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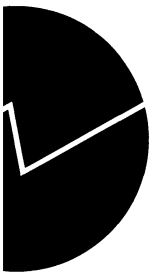

Kristin Rypdal

Anthropogenic Emissions of SO_2, NO_X, NMVOC and NH_3 in Norway

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Abstract

Kristin Rypdal

Anthropogenic Emissions of SO_2, NO_x, NH_3 and NMVOC in Norway

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The methodology for calculating the anthropogenic emissions to air of sulphur dioxide (SO_2), nitrogen oxides (NO_x), non methane volatile organic compounds (NMVOC) and ammonia (NH_3) in the Norwegian national emission inventory for 1992 is presented in this report. The emission factors, activity data, measurements and other sources relevant for emission estimates are described. The trends in the emissions are discussed briefly.

Due to the potential harmful effects of these gases on a regional scale, most European countries, including Norway, have signed protocols with obligations to reduce national emissions. In this context it is important to show in a transparent way how absolute emissions and time series are estimated.

The emission figures are estimated in collaboration between The Norwegian State Pollution Control Authority (SFT) and Statistics Norway. SFT is responsible for emissions from large plants and emission factors generally. Statistics Norway is responsible for activity data (e.g. on energy use), emission models and calculations.

Keywords: Acid rain, air, emissions, pollution, tropospheric ozone.

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1. Introduction

The methodology for estimating emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (NMVOC) and ammonia (NH_3) in Norway in 1992 will be reviewed in this report. The scope is to cover all anthropogenic emissions of these gases. The emission figures are estimated in collaboration between The State Pollution Control Authority (SFT) and Statistics Norway. SFT is responsible for emissions from large plants and emission factors generally. Statistics Norway is responsible for activity data (e.g. on energy use), emission models and calculations.

Norway has signed several protocols with obligations to limit emissions to air:

- SO_2: 76 per cent reduction in emissions from 1980 to 2000 (Oslo protocol).
- NO_x: Stabilizing of emissions at 1987 level by 1994 (Sofia protocol). (National goal: 30 per cent reduction in emissions from 1986 to 1998.)
- NMVOC: 30 per cent reduction in emissions in the mainland and the economic zone south of 62° from 1989 to 1999.

In this context it is obviously important to show how emissions and changes in emission are calculated.

National inventories may differ with respect to the emission sources included, methodologies of estimation, selection of activity data, emission factors and the limit of a national emission (what to be included). We will try to describe and justify the choices made in the Norwegian emission model. The documentation of emission estimates of greenhouse gases (CO_2, N_2O and CH_4) has been published in a separate report [1].

The emission figures described are those reported officially (e.g. to OECD, EUROSTAT, ECE). The same emission figures are used as a basis for evaluating various economical and technical possibilities for reducing the emissions [2].

2. Summary

In the Norwegian emission inventory system all emissions are calculated in a five dimensional cube model, with the axes pollutants, technical emission sources, emission carriers (e.g. fuels), economic sectors and territorial units. Thus, emissions may be listed by a multitude of combinations of fuels, sources and sectors for each territorial unit or nationally. The combustion emissions are calculated by combining the fuel consumption distributed between emission sources and economic sectors with fuel, source, sector and pollutant specific emission factors. If measured emission estimates are available, these are used instead of the calculated emissions. Emissions from road traffic are calculated in a detailed manner in a special model. Aggregated emission factors are input to the main emission model. The non-combustion emissions are estimated by combining activity data with emission factors, by more complicated calculations, estimated from measurements or taken from special investigations. They are fitted into the cube model by an appropriate emission carrier, emission source and economic sector.

The main factors that have influenced the trends in the emissions are:

- An overall increase in the fossil energy consumption for most purposes
- A decrease in use of oils (particularly heavy fuel oil) for heating during the last 15 years
- A decrease in use of gasoline for transport during the last few years
- A decrease in the sulphur content of liquid fuels
- A large increase in the volume of natural gas combusted in the North Sea
- A large increase in extraction and transport of crude oil and natural gas
- An increase in industrial production, but in many cases a decrease in the early nineties.
- Technical measures to reduce emissions: Abatement techniques in industry, catalytic converters in gasoline driven cars and control of fugitive emissions.

The combustion and non-combustion emissions as estimated in the Norwegian emission inventory for 1992, are summarized in table 2.1.

Totally 37.2 ktonnes SO_2, 220.3 ktonnes NO_x, 278.8 ktonnes NMVOC and 40.7 ktonnes NH_3 were emitted in 1992.

