile combustion for 9 per cent and stationary combustion for 2 per cent. Agriculture (non-combustion) alone accounts for 57 per cent of the emissions. Production of fertilisers (non-combustion) is also an important source and accounts for 29 per cent of the total. The trend in emissions from fertiliser production is therefore very important for the trend in total N_2O emissions. The importance of emissions from road traffic (mobile combustion) is increasing. Cars with catalytic converters emit more N_2O than cars without, and today all new cars have catalytic converters. These emissions accounted for 6 per cent of total N_2O emissions in 1997. Emissions of N_2O from road traffic have risen by 313 per cent from 1990 to 1997 because of the use of converters.

4.1.4. Hydrofluorocarbons (HFCs), perfluoro carbons (PFCs) and sulphur hexafluoride (SF_6)

Emissions of the greenhouse gases PFCs and SF_6 were reduced by 43 per cent and 77 per cent respectively from 1990 to 1997, mainly as a result of extensive measures to reduce emissions from the process industry (production of magnesium and aluminium). Emissions of HFCs rose from 0.1 tonne to 44 tonnes in the same period, because HFCs have begun to replace chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs) in cooling equipment during the 1990s.

4.1.5. Norway's commitments as regards emissions of greenhouse gases

According to the Kyoto Protocol, Norway's emissions of greenhouse gases may not rise by more than 1 per cent between 2008 and 2012 compared to the 1990 level. Nevertheless, Norway's aggregate emissions (in CO_2 equivalents) increased by 7 per cent from 1990 to 1997 (figure 4.3).

4.2. Acidifying gases

SO_2 and NO_X have an acidifying effect on soil and water. The extent of the damage depends on the type of soil and vegetation. Soils with a high lime content can resist acidification better than those with a lower lime content. Most Norwegian soils have a low lime content. Infrastructure is also damaged by acid rain, which increases corrosion and speeds up the decay of metals and buildings. Although some acid deposition in Norway is caused by Norwegian emissions, most of it originates from long-range transport of emissions from other European countries.

Table 4.2. Norwegian commitments under international environmental agreements

Pollutant	Base year	Target	By year	Achieved (1990-1998)
SO_2	1990	22 ktonnes (-58 per cent)[1]	2010	-44 per cent
NO_x	1990	156 ktonnes (-28 per cent)[1]	2010	+3 per cent
NMVOC	1990	195 ktonnes (-37 per cent)[1]	2010	+17 per cent
NH_3	1990	23 ktonnes (0 per cent)[1]	2010	+10 per cent
GHGs[3]	1990	+1 per cent[2]	2008-2012	+7 per cent[4]

[1] New LRTAP protocol.
[2] Kyoto Protocol.
[3] GHGs are the greenhouse gases CO_2, CH_4, N_2O, PFCs, HFCs and SF_6.
[4] 1990-1997.
Source: Proposition No. 1 (1999-2000) to the Storting, and the emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

NO_X is the most important acidifying gas emitted in Norway, and contributes about two thirds of national emissions of acidifying substances (figure 4.4). The largest source of NO_X emissions is national sea traffic. Unlike road traffic, sea traffic is not subject to technical regulations. The high level of sea traffic in Norway is explained by its long coastline, the volume of transport between the mainland and the offshore oil and gas facilities, and the large fishing fleet.

The main source of SO_2 emissions in Norway today is metal production. Norway produces large amounts of aluminium and ferroalloys using coal and coke as reducing agents. Unlike many other countries, Norway bases its electricity production on hydropower, and electricity is also extensively used for heating (table 4.3).

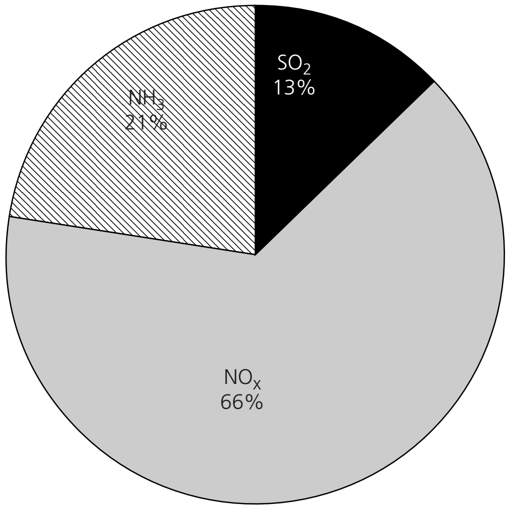
Agriculture (use of mineral fertiliser and manure) is the most important source of ammonia emissions.

Norway has signed international agreements to reduce emissions of the acidifying gases NO_X and SO_2. In late 1999, a new protocol for the gases SO_2, NO_X, NMVOC and NH_3 was signed. This protocol (the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone) has been negotiated within the framework of the ECE Convention on Long-range Transboundary Air Pollution (LRTAP). The new targets are shown in table 4.2. The protocol includes commitments for the year 2010 with 1990 as the base year. Because the new protocol will use 1990 as the base year, the emission figures for these gases in 1997 are compared to those for 1990 in this chapter. In chapter 3, on the other hand, the emission figures for 1997 are compared to the base years for the "old" agreements (1980 for SO_2, 1987 for NO_X and 1989 for NMVOC).

4.2.1. Sulphur dioxide (SO_2)

Norwegian SO_2 emissions totalled 30 ktonnes in 1997. This is a 42 per cent reduction from 1990 (figure 4.5), which is the base year for the new LRTAP protocol. The drop in SO_2 emissions can be explained by a changeover to the use of electricity rather than oil products, the use of lighter oil products, a reduction in the sulphur content of oil products and the installation of more and better equipment to control emissions.

Figure 4.4. Composition of emissions of acidifying gases. 1997. Measured as acid equivalents



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

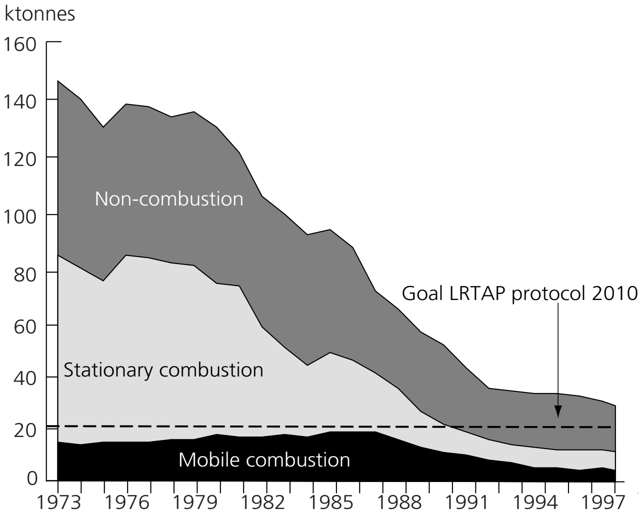
Table 4.3. Emissions of acidifying gases and NMVOC by SNAP source. 1997. ktonnes

SNAP source	SO_2	NO_X	NH_3	NMVOC
Total	30.3	222.3	26.4	359.4
01 Combustion in energy and transformation industries	0.9	31.2	-	1.8
02 Non-industrial combustion plants	1.4	2.6	-	10.0
03 Combustion in manufacturing industry	4.8	8.8	-	0.9
04 Production processes	18.7	8.3	0.3	21.2
05 Extraction and distribution of fossil fuels	-	-	-	204.8
06 Solvent and other product use	-	-	-	45.8
07 Road transport	1.7	59.6	1.1	56.3
08 Other mobile sources and machinery	2.8	105.9	0.0	17.7
09 Waste treatment and disposal	0.0	5.8	-	1.2
10 Agriculture	-	-	25.0	-

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

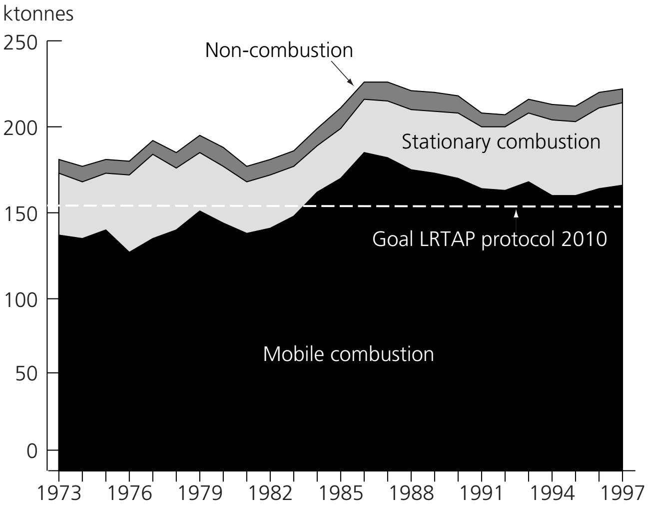
In 1997, 62 per cent of the emissions were from non-combustion sources, 23 per cent from stationary combustion and 15 per cent from mobile combustion. All of the non-combustion emissions are related to industrial processes. Metal production is most

Figure 4.5. Emissions of SO_2 by source. 1973-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Figure 4.6. Emissions of NO_x by source. 1973-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

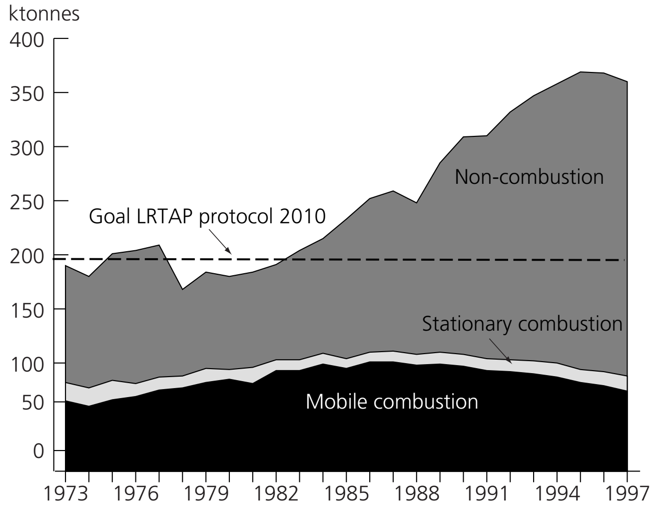
important, and accounts for 38 per cent of the national emissions. Road traffic accounted for 6 per cent of the emissions and national sea traffic for 8 per cent.

4.2.2. Nitrogen oxides (NO_X)

Norway emitted 222 ktonnes of NO_X in 1997 (figure 4.6), which is a 2 per cent increase from 1990.

Mobile combustion, stationary combustion and non-combustion sources accounted for 74, 22 and 4 per cent respectively of the total emissions. Shipping, road traffic and oil and gas extraction are the most important sources. Norway has achieved the target of the Sofia Protocol, which was to stabilise NO_X emissions at the 1987 level by 1994. NO_X emissions have been stable in spite of growth in energy use and production,

Figure 4.7. Emissions of NMVOC by source. 1973-1997



Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

mainly due to cleaner car technology. The growth in transport and in combustion of natural gas offshore have cancelled out the effect of reduced emissions per vehicle km.

4.2.3. Ammonia (NH_3)

In 1997, 26 ktonnes of NH_3 were emitted. This is a 15 per cent rise from 1990. Ammonia emissions are generated mainly by use of commercial fertiliser and manure and by the treatment of straw with ammonia. Non-combustion sources accounted for 96 per cent of the emissions, while 4 per cent was emitted by mobile combustion sources.

4.3. Other gases

4.3.1. Non-methane volatile organic compounds (NMVOC)

Emissions of NMVOC in Norway are high compared to those in other European countries because of emissions from the oil production industry. More than half of all NMVOC emissions in Norway originate from this industry (particularly from loading oil into ships).

In 1997, emissions of NMVOC totalled 359 ktonnes. This is a 16 per cent increase from 1990. According to the new LRTAP protocol, emissions are to be reduced by 37 per cent by 2010. According to the old NMVOC agreement, Norway was also to reduce its emissions, in this case by 30 per cent in the period 1989-1999. Despite this, there has been an 26 per cent increase in the period 1989 to 1998. If oil and gas production is excluded, emissions have been reduced by 10 per cent from 1989 to 1998. The rise in emissions is due to the growth in the volume of the crude oil transported and partly also to the growth in gasoline consumption. In 1996 and 1997 emissions were slightly lower than in 1995, but this is not enough to reach the target in 1999. The decrease is explained by a reduction in the average age of the car fleet and the introduction of a recovery facility for oil vapour at one of the terminals.

In 1997, 76 per cent of the emissions were from non-combustion sources, 21 per cent from mobile combustion and 4 per cent from stationary combustion. The two most important sources in Norway are evaporation during loading of crude oil (48 per cent in 1997) and emissions from road traffic (16 per cent).

4.4. Uncertainties

Uncertainty is an important aspect of inventory quality. The sources of uncertainty in the emission estimates include sampling errors, poor relevance of emission factors or activity data, and gross errors (SFT 1999e).

The emission estimates for the various pollutants in the Norwegian inventory may be ranked roughly in order of increasing uncertainty as follows:

Greenhouse gases:

$CO_2 \approx SF_6 < HFC < CF_4/C_2F_6 \approx CH_4 < N_2O$

Long-range air pollutants:

$SO_2 < NO_X < NH_3 \approx NMVOC$

Making an emission inventory is a laborious process involving several steps. There are two main ways of reducing uncertainties:

- Reducing the number of gross errors.
- Obtaining better scientific information, including improved input data.

The procedure of making annual estimates as well as several updates for each year gives several opportunities of detecting gross errors. Each new estimate is compared to the provisional estimate as well as to the latest estimate for the previous year. Any changes must be explained, and in this way gross errors may be detected.

The activity data are often statistical data. Official statistical data go through a systematic revision process, which may be manual or, more and more frequently, computerised. Revision significantly reduces the number of errors in the statistics used as input to the inventory. Finally, where alternative methodologies are available, emission estimates are often made by both methods and then compared. Such comparisons may reveal errors and suggest where methods can be improved, and they also indicate the level of uncertainty.

An emission inventory is never final. When better input data become available, emissions are updated for all years so that a consistent time series is maintained. Obtaining better scientific information and statistical data is a continuous process. Such information improves the emission factors, methodologies and in some cases also activity data, and thereby reduces the uncertainties in the inventory.

A review of uncertainties in the national greenhouse gas inventory may be found in SFT (1999e). Statistics Norway is currently working on further analysis of the uncertainties in GHG inventories (to be published early 2000).

5. The Norwegian emission model

This chapter describes the general structure of the emission model “Kuben” (“the Cube”).

The Norwegian emission inventory is organised around a general emission model called “Kuben” (“the Cube”). Several emission sources, e.g. road traffic, air traffic, and solvents, are covered by more detailed satellite models. Aggregated results from the side models are used as input to the general model. The satellite models are presented in the appropriate sections of chapter 3. This chapter describes the general emission model (sections 5.1-5.4) and the satellite model for road traffic emission (section 5.5).

5.1. Structure of the general emission model

The general emission model is based on the equation

$$Emissions\ (E) = Activity\ level\ (A) \cdot Emission\ Factor\ (EF)$$

The main activity data for estimating emissions to air concern energy use. In the Norwegian energy accounts, the use of different forms of energy is allocated to economic sectors. In order to calculate emissions to air, energy use must also be allocated to technical sources (e.g. equipment). After energy use has been allocated in this way, the energy accounts may be viewed as a cube in which the three axes are fuels, sectors, and sources.

For combustion-related emissions the emission factors for each pollutant depend on the fuels, sectors, and technical sources involved. Hence, they may fit into a four-dimensional cube in which pollutants are a fourth dimension in addition to fuel, sector and source. In principle, there should be one emission factor for each combination of fuel, sector, source, and pollutant. However, in a matrix with a cell for each combination, most of the cells would be empty (no consumption). In addition, the same emission factor would apply to many cells.

The model is easy to understand with respect to emissions from combustion. Combustion of a fuel (the emission carrier) takes place in a particular type of equipment (the technical source) in a certain economic sector. Thus, the Norwegian model for estimating emissions to air is constructed as a "cube" with four axes. The axes are emission carriers (e.g. fuels), economic sectors, technical sources, and pollutants.

Emissions from non-combustion activities are usually assigned to source and/or sector when the emissions are reported, *e.g.*, CH_4 emissions from domestic animals. In order to fit into the general model, such an emission has to be assigned to an emission carrier and a technical source. The emission carrier is then the physical object from which the emissions originate (*animals*), and the technical source is the process leading to the emissions (*bioprocesses*).

The calculations are carried out in three steps. The subscripts refer to the four axes emission carrier (i), economic sector (j), technical source (k), and pollutant (l).

1. The combustion emission factors are multiplied by energy use figures from the energy accounts, cell by cell, giving the calculated combustion emissions for each pollutant:

   $$E_{ijkl} = A_{ijk} \cdot EF_{ijkl}$$

2. Emissions of some pollutants from major manufacturing plants (point sources) are measured directly or determined from mass balances. When such measured data are available it is possible to replace the estimated values by the measured ones:

   $$E_{ijkl} = (A_{ijk} - APS_{ijk}) \cdot EF_{ijkl} + EPS_{ijkl}$$

   where *APS* and *EPS* are the activity and the measured emissions at the point sources, respectively.

3. Non-combustion emissions are calculated by combining appropriate activity data with emission factors or by more complicated methods. Some emissions may be obtained from current reports and investigations, and some are measured directly as described in chapter 3. These emissions are added to the appropriate cells in the cube (E_{ijkl}, where k refers to a non-combustion technical source).

Table 5.1. Emission carriers and sources in the Norwegian emission model

Emission carrier	Sources (non-combustion sources in italics)
Fuel wood, wood waste, black liquor	Heating, fire
Coal	Combustion, *redox, extraction, transformation*
Coal coke	Combustion, *redox*
Petrol coke	Combustion, *redox, carbide production*
Natural gas	Combustion, flaring, *transformation, extraction*
Other gases[1]	Combustion, flaring, *transformation*
LPG (liquefied petroleum gas)	Heating, flaring
Motor gasoline	Road traffic, boats, motor equipment, *evaporation*
Aviation gasoline	Air traffic
Kerosene (heating)	Heating
Jet fuel (kerosene)	Air traffic
Auto diesel	Heating, road traffic, railways, boats, motor equipment
Marine fuel	Combustion, ships
Light fuel oils	Heating, ships, motor equipment
Special distillate	Combustion, ships
Heavy fuel oils	Combustion, ships
Waste oil	Combustion
Waste	Combustion, *bioprocesses, transformation*
Crude oil	Flaring, *extraction, oil loading, transformation*
Nitrogen compounds/products	*Bioprocesses, evaporation, transformation, fertiliser production*
Other nitrogen[2]	*Bioprocesses*
Manure	*Bioprocesses*
Animals	*Bioprocesses*
Articles of food	*Bioprocesses*
Solvents	*Evaporation*
Sulphur compounds	*Boiling, transformation, redox*
Lime and Ca compounds	*Liming, transformation*
Clay	*Transformation*
Ore	*Redox, transformation*
Metals	*Transformation*
Silicon	*Transformation*
Asphalt	*Wear*

[1] *Other gases* include refinery gas, landfill gas and an excess gas (mainly methane and hydrogen) produced and consumed in the chemical industry. These gases are chemically different. A given sector consumes only one of these gases, so different emission factors are used for the different sectors.

[2] *Other nitrogen* is used to distinguish certain N_2O sources.

5.2. The four axes: Emission carriers, sources, sectors and pollutants

The emission carriers used in the model are shown in table 5.1. Most of them are fuels. Some fuels are also used in non-combustion activities, e.g. coal is used as a reducing agent.

The model uses approximately 130 economic sectors. The classification is almost identical to that used in the National Accounts, which is aggregated from the European NACE (rev. 1) classification (Statistics Norway 1994). The large number of sectors is an advantage in dealing with important emissions from manufacturing industries. The disadvantage is an unnecessary disaggregation of sectors with very small emissions. To make the standard sectors more appropriate for calculation of emissions, a few changes have been made, e.g. "Private households" is defined as a sector. The list of sectors is shown in appendix D.

The technical sources used in the model are shown in table 5.2. Most of the sources are easily understood. Others are not meaningful unless they are linked to an emission carrier or sector. Only anthropogenic sources are included in the model.

The emission model currently includes eleven pollutants. They are:

- Greenhouse gases: CO_2, CH_4, and N_2O.
- Acidifying gases: SO_2, NO_X, and NH_3.
- Other gases: NMVOC and CO.
- Heavy metals: Pb and Cd.
- Airborne particles (PM_{10}).

All emissions are calculated in the same way, as described in the previous section.

5.3. Regions: a fifth axis

Information about the geographical distribution of emissions is useful for modelling and control purposes. The model has been developed to handle allocations to geographical units (Daasvatn et al. 1994). The spatial distribution of emissions introduces another dimension (axis) to the general model.

5.3.1. Municipalities

The municipalities, of which there are 435 on the mainland, have been chosen as the smallest unit for regionalisation. In addition we have included the regions Svalbard, sea areas north and south of 62°N, and air space 100-1000 m and more than 1000 m above ground level.

Table 5.2. Sources in the Norwegian emission model

Source	Emission carrier
Stationary combustion	
Direct-fired furnaces	Coal, coke, gas, fuel oils
Boilers	Wood etc., coal, coke, gas, kerosene, fuel oils, waste
Small stoves	Wood , coal, coke, LPG, kerosene, fuel oils
Gas turbines	Gas, marine diesel
Flares	Gas, crude oil
Mobile combustion	
Road traffic (several categories)	Gasoline, auto diesel
Snow scooters	Gasoline
Two-stroke boats	Gasoline
Four-stroke boats	Gasoline, diesel
Ships	Marine diesel, heavy oil
Railway	Diesel
Air traffic (landing/take-off below 100 m)	Jet fuel (kerosene), aviation gasoline
Air traffic (landing/take-off 100-1000 m)	Jet fuel (kerosene), aviation gasoline
Air traffic (cruise)	Jet fuel (kerosene), aviation gasoline
Motorised tools (two-stroke)	Gasoline
Motorised tools (four-stroke)	Gasoline, auto diesel
Non-Combustion	
Oil loading (offshore)	Crude oil
Oil loading (onshore)	Crude oil
Fertiliser, ammonia and nitric acid prod.	Nitrogen compounds/products
Transformation	Coal, gas, crude oil, waste, nitrogen compounds/products, sulphur compounds, lime and Ca compounds, clay, ore, metals, silicon
Bioprocesses	Waste, nitrogen compounds/products, other nitrogen, animals, manure, food articles
Liming	Lime and Ca compounds
Extraction	Coal, natural gas
Evaporation	Gasoline, nitrogen compounds/products, solvents
Boiling	Sulphur compounds
Redox processes	Coal, coke, sulphur compounds, ore
Calcium carbide production	Petrol coke
Silicon carbide production	Petrol coke
Wear	Asphalt

Emissions are allocated to geographical units *after* the national totals have been calculated. Emissions are allocated in one of three ways:

- Emissions from *point sources* are allocated directly to municipalities.
- When figures for the activity used to calculate emissions are available *directly* at municipal level, these figures are used. Examples are fuel combustion in manufacturing industries and emissions from animals.
- When the activity at the municipal level is unknown, the national emissions are allocated *indirectly* using surrogate statistical data. For example, fuel combustion in service industries is allocated using employment figures. In a number of cases the activity is known directly at the intermediate level (county), but allocation within counties uses surrogate data.

Data from several important sources, e.g. industrial statistics, are not available at the municipal level until one and a half years after the year of emissions.

The model can handle the differentiation of combustion emission factors by municipality, but this possibility has not yet been used. If this is done, the national totals for *fuel use* rather than emissions will be allocated by municipality. Emissions will then be calculated at the municipal level.

5.3.2. Regions: EMEP grid squares

Emissions by EMEP 50 km x 50 km grid square are reported to the UNECE and used in models of long-range air pollution. The emissions are allocated to grid squares as follows:

- Emissions from large point sources are allocated directly to the appropriate squares.
- Emissions at sea from national sea traffic and offshore petroleum activities are allocated to squares on the basis of a detailed analysis of 1993 activity data (Flugsrud and Rypdal 1996). The 1993 emissions are projected using national emission trends for each of the categories fishing, other sea traffic, flaring, other combustion, and other emissions in the petroleum sector.

- The remaining emissions in each municipality are allocated to squares according to the proportion of the area of the municipality in each square.

The method assumes that emissions are evenly distributed within municipalities. In reality, emissions often occur only in small parts of a municipality. If a municipality is large relative to the grid squares, the emissions may be allocated wrongly. However, few municipalities measure more than 50 km across and the larger municipalities are usually sparsely populated, with small emissions. It is therefore assumed that the level of error due to the method is acceptable. The direct allocation of large point sources also reduces the potential error.

5.4. Emission model for road traffic

A model for estimating emissions from road traffic was developed in 1993 (SFT 1993) and revised in 1999 (SFT/SSB 1999). The results (as average aggregated emission factors) from this model have been used as input to the general emission model. When the model was revised in 1999, emissions of particles from the use of studded tyres were included for the first time.

5.4.1. Model structure

A fuel-based model has been chosen, where the total consumption of various fuels provides the framework for determining the emissions. The emission factors depend on the kind of vehicle (type, weight, technology, age), fuel type, and driving mode. The total number of vehicle-kilometres does not enter the calculations directly. However, fractions of the total are estimated for each combination of vehicle category and driving mode. These fractions are used to allocate fuel consumption to the various combinations. Emission factors may be given as emissions per vehicle-kilometre or per unit fuel consumed.

Total emissions (Q) of a pollutant *(j)* from fuel combustion *(k)*, while driving with a warm engine may be calculated from the two equations below:

$$Q_{jk} = M_k \sum_i \left(p_{ijk} \cdot \frac{l_{jk}}{\overline{\overline{l_k}}} \cdot \left(\frac{T_{ik}}{T_k} \right) \right)$$

or

$$Q_{jk} = M_k \sum_i \left(q_{ijk} \cdot \frac{1}{\overline{\overline{l_k}}} \cdot \left(\frac{T_{ik}}{T_k} \right) \right)$$

$$q_{ijk} = p_{ijk} \cdot l_{ik}$$

Q: Total emissions
M: Total fuel consumption
p: Emission factor, g/kg
q: Emission factor, g/km
l: Fuel consumption, kg/km
T: Vehicle-kilometres
$_k$: Fuel type
$_i$: Combination of vehicle type, fuel type, and driving mode
$_j$: Pollutant

l_k is the average consumption, kg/km, of fuel (*k*) and is determined by

$$\sum_k l_{ik} \cdot \left(\frac{T_{ik}}{T_k} \right)$$

Emissions from evaporation and cold starts are added to the tailpipe emissions from warm motors.

The fuel-based model calculates changes in emissions between years from changes in M_k (total fuel consumption) and

- the number of vehicles in the various categories
- technologies in use
- annual average distance (km) driven per vehicle
- driving patterns.

5.4.2. Model parameters

Road traffic emissions are calculated for each combination of the following parameters:

- Pollutants: all pollutants in the general emission model, excluding cadmium. In addition: $PM_{2.5}$, PAH, and benzene.
- Vehicle categories: there are 13 classes, which are different combinations of vehicle type, weight, and fuel.

Table 5.3. Vehicle categories[1] in the emission model for road traffic

Fuel	Type	Total weight
Gasoline	Passenger car	..
"	Light duty	< 3.5 t
"	Heavy duty	> 3.5 t
"	Bus	> 3.5 t
Diesel	Passenger car	..
"	Light duty	< 3.5 t
"	Light heavy duty	3.5 - 7.5 t
"	Medium heavy duty	7.5 - 16 t
"	Heavy heavy duty	> 16 t
"	Bus	> 3.5 t
LPG	Passenger car	..
"	Light duty	< 3.5 t
"	Bus	> 3.5 t

[1]Emissions from motorcycles and mopeds are calculated outside the main model.

- Vehicle age (0-29 and 30+ years, 31 age classes in all)
- Driving mode: Five modes are considered:

Urban	Speed limit	30 km/h or less
Urban	"	40 and 50 km/h
Rural	"	60 and 70 km/h
Rural	"	80 km/h
Highway	"	90 km/h

NB! The names of the driving modes do not indicate where driving actually takes place: for instance, driving is classified as urban driving if the speed limit is less than 50 km/h, even outside an urban area.

The modes apply only to driving with a warm engine. Emissions from cold start and evaporation are calculated separately.

The fractions T_{ik}/T_k of the vehicle-kilometre totals for each fuel are calculated using the following variables:

- Number of vehicles, by category and age.
- Average annual mileage, by category.
- Average annual mileage, by age and aggregate vehicle category.

These fractions are used to allocate

- total fuel used by road traffic in the current year.

The emissions are then calculated using the variables listed below. All factors are given by vehicle category and technology, and refer to new vehicles. Some factors also distinguish between driving modes:

- Fuel consumption factors: average fuel consumption (per km), by vehicle category, technology, and driving mode.
- Emission factors for driving with a warm motor expressed as g/km or g/kg fuel, by vehicle category, technology, and driving mode.
- Ageing: emission factors (hot and cold) and fuel consumption factors are corrected to take into account the change in values as the vehicles age.

The average emission factors for 1997 are shown in appendix E.

5.4.3. Emissions from evaporation and cold starts

Emissions and fuel consumption from evaporation and cold starts are calculated separately.

NMVOC evaporation from gasoline vehicles is calculated using the method given in the Corinair Emission Inventory Guidebook (EEA 1996). Emissions from running losses, hot soak emissions, and diurnal emissions are included. Average emission factors have been calculated, taking Norwegian climate conditions into account. Factors are given by vehicle category and technology.

In most cases, driving with a cold engine gives higher emissions than driving with a warm engine, particularly for CO and NMVOC. The extra emissions are called cold start emissions. These are calculated as an additional emission contribution per start. Factors are given by vehicle category and technology. They are mainly taken from Copert (EEA 1997) and Sérié and Joumard (1996). Detailed driving patterns and regional temperature data are used. The driving patterns are taken from a travel survey (Stangeland et al. 1999) and include trip length and time between trips. Engine temperatures are corrected for the use of engine pre-heaters.

The extra fuel consumption caused by evaporation and cold starts is subtracted from the total consumption before emissions from warm engines are calculated.