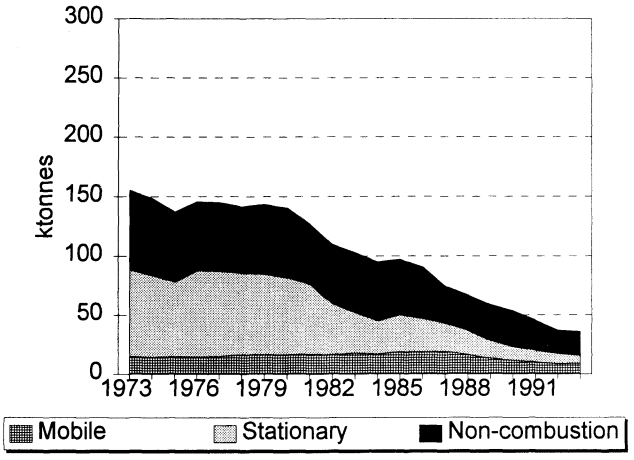
The trends in the emissions 1973-1993 are shown in figures 2.1, 2.2 and 2.3 for SO_2, NO_x and NMVOC, respectively. The emissions of SO_2 have decreased by 77% in the time period considered. The reduction 1980-1993 has been about 74%. The emissions of NO_x have increased by 29% in the period 1973-1993, while there has been a reduction by 3% since 1987. The NMVOC emissions have increased by 53% in the period 1973-1993. In the period 1989-1993 the in- crease has been 6 %. The emissions of NH_3 have been quite stable the last few years.

Historical emission figures have been changed when emission factors, definitions or methodologies have been changed.

The Norwegian national inventory seems to cover all the recognised important sources for emissions of the four considered pollutants. The industrial emissions are fairly well covered by measurements or emission factors, although there are some weaknesses. The emissions from extraction of oil and gas are estimated with the best available data. However, we have recognised several needs for improvements. Particularly emissions from ships and fishing vessels should be calculated by a more detailed methodology. NOx from manufacture of metals should be revised. Finally, more accurate emission factors and more information about technologies within each sector are in many cases needed.

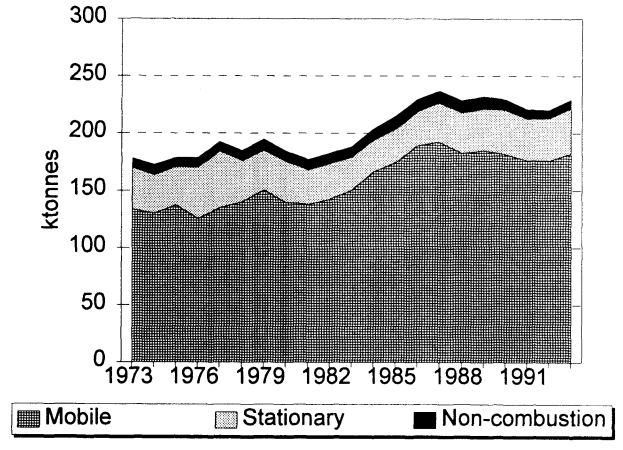
Summary tables of emission factors are given in tables 3.2. (SO_2 from combustion), 3.6. (NO_x from combustion), 3.7. (NMVOC from combustion) and 3.19. (non-combustion).

Figure 2.1. Emissions of SO_2 by source 1973-1993



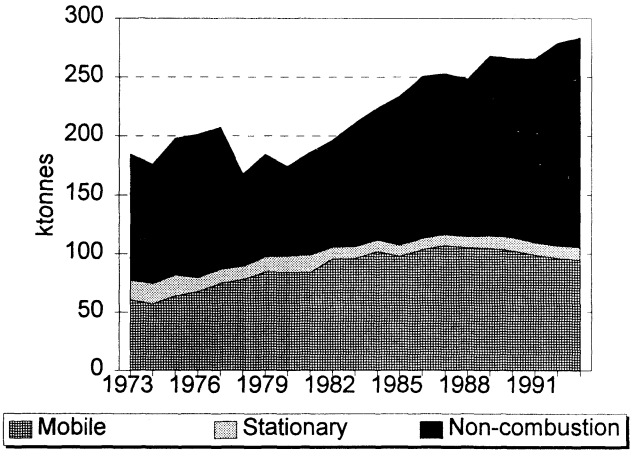
Sources: Statistics Norway and the State Pollution Control Authority