5.4.4. Sources of data

All activity data are, as far as possible, updated for every year of inventory. Data are as far as possible taken from official registers, public statistics and surveys. However, some of the data are based on assumptions. The sources of activity data are listed below:

- Total fuel consumption: the total amounts of fuels consumed are corrected for off-road use (in boats, snow scooters, motorised equipment, etc.). These corrections are estimated either from assumptions about the number of units, annual operation time, and specific fuel consumption, or from assumptions about and investigations of the fraction of consumption used off-road in each sector. The Norwegian Petroleum Industry Association supplies the data for total fuel consumption.
- Number of vehicles: the number of vehicles in the various categories and age groups is taken from the official register of the Norwegian Directorate of Public Roads.
- Average annual mileage: most figures are determined from surveys by Statistics Norway or the Institute of Transport Economics. In some instances assumptions are needed.
- Driving modes: the Directorate of Public Roads has data on the annual number of vehicle-kilometres driven on national and county roads. The data are allocated by speed limits and vehicle size (small/large). Similar data exist for municipal roads in the ten largest cities. The same distribution is assumed to be valid for other municipal roads.
- Driving with cold and lukewarm engines: number of starts where the engine temperature is below 20 °C is calculated by Statistics Norway on the basis of surveys made by the Institute of Transport

Economics (Stangeland et al. 1999) and data on outdoor temperatures (see below).
- Use of electric engine pre-heater: percentage of starts with pre-heated engine is taken from a survey done by Statistics Norway.
- Average temperature: This parameter is needed for the estimation of emissions from cold starts and NMVOC evaporation. The average temperatures by county and month of the year are collected from the Norwegian Meteorological Institute.

The emission factors are based on several sources. Complete lists of sources with references are given in SFT/SSB (1999). The most important are listed below:

- Copert II (EEA 1997), a computer program to calculate emissions from road traffic. Both this and the following report have been used for several purposes, including warm engine emissions from light and heavy vehicles, cold start emissions and emissions from mopeds and motorcycles.
- Previous version of Copert (Eggleston et al. 1991).
- A detailed report for the German *Umweltbundesamt* (Hassel et al. 1994) based on measurements from TÜV (Technischer Überwachungs-Verein Rheinland), used for emissions from light vehicles.
- Measurements performed by the National Institute of Technology in Norway (SFT 1993), used for emissions from light vehicles.
- Several reports from AB Svensk Bilprovning in Sweden (listed in SFT 1993), used for emissions from heavy vehicles.
- The Corinair Emission Inventory Guidebook (EEA 1996), used for evaporation.
- Results from the MEET programme (Methodologies for Estimating Air Pollution Emissions from Transport) (Sérié and Joumard 1996), used for cold start emissions.

References

Bang J. (1993): *Utslipp fra dieseldrevne anleggsmaskiner, arbeidsredskaper, traktorer og lokomotiver* (Emissions from diesel-powered construction machinery, tools, tractors and locomotives), Oslo: National Institute of Technology.

Bang, J. (1996): *Utslipp av NMVOC fra fritidsbåter og bensindrevne motorredskaper* (Emissions of NMVOC from leisure craft and gasoline-powered equipment), Oslo: National Institute of Technology.

Bleken (1996) is based on Bolstad (1994).

Bolstad, T. (1994): *Utskilling av nitrogen og fosfor i gjødsel og urin frå husdyr i Norge* (Nitrogen and phosphorus in manure and urine from domestic animals in Norway), Department of animal science, Ås: Agricultural University of Norway.

Braathen, O.A., N. Schmidbauer and O. Hermansen (1991): *Utslipp av metan og hydrokarboner fra vedfyring* (Emissions of methane and other hydrocarbons from wood-firing), OR28/91, Kjeller: Norwegian Institute for Air Research.

Bøeng, A.C. and R. Nesbakken (1999): *Energibruk i husholdningene 1993, 1994 og 1995. Gjennomsnittstall basert på forbruksundersøkelsen* (Survey of energy use in households 1993, 1994 and 1995), Reports 99/22, Statistics Norway.

Claesson, S. and S. Steinbeck (1991): *Växtnäring, hushålling - miljø* (Plant nutrients, their management and the environment), Speciella skrifter 41, Agricultural University of Sweden.

Daasvatn, L., K. Flugsrud, O.K. Hunnes and K. Rypdal (1994): Beregning av regionaliserte utslipp til luft. Beskrivelse av modell og metoder for estimering (Calculation of emissions to air on a regional basis. Description of a model and estimation methods), Notater 94/16, Statistics Norway.

ECETOC (1994): *Ammonia Emissions to Air in Western Europe,* ECETOC Technical report No. 62, Brussels, Belgium.

EEA (1996): *EMEP/Corinair. The Atmospheric Emission Inventory Guidebook*. First edition, Copenhagen: European Environmental Agency.

EEA (1997): *Copert II. Computer programme to calculate emissions from road transport. Methodology and emission factors*, European Environmental Agency, Topic report 1997.

Eggleston, Gorißen, Joumard, Rijkeboer, Samaras and Zierock (1991): *CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic. Volume 1: Methodology and Emission Factors,* Final report, December 1991.

EPA (1986): *Ferro-alloy Industry Particulate Emissions: Source Category Report*, Report no EPA/600/7-86/039, Environmental Protection Agency.

Flugsrud, K. and K. Rypdal (1996): *Utslipp til luft fra innenriks sjøfart, fiske og annen sjøtrafikk mellom norske havner* (Emissions to air from domestic shipping, fisheries and other maritime traffic between Norwegian ports), Reports 96/17, Statistics Norway

Hass, J. and K.Ø. Sørensen (1999): *Norwegian Economic and Environmental Accounts, Final report to Eurostat.* To be published in the series Reports, Statistics Norway.

Hassel, Jost, Weber, Dursbeck, Sonnborn and Plettau (1994): *Abgas-Emissionsfaktoren von Pkw in der Bundesrepublik Deutschland* (Exhaust emission factors for passenger cars in Germany), Berichte 8/94, Umweltbundesamt (UBA) 1994.

IPCC (1997a): Greenhouse Gas Inventory. Workbook. IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, London: Intergovernmental Panel on Climate Change.

IPCC (1997b): Greenhouse Gas Inventory. Reference Manual. Revised 1996. IPCC Guidelines for Natinal Greenhouse Gas Inventories, Volume 3, London: Intergovernmental Panel on Climate Change.

JORDFORSK (1998): Report from the monitoring of nutrients in 1997 (Authors: Vagstad, N., M. Bechmann, P. Stålnacke, H.O. Eggestad and J. Deelstra), Ås: Centre for Soil and Environmental Research.

Knudsen, S. and Strømsøe, S. (1990): *Kartlegging av utslipp til luft fra norsk sivil luftfart. Hovedrapport og vedleggsrapport* (Survey of emissions to air from Norwegian civil aviation), NILU report OR 88-90, Kjeller: Norwegian Institute for Air Research.

Lloyd's Register (1995): Marine Exhaust Emissions Research Programme, London: Lloyd's Register of Shipping.

Morken, J. (1994). *Ammoniakktap fra husdyrrom og gjødsellager* (Losses of ammonia from livestock housing and manure storage facilities), ITF report no. 13/94, Department of Agricultural Engineering, Ås: Agricultural University of Norway.

OLF (1993): OLF Environmental Programme. Phase II. Summary Report. March 1993, Stavanger: Norwegian Oil Industry Association.

OLF (1994): Anbefalte retningslinjer for utslippsberegning. Identifisering, kvantifisering og rapportering av forbruks- og utslippsdata fra aktiviteter i norsk oljevirksomhet (Recommended guidelines for emission calculations. Identification, quantification and reporting of data on consumption and emissions from activities in the Norwegian oil and gas sector), Stavanger: Norwegian Oil Industry Association.

Proposition No. 1 (1998-99) to the Storting: *For budsjetterminen 1999* (Input to the 1999 budget), Ministry of the Environment.

Proposition No. 1 (1999-2000) to the Storting. *For budsjetterminen 2000* (Input to the 2000 budget), Ministry of the Environment.

Rosland, A. (1987): Utslippskoeffesienter. Oversikt over koeffesienter for utslipp til luft og metoder for å beregne disse (Emission factors. Overview of factors for emissions to air and methods of calculating them), Oslo: Norwegian Pollution Control Authority.

Rypdal, K (1993): *Anthropogenic Emissions of the Greenhouse Gases CO_2, CH_4 and N_2O in Norway*, Reports 93/24, Statistics Norway.

Rypdal, K. (1995): *Løsemiddelbalanse for Norge* (Solvent balance for Norway), Rapport 95:02, Oslo: Norwegian Pollution Control Authority.

Rypdal, K. (1995a): *Anthropogenic Emissions of SO_2, NO_X, NMVOC and NH_3 in Norway*, Reports 95/12, Statistics Norway.

Rypdal, K. and B. Tornsjø (1997): *Utslipp til luft fra norsk luftfart* (Emissions to air from Norwegian air traffic), Reports 97/20, Statistics Norway.

Sérié E. and R. Joumard (1996): *Proposition of modelling of cold start emissions for road vehicles,* MEET Project. INRETS report LEN 9624, December 1996.

SFT (1990): Klimagassregnskap for Norge. Beskrivelse av utslippsmengder, drivhusstyrke og utslippsfaktorer. Bidrag til den interdepartementale klimautredningen (Greenhouse gas inventory for Norway. Emission figures, global warming potentials and emission factors. Contribution to the interministerial climate report.), Oslo: Norwegian Pollution Control Authority.

SFT (1993). *Emissions from road traffic in Norway. Method for estimation, input data and emission esimates*, Report 93:02 (Authors: Bang, J., E. Figenbaum, K. Flugsrud, S. Larssen, K. Rypdal and C. Torp), Oslo: Norwegian Pollution Control Authority.

SFT (1996): *Utslipp ved håndtering av kommunalt avfall* (Emissions from municipal waste management), Rapport 96:16 (Authors: Sandgren, J., A. Heie and T. Sverud), Oslo: Norwegian Pollution Control Authority.

SFT (1999a): *Utvikling av beregningsmodell for netto utslipp av metangass fra norske deponier. Historiske og framtidige utslippsmengder* (Development of a model to calculate net emissions of methane from Norwegian landfills. Historical and future emissions.), To be published 1999 (Authors: Frøiland Jensen, J. E., T. Williksen and J. Bartnes), Oslo: Norwegian Pollution Control Authority.

SFT (1999c). *Materialstrømsanalyse av SF_6. Beregning av potensielt og faktisk utslipp over tid* (Material flow analysis of SF_6. Calculation of potential and actual emissions over time), Rapport 99:14, Oslo: Norwegian Pollution Control Authority.

SFT (1999d): *Calculations of emissions of HFCs and PFCs in Norway. Tier 2 method*, Report 99:03, Oslo: Norwegian Pollution Control Authority.

SFT (1999e): *Evaluation of uncertainty in the Norwegian emission inventory*, Report 99:01 (Author: K. Rypdal), Oslo: Norwegian Pollution Control Authority.

SFT/SSB (1999). *Utslipp fra vegtrafikk i Norge. Dokumentasjon av beregningsmetode, data og resultater* (Emissions from road traffic in Norway - documentation of a calculation method, data and results), Rapport 99:04 (Author: Bang, J., K. Flugsrud, S. Holtskog, G. Haakonsen, S. Larssen, K.O. Maldum, K. Rypdal and A. Skedsmo), Oslo: Norwegian Pollution Control Authority.

SINTEF (1995): *Round robin test of a wood stove-emissions*, SINTEF Report STF12 F95012 (Author: Karlsvik, E.), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998a): *Emisjonsfaktorer for CO_2-utslipp fra sementproduksjon i Norge for 1990 og 1997* (Emission factors for CO_2 emissions from cement production in Norway for 1990 and 1997), SINTEF Report STF66 A98511 (Authors: Andersen, T. and K.H.Karstensen), Oslo: SINTEF (Institute of Social Research in Industry).

SINTEF (1998b): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 1. CO_2-utslipp fra forskjellige typer reduksjonsmaterialer* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 1. CO_2 emissions from various types of reducing agents), Revised edition, SINTEF Report STF24 A98550 (Author: Raaness, O.), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998c): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 2. Produksjon av ferrosilisium og silisiummetall i Norge* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 2. Production of ferro silicon and silicon metal in Norway), Revised edition, SINTEF Report STF24 A98537 (Author: Monsen, B.), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998d): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 3. Produksjon av ferromangan, silikomangan og ferrokrom i Norge* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 3. Production of ferro manganese, silicon manganese and ferro chromium in Norway), ST24 A98548 (Authors: Monsen, B. and S.E. Olsen), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998e): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 4. Utslipp av CO_2 ved produksjon av silisiumkarbid og kalsiumkarbid* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 4. CO_2 emissions from production of silicon carbide and calcium carbide), SINTEF Report STF24 A98549 (Authors: Raaness, O. and S. Olsen), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998f): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 5. Produksjon av magnesium* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 5. Magnesium production), SINTEF Report STF24 A98574 (Authors: Olsen, K., T. Støre and R. Tunold), Trondheim: SINTEF (Institute of Social Research in Industry).

Stangeland, I., J.V. Haugland and A. Skogly (1999): Reisevaner i Norge 1998 (Travel patterns in Norway in 1998). TØI Notat 418/1999, Oslo: TØI (Institute of Transport Economics).

Statistics Norway (1994): *Standard Industrial Classification*, NOS C182.

Statistics Norway (1998): Mer avfall, men økt gjenvinning (More waste, but more recycling), *Weekly bulletin* 25/98

Sundstøl, F. and Z. Mroz (1988): *Utskillelse av nitrogen og fosfor i gjødsel og urin fra husdyr i Norge* (Nitrogen and phosphorus in manure and urine from domestic animals in Norway) (*se Bolstad 1994*), Report no. 4 from the project "Agricultural policy and environmental management", Ås: Agricultural University of Norway.

TI (1991): Tiltak 4: Fordamping fra bensindistribusjon (STAGE 1) (Measure 4: Evaporation from gasoline distribution), unpublished, commissioned by Norwegian Pollution Control Authority, Oslo: National Institute of Technology.

Aakra, Å. and M.A. Bleken (1997): *N_2O Emissions from Norwegian Agriculture as Estimated by the IPCC Methodology*, Departement of Biotechnological Sciences, Ås: Agricultural University of Norway.

Appendix A

Abbreviations and prefixes

Abbreviations

Pollutants

C_2F_6	Hexafluoroethane
CF_4	Tetrafluoromethane
CFC	Chlorofluorocarbon
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
GHG	Greenhouse gas
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
N_2O	Nitrous oxide
NH_3	Ammonia
NMVOC	Non-methane volatile organic compound
NO_X	Nitrogen oxides (NO and NO_2)
PAH	Polycyclic aromatic hydrocarbon
Pb	Lead
PFC	Perfluorinated hydrocarbon
PM_{10}	Particulate matter (diameter $<10\mu m$)
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide

Other

CORINAIR	Programme for calculation and reporting of emissions to air in Europe
EEA	European Environment Agency
EMEP	Cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquified Petroleum Gas
LRTAP	Long-range transboundary air pollution
LTO	Landing and take-off
NACE	General nomenclature for economic activities in the European Community (Nomenclature générale des Activités économiques dans les Communautés Européennes)
NOREEA	Norwegian Economic and Environmental Accounts
OECD	Organisation for Economic Co-operation and Development
SFT	Norwegian Pollution Control Authority
SIC	Standard Industrial Classification
SNAP	Selected Nomenclature of Air Pollution (used in UNECE reporting)
UNECE	United Nations – Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

Prefixes

Name	Symbol	Factor
Micro	μ	10^{-6}
Kilo	k	10^{3}
Peta	P	10^{15}

Appendix B

Emission tables

Table B1. Emissions of greenhouse gases to air

	CO_2	CH_4	N_2O	HFK 23	HFK 32	HFK 125	HFK 134	HFK 143	HFK 152	HFK 227	C_3F_8	CF_4	C_2F_6	SF_6	CO_2-equivalents
	Mill. tonnes	1000 tonnes	Tonnes												Mill. tonnes
GWP[1]	1	21	310	11700	650	2800	1300	3800	140	2900	7000	6500	9200	23900	
1950		131	7	-	-	-	-	-	-	-	..	..	..	..	..
1960		175	10	-	-	-	-	-	-	-	..	..	..	..	..
1973	30.1	216[2]	122[2]	-	-	-	-	-	-	-	..	..	..	..	..
1974	27.2	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1975	30.1	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1976	32.8	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1977	33.0	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1978	32.2	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1979	34.4	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1980	32.6	267	14	-	-	-	-	-	-	-	..	..	..	..	..
1981	31.4	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1982	30.5	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1983	31.5	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1984	33.5	..	..	-	-	-	-	-	-	-	..	..	..	..	..
1985	31.9	..	..	-	-	-	-	-	-	-	..	409	18	199	..
1986	34.6	..	..	-	-	-	-	-	-	-	..	401	18	240	..
1987	33.5	299	15	-	-	-	-	-	-	-	..	388	17	240	52.9
1988	35.3	298	16	-	-	-	-	-	-	-	..	371	16	223	54.4
1989	34.7	312	17	-	-	-	-	-	-	-	..	360	16	107	51.5
1990	35.2	317	17	-	-	-	-	-	0	-	..	369	16	92	52.0
1991	33.6	322	17	-	-	-	0	-	0	-	..	313	14	86	49.9
1992	34.3	328	15	-	-	-	0	-	1	-	..	242	11	29	48.1
1993	35.9	332	16	-	-	-	2	-	1	-	..	254	11	30	50.3
1994	37.9	340	16	0	0	0	5	0	1	-	..	231	11	35	52.6
1995	38.2	343	16	0	0	2	10	2	1	-	0	209	9	24	52.5
1996	41.1	345	16	0	0	5	17	4	1	0	0	187	6	22	55.4
1997*	41.4	350	16	0	0	10	26	7	2	0	0	211	8	21	55.9
1998*	41.6	346	17	..	..	..	..	..	..	..	..	..	..	..	..

[1] Impact on greenhouse effect of emission of 1 tonne of the gas compared with that of 1 tonne CO_2.

[2] 1970 figure.

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table B2. Emissions to air

	SO_2	NO_x	NH_3	Acid equi-valents[1]	NMVOCs	CO	Particu-lates[2]	Pb	Cd
	1000 tonnes							Tonnes	kg
1973	156	181	..	..	190	707	24	891	..
1974	150.0	178.0	..	..	181.0	664.0	23.0	834.0	..
1975	138.0	182.0	..	..	202.0	720.0	22.0	925.0	..
1976	147.0	180.0	..	..	204.0	765.0	21.0	762.0	..
1977	146.0	193.0	..	..	209.0	811.0	23.0	762.0	..
1978	143.0	185.0	..	..	169.0	836.0	21.0	784.0	..
1979	144.0	195.0	..	..	184.0	870.0	22.0	827.0	..
1980	137.0	188.0	23.0	9.7	180.0	866.0	19.0	624.0	..
1981	128.0	177.0	..	..	184.0	851.0	22.0	573.0	..
1982	111.0	181.0	..	..	191.0	861.0	20.0	648.0	..
1983	104.0	186.0	..	..	204.0	854.0	20.0	556.0	..
1984	96.0	200.0	..	..	216.0	882.0	21.0	400.0	..
1985	98.0	210.0	..	..	234.0	886.0	22.0	405.0	1143
1986	91.0	226.0	..	..	253.0	918.0	23.0	341.0	..
1987	73.0	225.0	23.0	8.5	259.0	877.0	22.0	294.0	..
1988	68.0	221.0	21.0	8.2	248.0	903.0	22.0	291.0	..
1989	58.0	220.0	23.0	8.0	284.0	867.0	22.0	276.0	1212
1990	53.0	218.0	23.0	7.7	310.0	856.0	23.0	228.0	1193
1991	44.0	208.0	24.0	7.3	309.0	794.0	21.0	183.0	1165
1992	36	207	25	7.1	331	782	21	149	1064
1993	35	215	25	7.2	347	781	23	105	1103
1994	34	212	25	7.1	358	766	24	20	606
1995	34	212	26	7.2	370	728	23	14	619
1996	33	220	27	7.4	368	695	24	7	614
1997*	30	222	26	7.3	359	656	24	6	601
1998*	..	225	27	..	342	631	23	..	..

[1] Total acidifying effect of SO_2, NO_x and NH_3.

[2] Process emissions calculated for road dust only.

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table B3. Emissions of greenhouse gases to air by sector. 1996

	CO_2	CH_4	N_2O	HFK[1]	PFK[2]	SF_6	CO_2-equivalents
	Mill. tonnes	1000 tonnes		Tonnes			Mill. tonnes
Total	41.1	345.4	16.5	27.7	193.0	22.0	55.4
Energy sectors	12.3	30.7	0.1	-	-	2.4	13.1
Extraction of oil and gas[3]	10.0	27.2	0.1	-	-	-	10.6
Extraction of coal	0.0	3.2	0.0	-	-	-	0.1
Oil refining	2.0	0.1	0.0	-	-	-	2.0
Electricity supplies[4]	0.3	0.1	0.0	-	-	2.4	0.4
Manufacturing and mining	12.1	32.1	5.4	0.3	193.0	19.6	16.2
Oil drilling	0.4	0.2	0.0	-	-	-	0.4
Manufacture of pulp and paper	0.8	13.0	0.1	-	-	-	1.1
Manufacture of chemical raw materials	2.8	1.1	5.2	-	-	-	4.4
Manufacture of minerals[5]	2.0	0.0	0.1	-	-	-	2.0
Manufacture of iron, steel and ferro-alloys	3.0	0.0	0.0	-	-	-	3.0
Manufacture of other metals	2.0	0.0	0.0	-	193.0	19.5	3.7
Manufacture of metal goods boats, ships and oil platforms	0.3	0.0	0.0	-	-	0.2	0.3
Manufacture of wood plastic, rubber and chemical goods, printing	0.2	17.8	0.0	0.3	-	-	0.6
Manufacture of consumer goods	0.7	0.0	0.0	-	-	-	0.7
Other	16.7	282.7	11.0	27.4	0.0	-	26.1
Construction	0.6	0.1	0.1	-	-	-	0.7
Agriculture and forestry	0.7	108.1	9.4	-	-	-	5.9
Fishing, whaling and sealing	1.5	0.1	0.0	-	-	-	1.5
Land transport, domestic	2.9	0.2	0.1	-	-	-	3.0
Sea transport, domestic	1.3	0.1	0.0	-	-	-	1.4
Air transport[6]	1.0	0.0	0.0	-	-	-	1.0
Other private services	2.1	0.6	0.2	27.4	0.0	-	2.3
Public sector, municipal	0.3	163.9	0.4	-	-	-	3.9
Public sector, state	0.5	0.0	0.0	-	-	-	0.5
Private households	5.6	9.6	0.7	-	-	-	6.0

[1] Distribution by source uncertain, figures will be improved.
[2] Includes C_3F_8, CF_4 and C_2F_6.
[3] Includes gas terminal, transport and supply ships.
[4] Includes emissions from waste incineration plants.
[5] Including mining.
[6] Domestic air transport only, including emissions above 1000 m.
Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table B4. Emissions to air by sector. 1996

	SO_2	NO_x	NH_3	Acid equi-valents[1]	NMVOCs	CO	Particu-lates[2]	Pb	Cd
	1000 tonnes							Tonnes	kg
Total	33.2	220.1	26.5	7.4	368.1	694.9	23.8	7.0	614
Energy sectors	2.8	46.7	0.0	1.1	222.0	8.1	0.5	1.2	71
Extraction of oil and gas[3]	0.3	42.6	0.0	0.9	205.6	6.9	0.2	0.0	1
Extraction of coal	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0
Oil refining	1.7	2.7	0.0	0.1	16.0	0.0	0.1	0.0	0
Electricity supplies[4]	0.8	1.4	0.0	0.1	0.5	1.1	0.2	1.2	70
Manufacturing and mining	25.0	28.8	0.3	1.4	25.2	51.9	1.1	2.4	386
Oil drilling	0.1	6.0	0.0	0.1	0.5	0.3	0.0	0.0	1
Manufacture of pulp and paper	3.5	2.1	0.0	0.2	0.3	1.9	0.3	0.2	20
Manufacture of chemical raw materials	8.7	4.4	0.3	0.4	2.3	39.0	0.1	0.1	3
Manufacture of minerals[5]	2.3	6.3	0.0	0.2	2.0	0.9	0.3	1.5	62
Manufacture of iron, steel and ferro-alloys	6.8	5.0	0.0	0.3	1.5	0.1	0.0	0.1	12
Manufacture of other metals	2.2	1.4	0.0	0.1	0.0	1.7	0.1	0.5	253
Manufacture of metal goods, boats, ships and oil platforms	0.2	0.9	0.0	0.0	2.9	1.2	0.1	0.0	3
Manufacture of wood, plastic, rubber, and chemical goods, printing	0.3	0.8	0.0	0.0	14.2	5.3	0.1	0.0	31
Manufacture of consumer goods	0.8	1.9	0.0	0.1	1.4	1.6	0.1	0.1	2
Other	5.4	144.6	26.2	4.9	120.9	634.9	22.2	3.4	157
Construction	0.2	6.0	0.0	0.1	12.7	5.7	0.6	0.0	2
Agriculture and forestry	0.3	6.3	25.3	1.6	3.0	5.1	0.8	0.0	1
Fishing, whaling and sealing	0.7	33.1	0.0	0.7	0.8	6.8	0.2	0.1	3
Land transport, domestic	1.1	27.4	0.0	0.6	5.2	22.1	3.3	0.2	6
Sea transport, domestic	1.0	27.6	0.0	0.6	1.6	1.3	0.3	0.1	3
Air transport[6]	0.1	1.5	0.0	0.0	1.6	2.1	0.1	0.3	0
Other private services	0.6	11.8	0.2	0.3	18.8	80.6	0.7	0.5	3
Public sector, municipal[7]	0.1	0.4	0.0	0.0	1.5	0.4	0.0	0.0	1
Public sector, state	0.1	2.4	0.0	0.1	2.0	0.7	0.0	0.0	1
Private households	1.3	28.2	0.7	0.7	73.6	510.0	16.1	2.1	137

[1] Total acidifying effect of SO_2, NO_x and NH_3.
[2] Process emissions calculated for road dust only.
[3] Includes gas terminal, transport and supply ships.
[4] Includes emissions from waste incineration.
[5] Including mining.
[6] Emissions under 1000 m only, including international air transport.
[7] Includes water supplies.
Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table B5. Emissions to air by source[1]. 1996

	CO_2	CH_4	N_2O	SO_2	NO_x	NH_3	NMVOCs	CO	Particu-lates	Pb	Cd
	Mill. tonnes	1000 tonnes								Tonnes	kg
Total	41.1	345.4	16.5	33.2	220.1	26.5	368.1	694.9	23.8	7.0	614
Stationary combustion	17.6	11.3	0.3	8.5	46.9	-	13.3	153.1	15.2	1.8	329
Process emissions	8.6	330.7	14.9	20.5	8.7	25.6	276.2	40.3	2.0	1.9	266
Mobile combustion	15.0	3.4	1.3	4.2	164.5	1.0	78.6	501.5	6.7	3.3	19
Stationary combustion, total	17.6	11.3	0.3	8.5	46.9	-	13.3	153.1	15.2	1.8	328.6
Oil and gas extraction	9.0	3.2	0.1	0.2	31.6	-	1.5	6.7	0.1	0.0	-
- Natural gas	6.6	2.6	0.1	-	17.8	-	0.7	4.8	-	-	-
- Flaring	1.2	0.1	0.0	-	5.7	-	0.1	0.8	-	-	-
- Diesel combustion	0.4	0.0	0.0	0.2	7.2	-	0.5	0.5	0.1	0.0	-
- Gas terminal	0.7	0.5	0.0	0.0	0.9	-	0.2	0.6	-	-	-
Manufacturing and mining	5.9	0.5	0.1	6.4	11.3	-	1.8	7.6	0.9	0.5	129.1
- Refining	1.9	0.1	0.0	0.1	2.7	-	0.9	0.0	0.1	0.0	0.0
- Manufacture of pulp and paper	0.8	0.2	0.1	2.8	1.8	-	0.2	1.7	0.3	0.2	19.5
- Manufacture of mineral products	0.9	0.0	0.0	0.7	3.8	-	0.0	0.1	0.1	0.1	61.2
- Manufacture of chemicals	0.8	0.1	0.0	0.6	1.0	-	0.0	0.1	0.1	0.1	1.3
- Manufacture of metals	0.4	0.0	0.0	0.3	0.5	-	0.0	0.1	0.1	0.0	0.9
- Other manufacturing	1.2	0.1	0.0	1.9	1.6	-	0.6	5.7	0.3	0.1	46.1
Other industry	1.4	0.2	0.0	0.7	1.1	-	0.2	1.0	0.1	0.1	4.0
Dwellings, offices, etc.	1.2	7.3	0.1	0.9	1.9	-	9.5	137.7	14.0	0.0	136.3
Waste incineration	0.1	0.1	0.0	0.2	0.9	-	0.3	0.1	0.0	1.2	59.3
Process emissions, total	8.6	330.7	14.9	20.5	8.7	25.6	276.2	40.3	2.0	1.9	266.2
Oil and gas extraction	0.7	24.1	-	-	-	-	203.9	-	-	-	-
- Venting, leaks, etc	0.0	8.8	-	-	-	-	3.6	-	-	-	-
- Oil loading at sea	0.6	14.7	-	-	-	-	176.4	-	-	-	-
- Oil loading, onshore	0.1	0.1	-	-	-	-	22.1	-	-	-	-
- Gas terminal	0.0	0.6	-	-	-	-	1.8	-	-	-	-
Manufacturing and mining	7.5	4.2	5.2	20.5	8.7	0.3	18.6	40.3	-	1.8	266.2
- Refining	0.0	-	-	1.6	0.0	-	15.1	-	-	-	-
- Manufacture of pulp and paper	-	-	-	0.7	-	-	-	-	-	-	-
- Manufacture of chemicals	1.2	1.0	5.2	5.3	1.3	0.3	0.8	38.8	-	-	0.3
- Manufacture of mineral products	0.9	-	-	0.9	-	-	-	-	-	1.4	-
- Manufacture of metals	5.4	-	-	11.9	7.4	-	1.8	1.5	-	0.5	265.9
- - Iron, steel and ferro-alloys	3.7	-	-	9.5	6.7	-	1.8	-	-	0.1	13.8
- - Aluminium	1.5	-	-	1.7	0.6	-	-	-	-	0.4	102.0
- - Other metals	0.2	-	-	0.7	0.0	-	-	1.5	-	-	150.1
- Other manufacturing	0.0	3.2	-	0.1	-	-	0.9	-	-	-	-
Petrol distribution	0.0	-	-	-	-	-	6.2	-	-	-	-
Agriculture	0.2	108.1	9.3	-	-	25.3	-	-	-	-	-
Landfill gas	0.0	193.9	-	-	-	-	-	-	-	-	-
Solvents	0.1	-	-	-	-	-	47.6	-	-	-	-
Road dust	-	-	-	-	-	-	-	-	2.0	-	-
Other process emissions	0.0	0.4	0.4	-	-	-	-	-	-	0.0	-
Mobile combustion, total	15.0	3.4	1.3	4.2	164.5	1.0	78.6	501.5	6.7	3.3	19.2
Road traffic	8.9	2.7	0.8	1.8	65.5	1.0	61.2	442.3	4.1	2.7	8.3
- Petrol engines	5.0	2.4	0.7	0.4	31.8	0.9	53.0	412.0	0.5	2.5	-
- - Passenger cars	4.4	2.2	0.7	0.3	27.7	0.9	47.2	366.2	0.4	2.2	-
- - Other light vehicles	0.6	0.2	0.0	0.0	3.4	0.1	5.1	42.1	0.0	0.3	-
- - Heavy vehicles	0.0	0.0	0.0	0.0	0.7	0.0	0.7	3.8	0.0	0.0	-
- Diesel engines	3.8	0.2	0.1	1.4	33.7	0.0	4.4	17.4	3.6	0.1	8.3
- - Passenger cars	0.3	0.0	0.0	0.1	0.9	0.0	0.3	1.2	0.4	0.0	0.8
- - Other light vehicles	0.8	0.0	0.0	0.3	2.3	0.0	0.8	3.1	0.8	0.0	1.7
- - Heavy vehicles	2.7	0.1	0.0	1.0	30.5	0.0	3.2	13.1	2.4	0.1	5.9
- Motorcycles, mopeds	0.1	0.1	0.0	0.0	0.1	0.0	3.9	12.8	0.0	0.0	-
- - Motorcycles	0.0	0.1	0.0	0.0	0.1	0.0	1.3	8.0	0.0	0.0	-
- - Mopeds	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.8	0.0	0.0	-
Snow scooters	0.0	0.0	0.0	0.0	0.0	0.0	1.4	2.6	0.0	0.0	-
Small boats	0.2	0.2	0.0	0.0	1.0	-	8.8	19.7	0.3	0.1	0.1
Motorized equipment	0.8	0.1	0.3	0.3	11.9	0.0	3.9	25.6	1.4	0.1	1.6
Railways	0.1	0.0	0.0	0.0	1.0	-	0.1	0.2	0.1	0.0	0.2