Figure 2.2. Emissions of NO_x by source 1973-1993



Sources: Statistics Norway and the State Pollution Control Authority

Figure 2.3. Emissions of NMVOC by source 1973-1993



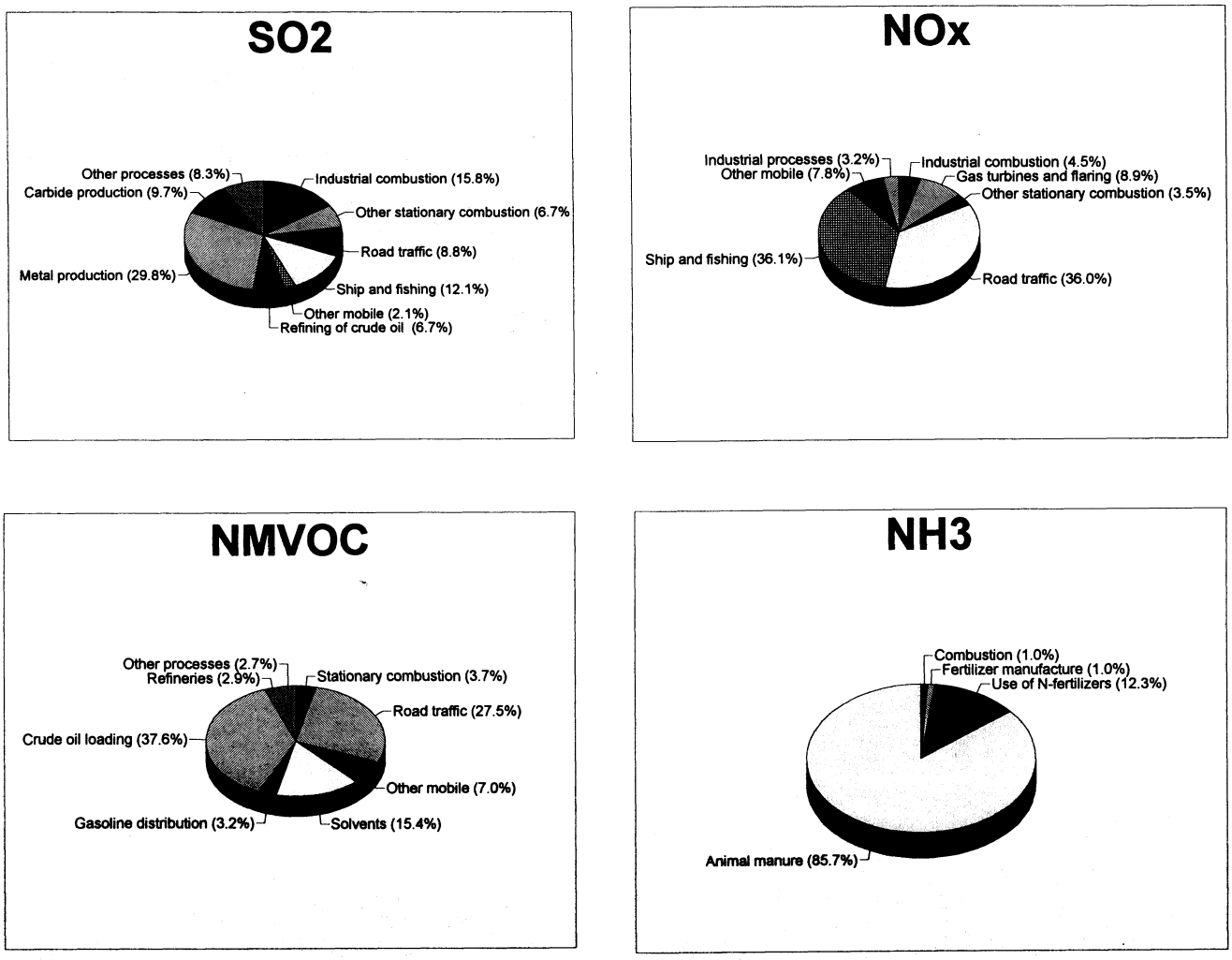
Sources: Statistics Norway and the State Pollution Control Authority

Table 2.1 Emissions of SO_2, NO_x, NMVOC and NH_3 by source. 1992. ktonnes.

	SO_2	NO_x	NMVOC	NH_3
Total	37.2	220.3	278.8	40.7
Stationary combustion	8.3	37.2	10.4	-
Oil and gas extraction	0.2	23.4	0.9	-
- Natural gas combustion	0.0	15.4	0.6	-
- Diesel combustion	0.2	4.2	0.3	-
- Flaring	0.0	3.8	0.0	-
Gas terminal and oil refineries	0.1	3.4	0.9	-
Other industry	5.8	7.0	0.7	-
Non-industrial combustion	1.9	2.3	7.6	-
Incineration of waste	0.3	1.2	0.3	-
Mobile combustion	8.7	176.2	96.2	0.4
Road traffic	3.3	79.4	76.6	0.4
- Gasoline	1.0	48.9	72.0	0.4
-- Passenger cars	0.9	44.5	66.4	0.0
-- Light duty vehicles	0.1	3.9	5.0	0.0
-- Heavy duty vehicles	0.0	0.5	0.6	0.0
- Diesel	2.3	30.4	4.6	0.0
-- Passenger cars	0.2	1.0	0.3	0.0
-- Light duty vehicles	0.3	1.3	0.5	0.0
-- Heavy duty vehicles	1.8	28.0	3.8	0.0
Motorcycles, two-stroke engines, leisure boats, tractors and motor-driven tools	0.6	12.0	15.8	0.0
Railways	0.1	1.5	0.1	-
Air traffic	0.1	3.8	0.6	-
Ships and mobile drilling platforms	4.5	79.5	3.1	-
Non-combustion*	20.2	7.0	172.2	40.3
Oil and gas extraction and drilling	-	-	3.6	-
Loading of crude oil	-	-	104.7	-
Gas terminal and refineries	2.5	-	8.9	-
Gasoline distribution	-	-	8.9	-
Chemical production	5.1	1.0	0.9	0.4
Solvents	-	-	42.9	
Metal production	11.1	6.0	1.3	-
- Ferroalloys	7.3	5.1	1.3	-
- Aluminium	3.0	0.6	-	-
- Other metals	0.8	0.2	-	-
Paper and pulp	0.9	-	-	-
Mineral production	0.4	-	-	-
Other processes	0.3	-	0.9	-
Agriculture	-	-	-	39.9

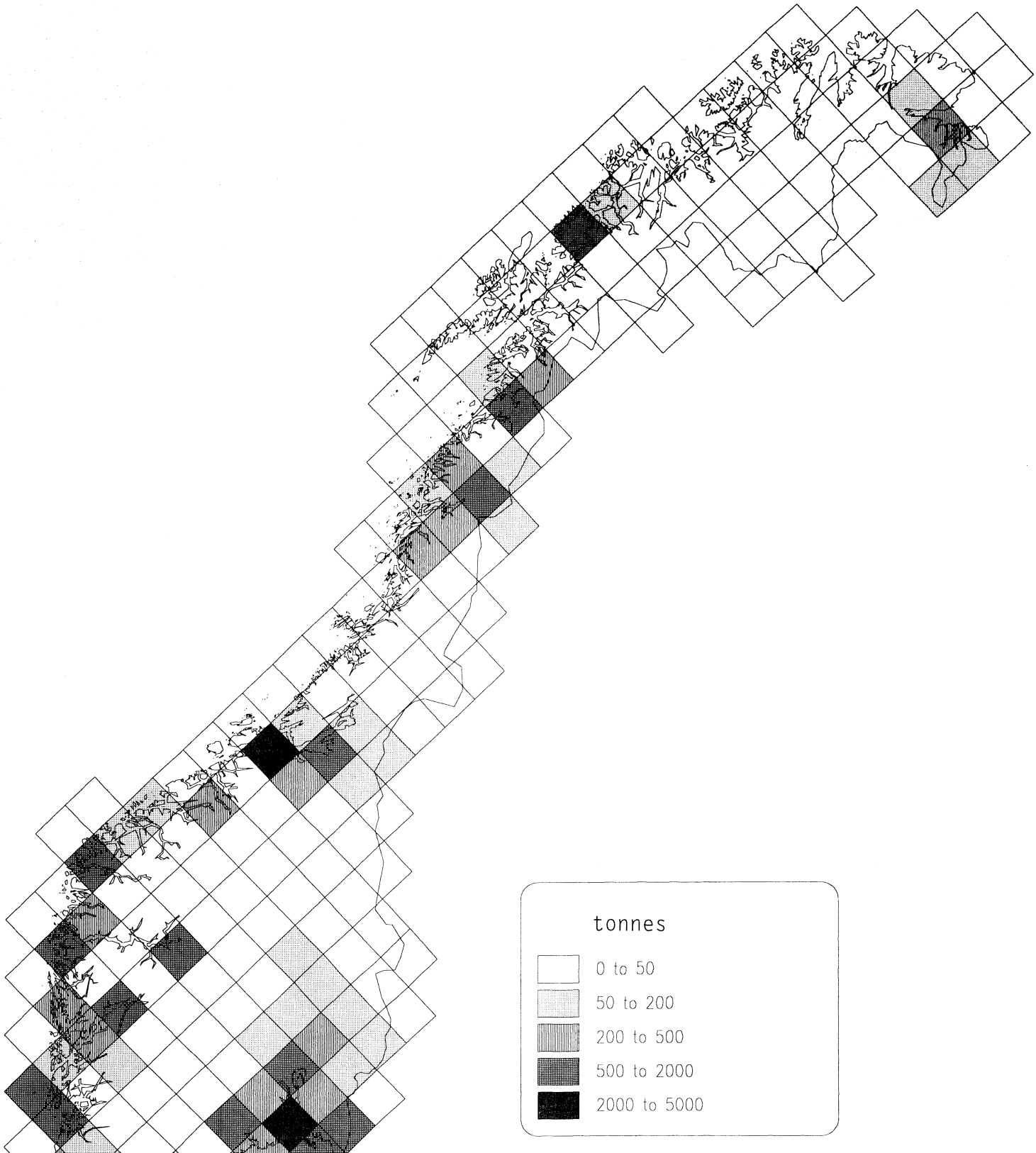
* Including fossil fuels used as raw materials and reducing agents
Sources: Statistics Norway and the State Pollution Control Authority

Figure 2.4. Emissions of SO_2, NO_x, NMVOC and NH_3 by source. 1992.