Table B5 (cont.). Emissions to air by source[1]. 1996

	CO_2	CH_4	N_2O	SO_2	NO_x	NH_3	NMVOCs	CO	Particulates	Pb	Cd
	Mill. tonnes	1000 tonnes								Tonnes	kg
Air traffic[2]	1.2	0.0	0.0	0.1	1.6	-	0.5	2.3	0.1	0.3	-
- Domestic < 1000m	0.4	0.0	0.0	0.1	1.2	-	0.5	2.0	0.0	0.3	-
- International < 1000m	:	:	:	0.0	0.4	-	0.0	0.3	0.0	0.0	-
- Domestic > 1000m	0.8	:	0.0	:	:	:	:	:	:	:	:
Shipping	3.8	0.3	0.1	2.0	83.3	-	2.8	8.8	0.7	0.2	8.9
- Coastal traffic etc.	2.1	0.2	0.1	1.3	44.6	-	1.6	1.9	0.4	0.1	5.0
- Fishing vessels	1.5	0.1	0.0	0.7	33.0	-	0.8	6.7	0.2	0.1	3.3
- Mobile oil rigs, etc.	0.3	0.1	0.0	0.1	5.7	-	0.4	0.3	0.0	0.0	0.6

[1] Does not include international sea traffic.

[2] Emissions from air traffic that is not included in national emissions inventories are marked with the symbol : (Not for publication).

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table B6. Emissions to air by county. 1996

	CO_2	CH_4	N_2O	SO_2	NO_x	NH_3	NMVOCs	CO	Particulates[1]	Pb	Cd
	Mill. tonnes	1000 tonnes								Tonnes	kg
Total	41.2	345.4	16.5	33.9	222.3	26.5	368.2	695.0	23.9	7.0	614.5
Of this, national emission figures	41.1	345.4	16.5	33.2	220.1	26.5	368.1	694.9	23.8	7.0	614.0
Of this, international sea traffic[2]	0.1	0.0	0.0	0.7	2.2	0.0	0.1	0.1	0.0	0.0	0.5
Østfold	1.7	16.7	0.7	4.8	6.6	1.8	9.2	36.9	1.5	1.8	19.6
Akershus	1.6	17.7	0.8	0.6	9.8	1.7	15.9	72.4	1.7	0.4	17.1
Oslo	1.4	5.0	0.1	0.7	6.8	0.1	13.5	44.6	1.0	0.9	6.3
Hedmark	0.9	20.8	1.0	0.4	5.8	2.4	7.2	41.8	1.9	0.2	21.4
Oppland	0.8	23.2	1.0	0.3	5.2	2.5	6.6	34.9	1.4	0.2	14.6
Buskerud	1.1	19.8	0.5	1.0	6.4	1.1	8.3	39.6	1.3	0.5	14.0
Vestfold	1.2	11.7	0.4	1.3	5.7	1.0	9.0	31.7	0.9	0.2	15.3
Telemark	3.4	11.6	3.7	1.6	7.5	0.8	7.0	30.1	1.1	0.2	48.2
Aust-Agder	0.6	7.6	0.2	3.2	2.4	0.3	3.9	53.5	1.0	0.1	8.6
Vest-Agder	1.1	12.2	0.3	2.1	4.0	0.6	5.5	24.4	0.9	0.2	17.3
Rogaland	2.8	38.7	1.3	1.3	9.0	3.4	15.9	47.0	1.5	0.3	49.0
Hordaland	3.4	29.7	0.6	2.1	10.2	1.4	45.4	52.6	2.1	0.3	169.2
Sogn og Fjordane	1.2	12.6	0.5	1.6	4.1	1.3	3.5	17.1	0.8	0.1	16.0
Møre og Romsdal	1.0	17.5	0.7	0.6	5.6	1.8	7.7	32.7	1.4	0.3	52.7
Sør-Trøndelag	1.4	17.8	0.8	3.5	6.3	1.8	7.1	36.8	1.2	0.2	64.5
Nord-Trøndelag	0.6	16.1	0.9	0.7	3.8	2.2	4.6	23.8	1.2	0.1	9.4
Nordland	2.5	21.0	2.4	4.2	9.0	1.5	6.9	28.4	0.9	0.4	43.9
Troms	0.7	9.5	0.3	1.1	3.9	0.6	4.3	19.7	0.7	0.1	7.5
Finnmark	0.3	6.7	0.2	0.3	2.3	0.2	2.6	11.6	0.5	0.1	3.4
Svalbard	0.1	3.2	0.0	0.5	0.2	0.0	0.1	0.2	0.1	0.0	8.4
Continental shelf	12.0	26.4	0.1	1.8	98.6	-	183.6	13.5	0.7	0.1	7.3
Airspace[3]	1.0	0.0	0.0	0.0	0.9	-	0.2	1.0	0.0	0.3	-
Open sea[4]	0.4	0.0	0.0	0.2	8.4	-	0.2	0.9	0.1	0.0	0.8

[1] Process emissions calculated for road dust only.

[2] Emissions from international sea traffic in Norwegian ports.

[3] Emissions of CO_2 from Norwegian aircraft above 100 m and emissions of other components between 100 m and 1000 m from domestic and international air transport.

[4] Emissions from Norwegian fishing vessels outside the Norwegian Economic Zone.

Source: Emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Appendix C

Energy

Table C1. Energy sources balance sheet. 1996. Physical units

	Coal	Coke	Fuel wood, black liquor, waste	Crude oil	Gasoline	Kerosene	Middle distillates	Heavy fuel oil	Liquefied gas	Natural gas	Other gases[1]	Electricity	District heating
	ktonnes		ktoe	ktonnes						Mill. Sm^3	ktoe	GWh	
1. Production	230	198	1036	149477	7017	1192	6751	1878	3309	41005	1078	104712[2]	1743
1.1. Prod. of primary energy bearers	230	.	1036	149477	3045[3]	.	.	-	2981[3]	41005	.	.	.
1.2. Prod. of derived energy bearers	.	198	.	.	3972	1192	6751	1878	329	-	1078	104712[2]	1743
2. Imports	832	967	2	1333	488	127	602	990	878	-	-	13212	-
3. Exports	156	138	0	136800	5052	446	3522	1476	2986	37825	-	4236	-
4. Bunkering[4]	-	-	-	-	-	-	346	433	-	-	-	.	-
5. Changes in stocks (+ net decrease, - net increase)	28	-57	-	-643	-40	-176	-172	-15	209	.	-	.	.
6. Gross domestic supply (1+2-3-4+5)	934	970	1038	13367	2413	697	3313	945	1410	3180	1078	113688	1743
8. Energy converted	28	29	115	14214	115	88	277	653	26	-	1	148	-
8.1. In blast furnaces	-	29	-	-	-	-	-	-	-	-	-	-	-
8.2. In crude petroleum refineries	-	-	-	14214	115	88	237	653	26	-	-	-	-
8.3. In thermal power plants	-	-	-	-	-	-	2	-	-	-	-	-	-
8.4. In combined heat and power plants	28	-	51	-	-	-	-	-	-	-	-	-	-
8.5. In district heating plants	-	-	64	-	-	-	39	-	-	-	1	148	-
9. Consumption by energy sector	-	-	-	-	2	0	141	1	-	3648	790	1861	-
9.1. Crude petroleum and natural gas production	-	-	-	-	-	-	132	-	-	3648	-	317	-
9.2. Coal mines	-	-	-	-	0	-	2	-	-	-	-	20	-
9.3. Petroleum refineries	-	-	-	-	0	-	0	1	-	-	790	501	-
9.4. Pumping storage power plants	-	-	-	-	-	-	-	-	-	-	-	408	-
9.5. Hydro electric power plants	-	-	-	-	2	0	7	0	-	-	-	593	-
9.6. Thermal power plants	-	-	-	-	-	-	-	-	-	-	-	4	-
9.7. Combined heat and power plants	-	-	-	-	-	-	0	-	-	-	-	6	-
9.8. District heating plants	-	-	-	-	-	-	0	-	-	-	-	11	-
10. Consumption, non-energy purposes	.	.	.	.	0	5	3	15	821	-	-	-	-
10.1. In chemical industry	.	.	.	.	-	0	-	-	821	-	-	-	-
10.2. In other industry	.	.	.	.	0	5	3	15	-	-	-	-	-
11. Losses in transport and distribution	..	..	..	..	..	..	..	..	..	..	17	7641	405[5]
12. Statistical differences (6-8-9-10-11-13)	-22	-31	-	-847	604	-176	-641	-168	473	-497[6]	-0	894	-0
13. Net domestic consumption	929	972	924	-	1691	779	3533	444	90	29	269	103144	1338
14. Manufacturing, mining and quarrying	925	970	387	-	9	2	373	427	75	29	264	43992	324
14.1. Mining and quarrying	-	-	-	-	0	0	5	15	0	-	-	564	-
14.2. Manufacture of paper and paper products	12	-	258	-	0	-	15	215	6	-	-	6660	-
14.3. Manufacture of industrial chemicals	185	195	0	-	0	0	19	49	2	4	239	6021	79
14.4. Manufacture of iron, steel and ferro-alloys	438	446	-	-	0	0	5	8	0	-	9	6796	1
14.5. Manufacture of aluminium and other non-ferrous metals	-	191	-	-	0	0	26	23	12	18	14	15751	-
14.6. Other manufacturing	290	138	129	-	8	2	303	117	55	6	2	8201	244
15. Transport	-	-	-	-	1679	595	1966	11	-	-	-	647	-
15.1. Railways and subways	-	-	-	-	-	-	25	-	-	-	-	618	-
15.2. Air transport	-	-	-	-	2	595	-	-	-	-	-	29	-
15.3. Road transport	-	-	-	-	1676	-	1319	-	-	-	-	-	-
15.4. Coastal shipping	-	-	-	-	-	-	622	11	-	-	-	-	-
16. Other sectors	3	2	536	-	4	182	1194	5	16	-	5	58505	1014
16.1. Fishing	-	-	-	-	4	0	433	3	-	-	-	89	-
16.2. Agriculture	0	-	-	-	-	1	167	3	-	-	-	1159	9
16.3. Households	3	2	533	-	-	175	196	-	3	-	-	35288	320
16.4. Other consumers	-	-	3	-	-	6	398	0	12	-	5	21969	685

[1] Includes blast furnace gas, methane, refinery gas and fuel gas.

[2] Of which electricity produced in thermal power plants and wind power, 564 GWh.

[3] Condensate from crude oil and natural gas production.

[4] Delivery to international maritime transport, regardless of nationality.

[5] Losses in the distribution network and cooling.

[6] Including consumption in pipeline transport and terminal system, losses and statistical differences.

Source: Energy Statistics, Statistics Norway.

Table C2. Energy balance sheet[1]. 1996. PJ

	Total	Coal	Coke	Fuel wood, black liquor, waste	Crude oil	Petro-leum pro-ducts	Natural gas and other gases	Water-fall energy[2]	Elec-tricity	District heating
1.1. Production of primary energy bearers	8787	6	.	44	6323	271	1702	441	.	.
2. Imports	291	23	30	0	56	133	-	-	48	-
3. Exports	7971	4	5	0	5787	590	1570	-	15	-
4. Bunkering	32	-	-	-	-	32	-	-	-	-
5. Changes in stocks (+ net decrease, - net increase)	-36	1	-2	..	-27	-8	.	-	.	.
7. Net domestic supply (1.1+2-3-4+5)	1038	26	23	44	565	-226	132	441	32	-
8. Energy converted	1098	1	1	5	601	48	0	441	1	-
1.2. Production of derived energy bearers	1044	.	7	.	.	608	46	-	377	6
9. Consumption by energy sector	198	-	-	-	-	6	185	-	7	-
10. Consumption for non-energy purposes	39	.	.	.	.	39	-	-	-	-
11. Losses in transport and distribution	30	..	..	..	..	..	1	-	28	1
12. Statistical differences (7-8+1.2-9-10-11-13)	-49	-1	-1	-	-36	6	-21	-	3	-
13. Net domestic consumption	767	26	31	39	-	282	13	-	371	5
13.1. Manufacturing, mining and quarrying	282	26	31	16	-	37	12	-	158	1
13.2. Transport	187	-	-	-	-	184	-	-	2	-
13.3. Other sectors	298	0	0	23	-	60	0	-	211	4
14. Calculated energy consumption[3]	582	21	24	25	-	123	12	-	371	5
14.1. Manufacturing, mining and quarrying	259	21	24	11	-	32	12	-	158	1
14.2. Transport	51	-	-	-	-	48	-	-	2	-
14.3. Other sectors	272	0	0	15	-	43	0	-	211	4
15. Energy losses in final consumption (13-14)	185	5	6	14	-	159	1	-	-	-
15.1. Manufacturing, mining and quarrying	23	5	6	6	-	5	1	-	-	-
15.2. Transport	136	-	-	-	-	136	-	-	-	-
15.3. Other sectors	26	0	0	8	-	18	0	-	-	-

[1] The energy balance is derived from the energy sources balance sheet.