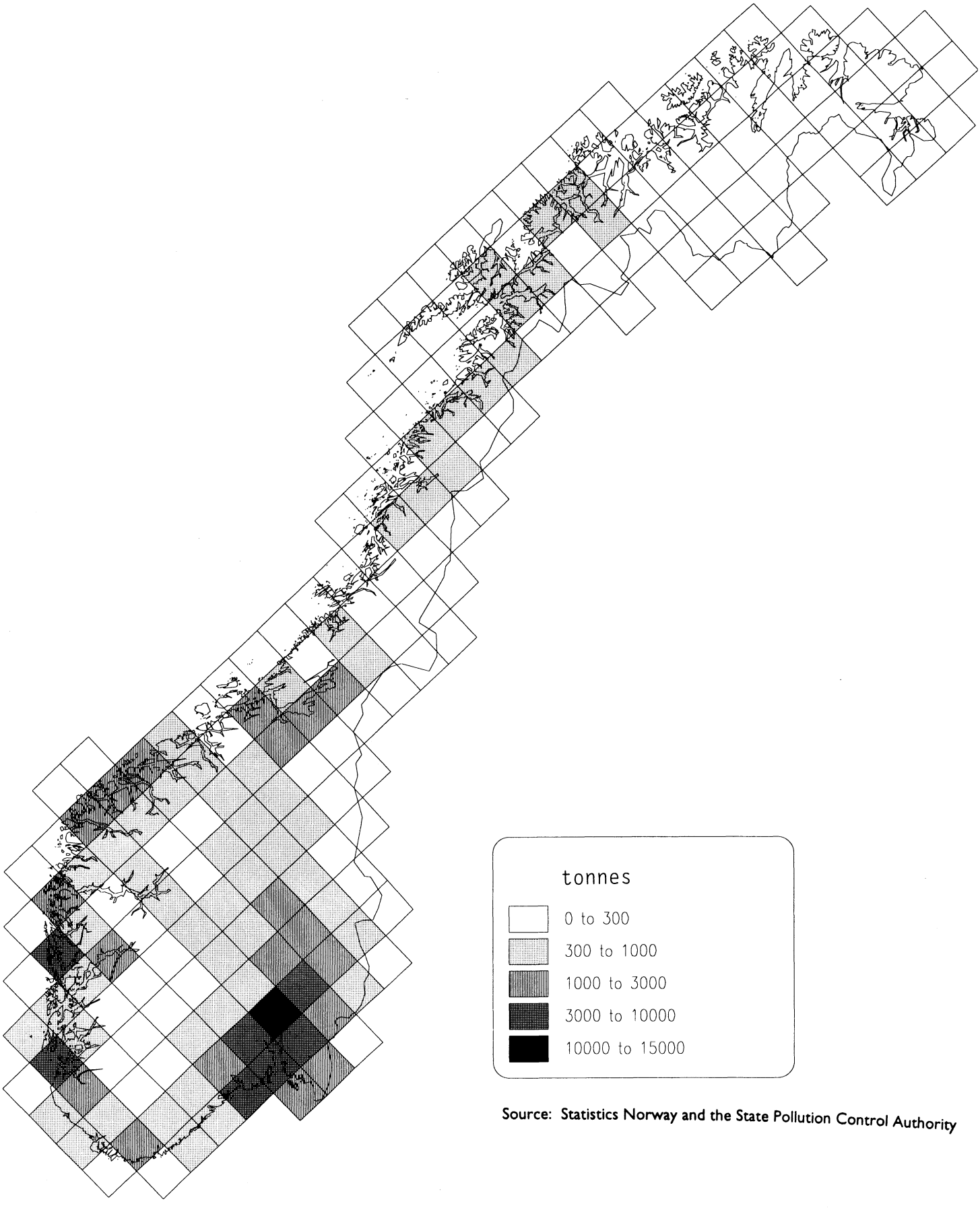
Sources: Statistics Norway and the State Pollution Control Authority