[2] Electricity is treated as derived energy. Waterfall energy is the primary energy source for the electricity produced in hydropower plants. It is estimated that average, 15 per cent of the potential energy is lost in production.

[3] Line 14, "Calculated energy consumption" shows the amount of energy actually utilized. The numbers are estimated by multiplying the values in line 13 by thermal efficiency coefficients.

Source: Energy Statistics, Statistics Norway.

Table C3. Energy accounts. Extraction, conversion and use[1] of energy goods. 1996. Physical units

	Coal	Coke[2]	Fuel wood, wood waste, waste	Crude oil	Natural gas	Other gases, lique-fied gas	Gaso-line	Kero-sene	Middle distil-lates	Heavy fuel oil	Elec-tricity	Dis-trict heat-ing
	ktonnes		ktoe	ktonnes	Mill. Sm^3	ktoe	ktonnes				GWh	
Extraction of energy commodities	230	-	-	149477	41005	3249[3]	3045[4]	-	-	-	104148	-
Energy use in extraction sectors	-	-	-	-	-3648[5]	-	-2	-0	-292	-0	-1338	-
Imports and Norwegian purchases abroad	832	967	2	1333	-	957	516	243	2262	2999	13212	-
Exports and foreign purchases in Norway	-156	-138	-0	-136800	-37825	-3254	-5080	-541	-3757	-1739	-4236	-
Stocks (+ Decrease, - Increase)	28	-57	.	-643	.	227	-40	-176	-172	-15	.	.
Primary supplies	934	772	2	13367	-469	1178	-1561	-474	-1958	1246	111785	-
Petroleum refineries	-	198	-	-14214	-	330	3810	1104	6514	1178	-501	-
Other energy sectors, other supplies	-28	-	922	-	-	269	47	1	-41	47	395	1743
Registered losses, statistical errors	22	31	-	847	497	-527	-604	176	641	168	-8535	-405
Registered use outside energy sectors	929	1001	924	-	29	1251	1691	806	5156	2639	103144	1338

[1] Including energy goods used for non-energy purposes.

[2] Including petrol coke.

[3] Natural gas liquids from Kårstø.

[4] Condensate from Kårstø.

[5] Including gas terminals.

Source: Energy Statistics, Statistics Norway.

Table C4. Energy accounts. Use of energy goods outside the energy sectors, by industry[1]. 1996. Physical units

	Coal	Coke[2]	Fuel wood, wood waste, refuse	Gas[3]	Gaso-line	Kero-sene	Middle distil-lates	Heavy fuel oil	Elec-tricity
	ktonnes		ktoe		ktonnes				GWh
Total	929	1001	924	1279	1691	806	5156	2639	103144
Agriculture and fisheries	0	-	-	-	9	2	630	5	1248
Agriculture	0	-	-	-	4	1	154	3	1159
Forestry	-	-	-	-	1	-	14	-	-
Fisheries	-	-	-	-	4	0	462	3	89
Mining	-	-	-	0	0	1	35	15	564
Metal ore mining	-	-	-	0	0	1	6	13	310
Other mining	-	-	-	0	0	0	29	2	254
Manufacturing	925	999	387	1258	9	7	480	428	43428
Food, beverages etc.	-	-	0	18	3	1	144	38	2427
Textiles, leather etc.	-	-	0	1	0	0	10	5	200
Wood and wood products	-	-	119	0	0	0	17	10	686
Paper and paper products	12	-	258	6	0	0	22	215	6660
Printing, publishing etc.	-	-	-	2	1	-	3	-	457
Industrial chemicals	185	195	0	1132	0	0	27	49	6021
Other chemical products, petroleum, coal, rubber and plastic products	-	-	-	8	1	2	23	18	546
Cement and lime	178	6	-	-	-	-	2	20	492
Other mineral products	111	15	0	31	0	0	44	26	612
Iron and steel	93	64	-	0	0	0	5	8	769
Ferro-alloys	345	411	-	0	0	-	2	-	6027
Aluminium	-	180	-	30	0	0	33	5	13886
Other metals	-	11	-	15	0	-	2	18	1865
Rolling and founding of metals	-	-	0	0	0	0	3	-	192
Fabricated metal products, machinery and equipment, other manufacturing	1	117	10	15	2	4	61	14	2590
Crude oil drilling	-	-	-	-	-	-	82	-	-
Collection, purification and distribution of water	-	-	-	-	-	-	8	-	-
Construction	-	-	3	13	12	1	159	-	703
Wholesale and retail trade, hotels and restaurants	-	-	-	-	216	3	226	-	6085
Wholesale and retail trade	-	-	-	-	214	3	204	-	4811
Hotels and restaurants	-	-	-	-	3	-	22	-	1275
Transport, storage and communication	-	-	-	-	73	539	3079	2191	1786
Railways, tramways and other scheduled land transport	-	-	-	-	0	-	148	-	618
Taxi operation	-	-	-	-	12	-	28	-	-
Other land transport	-	-	-	-	23	-	719	-	-
International maritime transport	-	-	-	-	-	-	1742	2180	-
Coastal and inland water transport	-	-	-	-	-	-	412	11	-
Air transport	-	-	-	-	2	539	-	-	29
Services related to transport	-	-	-	-	4	0	24	-	556
Post and telecommunications	-	-	-	-	32	-	6	-	584
Financial institutions, insurance, real estate and business services	-	-	-	-	27	0	23	-	1857
Other private service industries	-	-	-	-	28	4	76	-	4363
Production sectors, general government	-	-	-	5	2	75	165	0	7821
Public administration, except defence	-	-	-	-	1	-	12	-	2332
Education and research	-	-	-	-	-	-	45	-	2242
Health, social work, veterinary services	-	-	-	-	-	0	48	-	2043
Other public services	-	-	-	5	0	74	59	0	1205
Private households	3	2	533	4	1315	175	277	-	35288

[1] Including energy goods used as raw materials. District heating is not included.

[2] Including petrol coke.

[3] Natural gas, fuel gas, liquefied gas and methane.

Source: Energy statistics from Statistics Norway.

Table C5. Energy accounts. Extraction, conversion and use[1] of energy goods. 1996. PJ

	Total	Coal	Coke[2]	Fuel wood, wood waste, refuse	Crude oil	Natural gas	Other gases, liquefied gas	Gaso-line	Kero-sene	Middle distil-lates	Heavy fuel oil	Elec-tricity	Dis-trict heat-ing
Extraction of energy commodities	8677	6	-	-	6323	1702	137[3]	134[4]	-	-	-	375	-
Energy use in extraction sectors	-169	-	-	-	-	-151[5]	-	-0	-0	-13	-0	-5	-
Imports and Norwegian purchases abroad	450	23	30	0	56	-	40	23	10	97	122	48	-
Exports and foreign purchases in Norway	-7997	-4	-5	-0	-5787	-1570	-138	-223	-23	-162	-71	-15	-
Stocks (+ Decrease, - Increase)	-36	1	-2	.	-27	.	10	-2	-8	-7	-1	.	.
Primary supplies	925	26	23	0	565	-19	50	-69	-20	-84	51	402	-
Petroleum refineries	-39	-	7	-	-601	-	14	167	48	281	48	-2	-
Other energy sectors, other supplies	60	-1	-	39	-	-	11	2	0	-2	2	1	6
Registered losses, statistical errors	19	1	1	-	36	21	-22	-27	8	28	7	-31	-1
Registered use outside energy sectors	965	26	31	39	-	1	53	74	35	222	107	371	5
International maritime transport	164	-	-	-	-	-	-	-	-	75	88	-	-
Domestic use	802	26	31	39	-	1	53	74	35	147	19	371	5
- Agriculture and fisheries	32	0	-	-	-	-	-	0	0	27	0	4	0
- Energy-intensive manufacturing	203	18	27	0	-	1	1	0	0	1	1	103	0
- Other manufacturing and mining	124	8	5	16	-	0	51	0	0	21	17	56	1
- Other industries	214	-	-	0	-	-	1	16	27	86	0	81	2
- Private households	228	0	0	23	-	-	0	58	8	12	-	127	1

[1] Including energy goods used for non-energy purposes.

[3] Natural gas liquids from Kårstø.

[4] Condensate from Kårstø.

[5] Including gas terminals.

Source: Energy Statistics, Statistics Norway.

Appendix D

Economic sectors in the Norwegian emission model

The classification is almost identical to that used in the National Accounts. To make the standard sectors more appropriate for emission calculation a few changes have been made, e.g. "Private households" is defined as a sector. The classification is aggregated from the Norwegian *Standard Industrial Classification*, SIC (Statistics Norway 1994). The SIC is identical to the European NACE (rev. 1) classification up to the four-digit level. A national level has been introduced at the five-digit level.

All sector numbers in the model have six digits. The first two digits refer to the main sectors of the economy: 23 = private sector, 24 = central government, 25 = local government, 33 = private households, and 66 = foreign activity. For clarity, the two first digits are only included for the first sector listed in each main sector in the table below.

The last four digits are approximate SIC codes. The first two of these always correspond to SIC at the two-digit level. (Exceptions: sectors 235000 and 236500 are aggregates of several SIC divisions). For around two thirds of the sectors, all non-zero digits correspond to SIC. The detailed relationship is shown in the following table, where the sectors are listed with the corresponding SIC codes.

Sector number	SIC code	Sector name
Agriculture and forestry		
230100	01.1-3	Agriculture
0140	01.4-5	Services related to agriculture and forestry
0200	02	Forestry and logging
Fishing		
0510	05.01	Fishing
0520	05.02	Operation of fish farms
Energy sectors		
1000	10.1-2	Coal mining
1110	11.1	Extraction of crude petroleum and natural gas
1200	12	Mining of uranium and thorium ores
2320	23.2 part	Manufacture of refined petroleum products
2330	23.3	Processing of nuclear fuel
2340	11.1	Gas terminal
4010	40.101	Production of electricity
4020	40.102	Distribution of electricity
4030	40.2	Manufacture and distribution of gas
4040	40.3	Steam and hot water supply
Mining/manufacturing		
1120	11.2	Oil drilling
1300	13	Mining of metal ores
1400	14, 10.3	Other mining and quarrying
1510	15.1	Production, processing and preserving of meat and meat products
1520	15.2	Processing and preserving of fish and fish products
1530	15.3	Processing and preserving of fruit and vegetables
1540	15.4	Manufacture of vegetable and animal oils and fats
1550	15.5	Manufacture of dairy products
1560	15.6	Manufacture of grain mill products, starches and starch products
1570	15.7	Manufacture of prepared animal feeds
1580	15.8	Manufacture of other food products
1590	15.9	Manufacture of beverages
1600	16	Manufacture of tobacco products
1700	17	Manufacture of textiles and textile products

Sector number	SIC code	Sector name
Mining/manufacturing (cont.)		
1810	18.1	Manufacture of leather clothes
1820	18.2	Manufacture of other wearing apparel and accessories
1830	18.3	Dressing and dyeing of fur, manufacture of articles of fur
1910	19.1-2	Tanning and dressing of leather, manufacture of luggage, handbags, saddlery and harness
1930	19.3	Manufacture of footwear
2010	20.1	Sawmilling and planing of wood, impregnation of wood
2020	20.2	Manufacture of particle board, fibre board and other panels and boards
2030	20.3	Manufacture of builders' carpentry and joinery
2040	20.4-5	Manufacture of other products of wood
2110	21.11	Manufacture of pulp
2120	21.12	Manufacture of paper and paperboard
2130	21.2	Manufacture of articles of paper and paperboard
2210	22.1	Publishing
2220	22.2	Printing and service activities related to printing
2230	22.3	Reproduction of recorded media
2310	23.1	Manufacture of coke oven products
2322	23.2 part	Manufacture of asphalt
2411	24.11	Manufacture of industrial gases
2412	24.12-13	Manufacture of dyes and pigments and other inorganic basic chemicals
2415	24.15, 24.2	Manufacture of fertilisers, nitrogen compounds and pesticides
2416	24.14, 24.16-17	Manufacture of plastics and synthetic rubber in primary forms, manufacture of other organic basic chemicals
2430	24.3	Manufacture of paints and varnishes, printing ink and mastics
2440	24.4	Manufacture of basic pharmaceutical products and pharmaceutical preparations
2450	24.5	Manufacture of soap and detergents and toilet preparations
2460	24.6	Manufacture of other chemical products
2470	24.7	Manufacture of man-made fibres
2500	25	Manufacture of rubber and plastic products
2610	26.1	Manufacture of glass and glass products
2620	26.2-3	Manufacture of ceramic goods
2640	26.4,6-8	Manufacture of other mineral products
2650	26.5	Manufacture of cement, lime and plaster
2710	27.1-3 except 27.35	Manufacture of basic iron and steel
2720	27.35	Manufacture of ferro-alloys
2730	27.42	Aluminium production
2740	27.4 except 27.42	Other non-ferrous metal production
2750	27.5	Casting of metals
2810	28.1-5	Manufacture of fabricated metal products, except machinery and equipment
2860	28.6	Manufacture of cutlery, tools and general hardware
2870	28.7	Manufacture of other metal products
2910	29.1-2	Manufacture of general purpose machinery
2930	29.3-5	Manufacture of special purpose machinery
2960	29.6	Manufacture of weapons and ammunition
2970	29.7	Manufacture of domestic appliances
3000	30	Manufacture of office machinery and computers
3110	31.1-2	Manufacture of electric motors, generators and transformers, manufacture of electricity distribution and control apparatus
3130	31.3	Manufacture of insulated wire and cable
3140	31.4-6	Manufacture of other electrical apparatus and equipment
3210	32.1-2	Manufacture of electronic components and television and radio transmitters
3230	32.3	Manufacture of television and radio receivers, sound or video recording apparatus
3310	33.1-3	Manufacture of medical and precision instruments
3340	33.4-5	Manufacture of optical instruments, photographic equipment, watches and clocks
3400	34	Manufacture of motor vehicles and parts and accessories for motor vehicles
3510	35.1 except 35.114	Building and repair of ships and boats
3520	35.114	Building and repair of oil platforms