Figure 2.5. Emissions of SO_2 by EMEP grid square. 1992



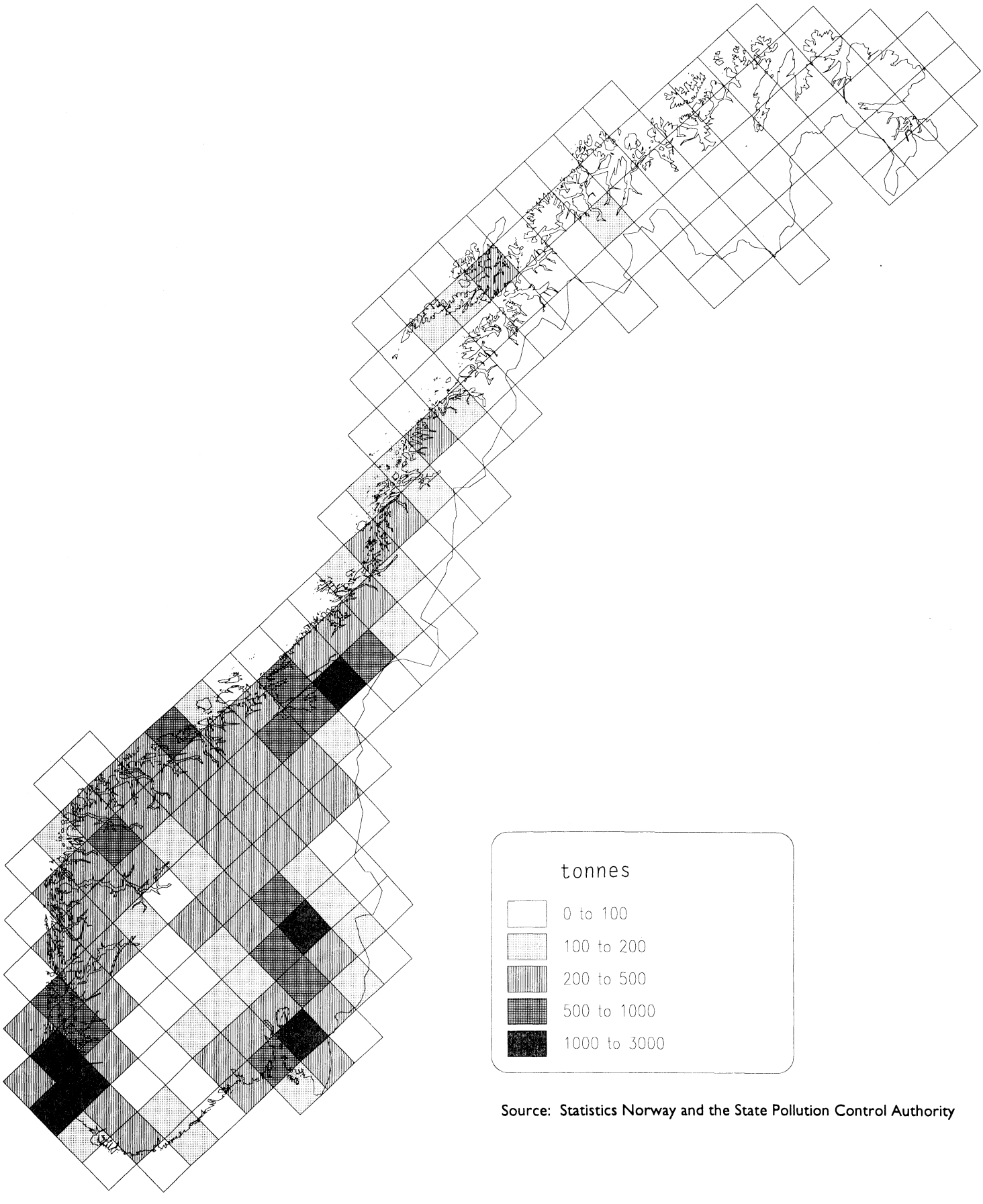
Source: Statistics Norway and the State Pollution Control Authority

Figure 2.6. Emissions of NO_x by EMEP grid square. 1992



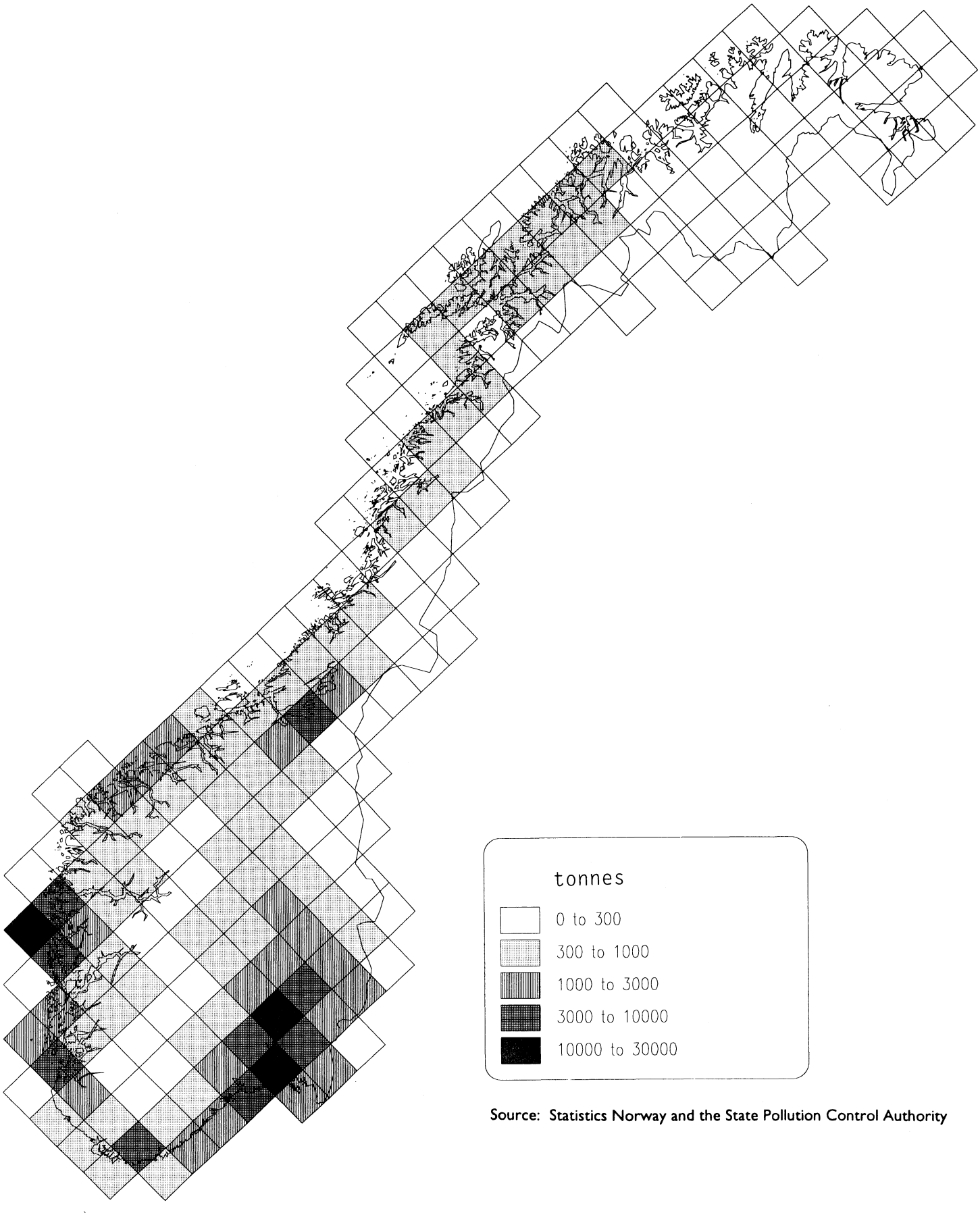
Source: Statistics Norway and the State Pollution Control Authority

Figure 2.7. Emissions of NH_3 by EMEP grid square. 1992



Source: Statistics Norway and the State Pollution Control Authority

Figure 2.8. Emissions of NMVOC by EMEP grid square. 1992



Source: Statistics Norway and the State Pollution Control Authority

3. Calculations of emissions to air

The structure of the Norwegian emission model will be introduced in section 3.1. The methodology, energy data and emission factors for calculating combustion emissions are reviewed in section 3.2. The sources and estimation methods for non-combustion emissions are described in section 3.3.

Emissions of most gases have been estimated since 1973 [3,4]. The model presented below is thoroughly described in [5] and [6], and has been used since the 1989 inventory.

3.1. The Norwegian emission model

3.1.1. Structure

The main activity data for estimating emissions to air is energy use. In the Norwegian energy accounts the consumption of different forms of energy is distributed between economic sectors. In order to calculate emissions to air, the energy consumption has to be distributed between the technical combustion sources as well (e.g. equipment). Hence, the energy account after this distribution may be viewed as a cube with three axes: fuels, sectors and sources.

The combustion emission factors for each pollutant depend on the fuels, sectors and technical sources. Hence, they may fit into a four-dimensional cube with pollutant as the 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, most of the cells will be empty (with no consumption), and many cells will use equal factors.

Thus, the Norwegian model for estimating emissions to air is constructed as a "cube" with four axes, see figure 3.1. The axes are emission carriers (e.g. fuels), economic sectors, technical sources and pollutants, respectively. The model is easy to understand with respect to emissions from combustion: A fuel (the emission carrier) is combusted in an equipment (the technical source) in a certain economic sector. For non-combustion activities the definition of emission carrier and source is less straightforward.

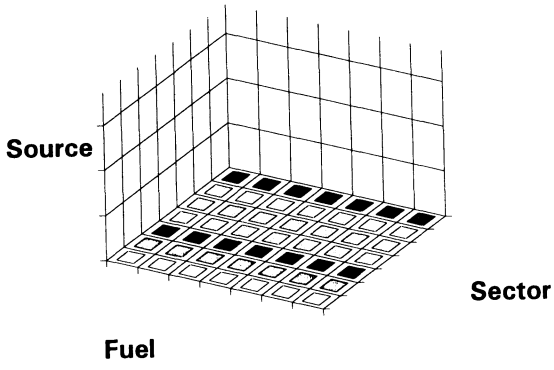
Information about the geographical distribution of emissions is useful for modelling and control purposes. The emission model has been developed to handle allocations to geographical units [6]. The municipalities (administrative counties), of which there are more than 400, are chosen as the smallest unit. The spatial distribution of emissions will introduce another dimension (axis) to the emission model. Emission factors may in principle be municipality spesific. Emissions are either allocated directly to the municipality (point sources) or distributed by surrogate statistical data.