Sector number	SIC code	Sector name
Mining/manufacturing (cont.)		
3530	35.2	Manufacture and repair of railway and tramway locomotives and rolling stock
3540	35.3	Manufacture and repair of aircraft and spacecraft
3550	35.4-5	Manufacture of other transport equipment
3610	36.1	Manufacture of furniture
3620	36.2	Manufacture of jewellery and related articles
3630	36.3-6	Other manufacturing
3710	37.1	Recycling of metal waste and scrap
3720	37.2	Recycling of non-metal waste and scrap
Water supply		
4100	41	Collection, purification and distribution of water
Construction		
4500	45	Construction
Wholesale and retail trade/hotels and restaurants		
5000	50-52	Wholesale and retail trade, repair of motor vehicles and personal and household goods
5500	55	Hotels and restaurants
Transport etc.		
6010	60.1	Transport via railways
6020	60.21	Tramway and suburban transport, other scheduled passenger land transport
6030	60.22	Taxi operation
6040	60.23-24	Other land passenger transport, freight transport by road
6080	60.3	Transport via pipelines
6110	61.101-102	Ocean transport, sea and coastal transport in Europe
6130	61.103-109, 61.2	Inland and coastal water transport
6202	62 part	Domestic air transport
6203	62 part	International air transport
6300	63	Supporting and auxiliary transport activities
6400	64	Post, telecommunications
Financing, insurance, real estate and business services		
6500	65-67	Financial intermediation, insurance
7000	70	Real estate activities
7100	71	Renting of machinery and equipment
7200	72	Computer and related activities
7300	73	Research and development
7400	74	Other business activities
8000	80	Education
8500	85	Health and social work
9000	90	Sewage and refuse disposal, sanitation and similar activities
9100	91	Activities of membership organisations
9200	92	Recreational, cultural and sporting activities
9300	93	Other service activities
9500	95	Private households with employed persons
Central government		
246300	63	Supporting and auxiliary transport activities
7300	73	Research and development
7400	74	Other business activities
7510	75.1, 75.21, 23, 24, 75.3	Public administration
7520	75.22	Defence
8000	80	Education
8500	85	Health and social work
9200	92	Other service activities

Sector number	SIC code	Sector name
Local government		
257510	75.1, 75.25	Public administration
8000	80	Education
8500	85	Health and social work
9000	90	Sewage and refuse disposal, sanitation and similar activities
9200	92, 93.03	Other service activities
Private households		
330000	n.a.	Private household
Foreign activities in Norway		
660000	n.a.	Foreign activities in Norway

Appendix E

Emission factors, combustion. 1997

Table E1. SO_2. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (heat-ing)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Direct-fired furnaces	General	16	18	18		-	-							1.2	1.2	3.8	12.6	9.2
	Structural clay	9																
	Refineries						-											
Gas turbines						-	-							1.2				
Flares	General					-	-											
	Refuse disposal						0.02											
Boilers	General	16	18		0.4	-	-	-			0.5		1.2		1.2	3.8	12.6	9.2
	Manufacturing	16	18	18.0	0.4	-	-	-			0.5				1.2	3.8	12.6	9.2
Small stoves	General										0.5				1.2			
	Private households	20	18		0.4			-			0.5				1.2			
Light duty vehicles (<3500kg)									0.2				1.2					
Light duty vehicles (>3500kg)									0.2				1.2					
Heavy duty vehicles									0.2				1.2					
Railways													1.2					
Air traffic (landing/take-off below 100 m)										0.4		0.5						
Air traffic (landing/take-off 100-1000 m)										0.4		0.5						
Air traffic (cruising)									0.2	0.4		0.5						
MCs									0.2									
Mopeds									0.2									
Snow scooters									0.2									
Two-stroke boats									0.16									
Four-stroke boats									0.16				1.2					
Ships	General													1.2	1.2	3.8	13	
	Fishing													1.2		3.8	45	
	National sea traffic													1.2		3.8	26	
	International sea traffic													1.2		3.8	38	
	Foreign activities in Norway													1.2		3.8	38	
	Extraction of oil and gas													1.2		3.8	47	
Motorised equipment (two-stroke)									0.16				1.2					
Motorised equipment (four-stroke)									0.16				1.2		1.2			

Source: Norwegian Petroleum Industry Association.

Table E2. CO_2. tonnes/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gasoline	Avia-tion gaso-line	Kero-sene (heat-ing)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Direct-fired furnaces	General		3.2	3.59		2.75	2.5	3,0						3.17		3.17	3.2	3.2
	Cement	2.4						3.0								3.17	3.2	3.2
	Structural clay	2.4						3,0								3.17	3.2	
	Refineries		3.2			2.75	2.8	3.0								3.17	3.2	
Gas turbines						2.75	2.9							3.17				
Flares	General					2.75	3.0											
	Extraction of oil and gas					2.86	3.0											
	Refineries					2.75	2.8											
	Refuse disposal						-											
Boilers	General	2.4	3.2		-	2.75	3.0	3.0			3.15		3.17		3.17	3.17	3.2	3.2
	Manufacturing	2.4	3.2	3.59	-	2.75	3.0	3.0			3.15				3.17	3.17	3.2	3.2
	Chemical	2.4	3.2	3.59	-	2.75	2.5	3.0			3.15				3.17	3.17	3.2	
	Metals	2.4	3.2	3.59	-	2.75	2.5	3.0			3.15				3.17	3.17	3.2	3.2
	Refineries	2.4	3.2	3.59	-	2.75	2.8	3.0			3.15				3.17	3.17	3.2	
	Refuse disposal						0.28											
	Private households														3.17	3.17	3.2	
Small stoves	General										3.15				3.17	3.17		
	Private households	2.4	3.2		-			3.0			3.15							
Light duty vehicles (<3500kg)									3.13				3.17					
Light duty vehicles (>3500kg)									3.13				3.17					
Heavy duty vehicles									3.13				3.17					
Railways													3.17					
Air traffic (landing/ take-off below 100 m)										3.13		3.15						
Air traffic (landing/ take-off 100-1000 m)										3.13		3.15						
Air traffic (cruising)										3.13		3.15						
MCs									3.13									
Mopeds									3.13									
Snow scooters									3.13									
Two-stroke boats									3.13									
Four-stroke boats									3.13				3.17					
Ships														3.17	3.17	3.17	3.2	
Motorised equip-ment (two-stroke)									3.13				3.17					
Motorised equip-ment (four-stroke)									3.13				3.17		3.17			

Source: Norwegian Petroleum Industry Association,.and SFT (1990).

Table E3. NO_x. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (heat-ing)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Direct-fired furnaces	General		20	20		7	5							70		5	5	5
	Cement	16	20	20												24	24	24
	Structural clay	16														10	10	
Gas turbines	General					8	8											
	Extraction of oil and gas					7	8							16				
Flares	General					8	7											
	Extraction of oil and gas					19	7											
	Refineries						7											
	Refuse disposal						0.17											
Boilers	General	3.0	3.0		0.9		3.0	2.3			3.0		2.5		2.5	2.5	4.2	4.2
	Manufacturing	4.5	3.4	3.4	0.9	3.0	3.0	2.3			3.0				3.0	3.0	5.0	5.0
	Chemical	4.5	3.4	3.4	0.9	3.0	2.9	2.3			3.0				3.0	3.0	5.0	
	Metals	4.5	3.4	3.4	0.9	3.0	2.9	2.3			3.0				3.0	3.0	5.0	5.0
	Refuse disposal						0.01											
	Private households														2.5	2.5	4.2	
Small stoves	General	3.0	3.0		0.7						2.5				2.5	2.5		
	Private households	1.4	1.4		0.7			2.3			2.5							
Light duty vehicles (<3500kg)									18				8					
Light duty vehicles (>3500kg)									15				8					
Heavy duty vehicles									55				35					
Railways													47					
Air traffic (landing/take-off below 100 m)	General									-		9						
	International air transport									-		10						
	Defence									-		14						
	Foreign activities in Norway									-		10						
Air traffic (landing/take-off 100-1000 m)	General									3.6		10						
	International air transport									3.6		12						
	Defence									3.6		13						
	Foreign activities in Norway									3.6		12						
Air traffic (cruising)	General									4.4		8						
	International air transport									4.4		10						
	Defence									4.4		12						
	Foreign activities in Norway									4.4		10						
MCs									7									
Mopeds									3									
Snow scooters									3									
Two-stroke boats									6									
Four-stroke boats									12				54					
Ships	General													65	65	65	65	
	Fishing													71	71	71	71	
	Oil drilling													70	70	70	70	
	Extraction of oil and gas													75	75	75	75	
	Defence													63	63	63	63	
Motorised equipment (two-stroke)									2									

Table E3 (cont.). NO_x. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (heat-ing)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Motorised equipment (four-stroke)	General								10				50		50			
	Agriculture												54		54			
	Forestry												52		52			
	Mining of metal ores												47		47			
	Soil and stone												48		48			
	Construction								10				46		46			
	Railways												47		47			
	Defence												48		48			

Source: SFT/SSB (1999), Bang (1993), Rosland (1987), Rypdal and Tornsjø (1997) and Flugsrud and Rypdal (1996).

Table E4. NMVOC. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (hea-ting)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Direct-fired furnaces	General	-	-	-		-	-							5.0		0.3	0.3	0.3
	Cement	-	-	-												-	-	-
	Structural clay	-														0.9	0.9	
	Refineries						0.1											
Gas turbines	General					0.3	0.3											
	Extraction of oil and gas					0.3	0.3							0.0				
	Gas terminals					0.5	0.3											
Flares	General					2.2	0.3											
	Extraction of oil and gas					0.0	0.3											
	Refineries					2.2	13.5											
	Refuse disposal						-											
Boilers	General	1.1	0.6		1.3		0.1	0.1			0.4		0.4		0.4	0.4	0.3	0.3
	Manufacturing	0.8	0.6	0.6	1.3	0.1	0.1	-			0.4				0.4	0.4	0.3	0.3
	Cellulose	0.8	0.6	0.6	-	0.1	0.1	-			0.4				0.4	0.4	0.3	0.3
	Chemical	0.8	0.6	0.6	1.3	0.1	-	-			0.4				0.4	0.4	0.3	
	Metals	0.8	0.6	0.6	1.3	0.1	-	-			0.4				0.4	0.4	0.3	0.3
	Refineries	0.8	0.6	0.6	1.3	0.1	0.1	-			0.4				0.4	0.4	0.3	
	Refuse disposal						-											
	Private households														0.6	0.6	0.3	
Small stoves	General	1.1	0.6		6.9						0.4				0.4	0.4		
	Private households	10.0	0.6		6.9			0.1			0.6							
Light duty vehicles (<3500kg)									31.2				2.9					
Light duty vehicles (>3500kg)									23.1				3.4					
Heavy duty vehicles									50.3				3.6					
Railways													4.0					
Air traffic (landing/take-off below 100 m)	General									25		4.5						
	International air transport									25		1.5						
	Defence									25		7.4						
	Foreign activities in Norway									25		1.5						
Air traffic (landing/take-off 100-1000 m)	General									10		2.6						
	International air transport									10		0.4						
	Defence									10		7.4						
	Foreign activities in Norway									10		0.4						
Air traffic (cruising)	General									11		2.4						
	International air transport									11		0.8						
	Defence									11		4.3						
	Foreign activities in Norway									11		0.8						
MCs									119									
Mopeds									368									
Snow scooters									368									
Two-stroke boats									240									
Four-stroke boats									40				27					

Table E4 (cont.). NMVOC. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (hea-ting)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Ships	General													2.4	2.4	2.4	2.4	
	Fishing													1.5	1.5	1.5	1.5	
	Oil drilling													5.0		6.4	6.4	
	Extraction of oil and gas													2.3	2.3	2.3	2.3	
	Defence													2.2	2.2	2.2	2.2	
Motorised equipment (two-stroke)									500									
Motorised equipment (four-stroke)	General								110				6.0		6.0			
	Agriculture												7.2		7.2			
	Forestry												5.7		5.7			
	Mining of metal ores												4.0		4.0			
	Soil and stone												4.8		4.8			
	Construction								110				3.8		3.8			
	Railways												4.0		4.0			
	Defence												4.8		4.8			

Source: SFT/SSB (1999), Bang (1993 and 1996), Rosland (1987), Rypdal and Tornsjø (1997) and Flugsrud and Rypdal (1996).

Table E5. CH_4. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gasoline	Aviation gasoline	Kerosene (heating)	Jet fuel (kerosene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Direct-fired furnaces	General		-	-		0.05	0.05							0.02		0.04	0.04	0.04
	Cement	0.03	-	-		-	0.05									0.04	0.04	0.04
	Structural clay	0.03	-	-		-	-									0.04	0.04	
	Refineries						0.05											
Gas turbines	General					1.1	0.05											
	Extraction of oil and gas					1.1	0.05							-				
	Gas terminals					1.1	0.05											
Flares	General					0.3	0.3											
	Extraction of oil and gas					0.3	0.3											
	Refineries					0.3	0.3											
	Refuse disposal						0.4											
Boilers	General	0.3	0.3	0.3	0.3	0.2	0.2	0.2			0.2		0.1		0.4	0.4	0.4	0.4
	Manufacturing	0.3	0.3	0.3	0.3	0.2	0.2	0.2			0.2				0.1	0.1	0.1	0.1
	Extraction of coal	0.03				0.05									0.1	0.1	0.1	0.1
	Extraction of oil and gas	0.03				0.05									0.1	0.1	0.1	0.1
	Refineries	0.03				0.05									0.1	0.1	0.1	0.1
	Gas terminals	0.03				0.05									0.1	0.1	0.1	0.1
	Production of electricity	0.03				0.05									0.1	0.1	0.1	0.1
	Private households										0.2				0.4	0.4	0.4	
Small stoves	General	8.40	8.40		5.30			0.2			0.3				0.4	0.4		
	Private households	8.40	8.40		5.30			0.2			0.3				0.4	0.4		
Light duty vehicles (<3500kg)									1.6				0.1					
Light duty vehicles (>3500kg)									1.0				0.1					
Heavy duty vehicles									2.4				0.2					
Railways													0.2					
Air traffic (landing/take-off below 100 m)	General									1.5		0.7						
	International air transport									1.5		1.1						
	Defence									1.5		0.4						
	Foreign activities in Norway									1.5		1.1						
Air traffic (landing/take-off 100-1000 m)	General									1.4		0.1						
	International air transport									1.4		0.1						
	Defence									1.4		0.4						
	Foreign activities in Norway									1.4		0.1						
Air traffic (cruising)										-		-						
MCs									4.9									
Mopeds									5.9									
Snow scooters									5.9									
Two-stroke boats									5.1									
Four-stroke boats									1.7				0.2					
Ships	General													0.2	0.2	0.2	0.2	
	Oil drilling													0.8			1.9	

Table E5 (cont). CH_4. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gasoline	Aviation gasoline	Kerosene (heating)	Jet fuel (kerosene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Motorised equipment (two-stroke)	General								6.0									
	Agriculture								6.2									
	Forestry								7.7									
	Manufacturing								6.0									
	Private households								8.1									
Motorised equipment (four-stroke)	General								2.2				0.2		0.2			
	Agriculture								3.7				0.2					
	Manufacturing								2.2				0.2					
	Private households								5.5				0.2					

Source: IPCC (1997b), OLF (1994), Det norske Veritas, SFT/SSB (1999), Rypdal and Tornsjø (1997) and Flugsrud and Rypdal (1996).

Table E6. N_2O. kg/tonne fuel

Source	Sector	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (heat-ing)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Special distillate	Heavy fuel oil	Waste oil
Direct-fired furnaces	General		-	-		0.02	0.02							0.03		0.03	0.03	0.03
	Cement	-	-	-		0.02	0.02									0.03	0.03	0.03
	Structural clay	-	-	-		0.02	0.02									0.03	0.03	
Gas turbines						0.02								0.02				
Flares	General					0.02	0.02							0.02				
	Refuse disposal						0.00											
Boilers	General	0.04	0.04	0.04	0.07	0.01	0.01	0.03			0.03		0.03	0.03	0.03	0.03	0.03	0.03
Small stoves	General										0.03				0.03	0.03		
	Private households	0.04	0.04		0.07			0.03			0.03							
Light duty vehicles (<3500kg)									0.6				0.2					
Light duty vehicles (>3500kg)									0.3				0.2					
Heavy duty vehicles									0.04				0.0					
Railways													1.2					
Air traffic (landing/take-off below 100 m)	General									0.1		0.1						
	International air transport									0.1		0.1						
	Defence									0.1		0.1						
	Foreign activities in Norway									0.1		0.1						
Air traffic (landing/take-off 100-1000 m)										0.1		0.1						
Air traffic (cruising)										0.1		0.1						
MCs									0.05									
Mopeds									0.06									
Snow scooters									0.06									
Two-stroke boats									0.02									
Four-stroke boats									0.08				0.03					
Ships	General													0.08	0.08	0.08	0.08	
	Oil drilling													0.02				
Motorised equipment (two-stroke)									0.02									
Motorised equipment (four-stroke)	General								0.07				1.3		1.3			
	Agriculture								0.07									
	Manufacturing								0.08									
	Private households								0.07									

Source: IPCC (1997b), SFT/SSB (1999), Rypdal and Tornsjø (1997) and Flugsrud and Rypdal (1996).

Table E7. NH_3. All sectors. kg/tonne fuel

Source	Coal	Coal coke	Petrol coke	Fuel wood, wood waste, black liquor	Natural gas	Other gases	LPG	Motor gaso-line	Avia-tion gaso-line	Kero-sene (heat-ing)	Jet fuel (kero-sene)	Auto diesel	Marine fuel	Light fuel oils	Spe-cial distil-late	Heavy fuel oil	Waste oil
Direct-fired furnaces	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gas turbines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flares	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boilers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Small stoves	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Light duty vehicles (<3500kg)	-	-	-	-	-	-	-	0.77	-	-	-	0.02	-	-	-	-	-
Light duty vehicles (>3500kg)	-	-	-	-	-	-	-	0.35	-	-	-	0.01	-	-	-	-	-
Heavy duty vehicles	-	-	-	-	-	-	-	0.00	-	-	-	0.003	-	-	-	-	-
Railways	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Air traffic (landing/take-off below 100 m)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Air traffic (landing/take-off 100-1000 m)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Air traffic (cruising)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCs	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
Mopeds	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
Snow scooters	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-
Two-stroke boats	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Four-stroke boats	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ships	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motorised equipment (two-stroke)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motorised equipment (four-stroke)	-	-	-	-	-	-	-	-	-	-	-	0.005	-	0.005	-	-	-

Source: SFT/SSB (1999).

Table E8. Sector name in the emission factor tables (E1-E7) and the corresponding sector number in the model[1]

Sector name in the emission factor tables	Sector number in the emission model
Agriculture	230100
Forestry	230200
Fishing	230510
Manufacturing	231000-233720
Extraction of coal	231000
Extraction of oil and gas	231110
Oil drilling	231120
Mining of metal ores	231300-231400
Pulp	232110
Chemical	232411-232470
Refineries	232320
Gas terminals	232340
Structural clay	232640
Soil and stone	232640
Cement	232650
Metals	232710-232740
Electricity	234010-234040
Construction	234500
Railways	236010
International sea traffic	236110
National sea traffic	236130
International air transport	236203
Defence	247520
Refuse disposal	259000
Private households	330000
Foreign activities in Norway	660000

[1] See appendix D.

Table E9. Average emission factors and fuel consumption per km. Road traffic. Cold start emissions and evaporation included. Vehicle class. 1997

	Fuel	CO_2	CH_4	N_2O	SO_2	NO_x	NH_3	NM-VOC	CO	Pb	PM_{10}	$PM_{2.5}$	PAH[1]	Ben-zene
	kg/km		g/km							mg/km	g/km		mg/km	g/km
Gasoline														
Passenger cars	0.06	0.20	0.10	0.04	0.01	1.12	0.05	1.95	15.1	0.09	0.02	0.02	0.01	0.07
Other light duty	0.10	0.32	0.10	0.03	0.02	1.55	0.04	2.37	19.9	0.14	0.02	0.02	0.02	0.10
Goods	0.16	0.49	0.36	0.01	0.03	8.54	0.00	7.74	43.8	0.22	0.02	0.02	0.03	0.18
Buses	0.16	0.50	0.46	0.01	0.03	9.56	0.00	9.24	43.3	0.22	0.02	0.02	0.03	0.17
Mopeds	0.02	0.06	0.11	0.00	0.003	0.05	0.00	6.93	13.2	0.03	0.00	0.00	-	-
Motorcycles	0.04	0.12	0.20	0.00	0.006	0.28	0.00	4.70	28.0	0.06	0.01	0.01	-	-
Diesel														
Passenger cars	0.05	0.16	0.00	0.01	0.06	0.39	0.00	0.14	0.56	0.01	0.17	0.16	0.02	0.00
Other light duty	0.08	0.25	0.01	0.01	0.09	0.66	0.00	0.27	1.00	0.01	0.24	0.23	0.02	0.01
Light goods	0.13	0.41	0.02	0.01	0.16	4.13	0.00	0.53	2.26	0.02	0.28	0.27	0.06	0.01
Medium goods	0.17	0.55	0.03	0.01	0.21	6.05	0.00	0.68	2.58	0.02	0.46	0.43	0.09	0.01
Heavy goods	0.27	0.85	0.04	0.01	0.32	8.84	0.00	1.00	3.83	0.03	0.66	0.62	0.13	0.02
Buses	0.25	0.80	0.03	0.00	0.30	10.0	0.00	0.73	2.64	0.03	0.65	0.62	0.10	0.01

[1] Four selected PAH components: benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1.2.3-cd)pyrene.
Source: SFT/SSB (1999) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Table E10. Average emission factors per kg fuel consumed. Road traffic. Cold start emissions and evaporation included. Vehicle class. 1997

	CO_2	CH_4	N_2O	SO_2	NO_x	NH_3	NM-VOC	CO	Pb	PM_{10}	$PM_{2.5}$	PAH[1]	Ben-zene
	kg/kg	g/kg							mg/kg	g/kg		mg/kg	g/kg
Gasoline													
Passenger cars	3.13	1.6	0.6	0.16	17.9	0.8	31.2	240.7	1.4	0.3	0.3	0.15	1.2
Other light duty	3.13	1.0	0.3	0.16	15.1	0.3	23.1	194.7	1.4	0.2	0.2	0.16	1.0
Goods	3.13	2.3	0.0	0.16	54.5	0.0	49.4	279.7	1.4	0.1	0.1	0.21	1.2
Buses	3.13	2.9	0.1	0.16	60.0	0.0	58.1	271.8	1.4	0.1	0.1	0.19	1.0
Mopeds	3.13	5.9	0.1	0.16	2.7	0.1	367.5	699.9	1.4	0.1	0.1	-	-
Motorcycles	3.13	4.9	0.1	0.16	7.1	0.1	118.8	708.3	1.4	0.1	0.1	-	-
Diesel													
Passenger cars	3.17	0.1	0.2	1.2	8.1	0.0	2.9	11.4	0.1	3.5	3.3	0.43	0.1
Other light duty	3.17	0.1	0.2	1.2	8.4	0.0	3.4	12.7	0.1	3.1	2.9	0.23	0.1
Light goods	3.17	0.2	0.0	1.2	31.9	0.0	4.1	17.5	0.1	2.2	2.1	0.48	0.1
Medium goods	3.17	0.2	0.0	1.2	34.7	0.0	3.9	14.8	0.1	2.6	2.5	0.53	0.1
Heavy goods	3.17	0.2	0.0	1.2	33.0	0.0	3.7	14.3	0.1	2.5	2.3	0.49	0.1
Buses	3.17	0.1	0.0	1.2	40.0	0.0	3.0	10.5	0.1	2.6	2.5	0.40	0.1

[1] Four selected PAH components: benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1.2.3-cd)pyrene.
Source: SFT/SSB (1999) and emission inventory from Statistics Norway and Norwegian Pollution Control Authority.

Tidligere utgitt på emneområdet
Previously issued on the subject

Norges offisielle statistikk (NOS)
C 182: Standard Industrial Classification
C 518: Energy Statistics 1997

Notater
92/17: Modell for beregning av nasjonale utslipp til luft (Model for calculating national emissions to air)
94/16: Beregning av regionaliserte utslipp til luft (Calculation of emissions to air on a regional basis)
98/29: Utslippsfaktorer for lokale utslipp - PAH, partikler og NMVOC (Emission factors for local emissions - PAH, particles and NMVOC)
98/52: Energibruk og utslipp til luft i Oslo, Drammen, Bergen og Trondheim (Energy use and emissions to air in Oslo, Drammen, Bergen and Trondheim)

Rapporter (RAPP)
93/24: Anthropogenic Emissions of the Greenhouse Gases CO2, CH4 and N2O in Norway
95/12: Anthropogenic Emissions of SO2, NOx, VOC and NH3 in Norway
96/17: Utslipp til luft fra innenriks sjøfart, fiske og annen sjøtrafikk mellom norske havner (Emissions to air from domestic shipping, fisheries and other maritime traffic between Norwegian ports)
97/7: Energibruk og utslipp til luft fra transport i Norge (Energy use and emissions to air from transport in Norway)
97/20: Utslipp til luft fra norsk luftfart (Emissions to air from Norwegian air transport)
98/22: Utslipp til luft fra utenlandske skip i norske farvann 1996 og 1997 (Emissions to air from foreign shipping in Norwegian waters, 1996 and 1997)
99/22: Energibruk i husholdningene 1993, 1994 og 1995 (Survey of energy use in households 1993, 1994 and 1995)
00/?: Norwegian Economic and Environmental Accounts (NOREEA), Final report to Eurostat (to be published)

Documents
99/3: Nomenclature for Solvent Production and Use
99/4: Construction of Environment Pressure Information System (EPIS) for the Norwegian Offshore Oil and Gas Production
1999/16: Inventory of Climate Change Indicators for the Nordic Countries
1999/19: Methodological Choice in Inventory Preparation. Suggestions for Good Practice Guidance

Statistical Analyses (SA)
26: Natural Resources and the Environment 1998
30: Natural Resources and the Environment 1999

Economic Survey (articles)
1998/1: Environmental profiles and benchmarking of Norwegian industries. Results from the Norwegian economic and environmental accounts (NOREEA) project, pp. 28-38

De sist utgitte publikasjonene i serien Rapporter
Recent publications in the series Reports

Merverdiavgift på 23 prosent kommer i tillegg til prisene i denne oversikten hvis ikke annet er oppgitt

99/16 B. Aardal, H. Valen og I. Opheim: Valgundersøkelsen 1997: Dokumentasjonsrapport. 1999. 109s. 165 kr inkl. mva. ISBN 82-537-4699-7

99/17 A. Benedictow: Norsk eksport av metaller. 1999. 47s. 125 kr inkl. mva. ISBN 82-537-4701-2

99/18 F. Gundersen: Produksjon av svalbardstatistikk: Begrensninger og muligheter. 1999. 34s. 125 kr inkl. mva. ISBN 82-537-4702-0

99/19 P. Rees, L. Østby, H. Durham og M. Kupiszewski: Internal Migration and Regional Population Dynamics in Europe: Norway Case Study. 1999. 60s. 140 kr inkl. mva. ISBN 82-537-4703-9

99/20 B.K. Wold og J. Grave: Poverty Alleviation Policy in Angola, Pursuing Equity and Efficiency. 1999. 94s. 140 kr inkl. mva. ISBN 82-537-4704-7

99/21 T.N. Evensen: Turismens betydning for norsk økonomi: Satellittregnskap for turisme 1988-1995. 1999. 64s. 140 kr inkl. mva. ISBN 82-537-4707-1

99/22 A.C. Bøeng og R. Nesbakken: Energibruk til stasjonære og mobile formål per husholdning 1993, 1994 og 1995: Gjennomsnitts-tall basert på forbruksundersøkelsen. 1999. 59s. 140 kr inkl. mva. ISBN 82-537-4710-1

99/23 T. Eika og K. Moum: Aktivitetsregulering eller stabil valutakurs: Om pengepolitik-kens rolle i den norske oljeøkonomien. 1999. 42s. 125 kr inkl. mva. ISBN 82-537-4709-8

99/24 T. Bye, J. Larsson og Ø. Døhl: Klimagasskvoter i kraftintensive næringer: Konsekvenser for utslipp av klimagasser, produksjon og sysselsetting. 1999. 34s. 125 kr inkl. mva. ISBN 82-537-4719-5

99/25 S. Todsen: Kvartalsvis nasjonalregnskap - dokumentasjon av beregningsopplegget. 1999. 81s. 140 kr inkl. mva. ISBN 82-537-4720-9

99/26 B. Bye, E. Holmøy og B. Strøm: Virkninger på samfunnsøkonomisk effektivitet av en flat skattereform: Betydningen av generelle likevektseffekter. 1999. 40s. 125 kr inkl. mva. ISBN 82-537-4721-7

1999/27 H.K. Reppen og E. Rønning: Barnefamiliers tilsynsordninger, yrkesdeltakelse og bruk av kontantstøtte våren 1999: Kommentert tabellrapport. 1999. 132s. 165 kr inkl. mva. ISBN 82-537-4726-8

1999/28 A.K. Enge: Kvalitetsendring i byggeareal-statistikken - årsaker og konsekvenser. 1999. 31s. 125 kr inkl. mva. ISBN 82-537-4727-6

1999/29 M.V. Dysterud, E. Engelien og P. Schøning: Tettstedsavgrensing og arealdekke innen tettsteder: Metode og resultater. 1999. 81s. 140 kr inkl. mva. ISBN 82-537-4734-9

1999/30 M. Takle, A. Bjørsvik, R. Jensen, A. Kløvstad og K. Mork: Kontroll av kvaliteten på to kjennemerker i GAB-registeret: Bruk av GIS for analyse og presentasjon. 1999. 46s. 125 kr inkl. mva. ISBN 82-537-4736-5

1999/32 A. Bruvoll og K. Ibenholt: Framskrivning av avfallsmengder og miljøbelastninger knyttet til sluttbehandling av avfall. 1999. 34s. 125 kr inkl. mva. ISBN 82-537-4740-3

1999/33 J.-E. Lystad: Nordmenns ferievaner 1998. 1999. 62s. 140 kr inkl. mva. ISBN 82-537-4741-1

1999/34 Ø. Andresen: Organisasjonsdeltakelse i Norge fra 1983 til 1997. 1999. 52s. ISBN 82-537-4743-8

1999/35 J. Lyngstad: Studenters inntekt og økonomiske levekår. 1999. 37s. 125 kr inkl. mva. ISBN 82-537-4746-2

1999/36 T.W. Bersvendsen, J.L. Hass, K. Mork og R.O. Solberg: Ressursinnsats, utslipp og rensing i den kommunale avløpssektoren, 1998. 1999. 77s. 140 kr inkl. mva. ISBN 82-537-4747-0