The calculations take place in three steps:

- The combustion emission factors are multiplied by the energy consumption of the energy account, cell by cell, giving the calculated combustion emissions of each pollutant.
- Emissions of some pollutants are measured directly or determined from mass balances at major manufacturing plants (point sources). When such data are available it is possible to replace the calculated values.
- The non-combustion emissions are calculated by combining appropriate activity data with emission factors or by more complicated methods, they may be taken from current reports and investigations or they are directly measured. These emissions are added to the appropriate cells in the cube.

These steps are expressed mathematically in equation 3.1.

Figure 3.1. The cube model for calculating emissions to air. There will be one such cube for each pollutant and territorial unit.



Emissions are disaggregated in the cells in the cube. They may be aggregated by combining sources, sectors, emissions carriers and territorial units to fit various demands for reporting or analyses.

(3.1.)

$$E_{ijklm} = [C_{jklm} - CPS_{jklm}]*EF_{ijklm}+EPS_{ijkl}+ENC_{ijklm}$$

Where

E_{ijklm} = Emission of pollutant i from combustion of fuel j in source k in sector l in municipality m.

C_{jklm} = Consumption of fuel j in source k in sector l in municipality m.

CPS_{jklm} = Consumption of fuel j in source k in point sources in sector l in municipality m.

EF_{ijklm} = Emission factor for pollutant i from combustion of fuel j in source k in sector l in municipality m.

EPS_{ijklm} = Emission of pollutant i from combustion of fuel j in source k in point sources in sector l in municipality m.

ENC_{ijklm} = Non-combustion emission of pollutant i from emission carrier j in source k in sector l in municipality m.

The advantage of this model is that the calculation procedure is very straightforward. The emissions of all pollutants are calculated in a uniform manner. The cell structure gives very disaggregated data, with flexible possibilities for aggregation. Thus, emissions may be listed for a multitude of combinations of sectors, sources and fuels. Very detailed analyses of origins of emissions are possible, e.g. within a certain sector or for a particular pollutant, source, fuel or municipality. We have also calculated emission estimates useful for economical analyses without losing the accuracy of more technical approaches.

The main disadvantage is the difficulty in handling several dimensions and the size of the model.

3.1.2. Sources, sectors, emission carriers and components

The emission carriers used in the model are shown in box 3.1. Most of them are fuels. Some fuels also are used in non-combustion activities, e.g. extraction of coal. 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, but may be distinguished by sector.

Box 3.1. Emission carriers in the Norwegian emission model. Sources in brackets.

Emission carrier	Sources
Coal	[Combustion, Redox, Extraction, Transformation]
Coal coke	[Combustion, Redox]
Petrol coke	[Combustion, Redox, Carbide production]
Fuel wood, wood waste, black liquor	[Heating]
Natural gas	[Combustion, Flaring, Extraction]
Other gases	[Heating, Flaring, Transformation]
LPG (liquefied petroleum gas)	[Heating, Transformation]
Motor gasoline	[Road traffic, Boats, Motor equipment, Evaporation]
Aviation gasoline	[Air traffic]
Kerosene (heating)	[Heating]
Jet fuel (kerosene)	[Air traffic]
Auto diesel	[Road traffic]
Marine fuel	[Ships, Fishing vessels]
Light fuel oils	[Heating]
Special distillate	[Ships, Fishing vessels, Heating]
Heavy fuel oils	[Ships, Fishing vessels, Heating]
Waste	[Combustion, Bioprocesses, Transformation]
Crude oil	[Extraction, Oil loading, Transformation]
Nitrogen compounds/ products	[Fertilizer production, Bioprocesses]
Manure	[Bioprocesses]
Animals	[Bioprocesses]
Solvents	[Evaporation]
Article of food	[Bioprocesses]
Sulphur compounds	[Boiling, Redox]
Lime and Ca-compounds	[Liming, Transformation]
Clay	[Transformation]
Ore	[Redox, Transformation]

The model uses approximately 120 economic sectors. The classification is nearly identical to the one used in the National Accounts, which is aggregated from the NACE (rev. 1) classification. The high number of sectors is an advantage in dealing with important emissions from manufacturing industries. The disadvantage is an unnecessary disaggregation into sectors with very small emissions. 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 sector list is shown in appendix 1.

The technical sources used in the model are shown in box 3.2. Most of the sources are easily understood. Others are not meaningful if not connected to an emission carrier or sector. Only anthropogenic sources are covered.

Currently eleven pollutants are covered by this emission model. In addition to the gases to be discussed in this report (SO_2, NO_x, NMVOC and NH_3), emissions of CO_2, CH_4, N_2O, CO, Pb, Cd and airborne particles are calculated in a uniform manner.

Emissions are calculated for the more than 400 municipalities in mainland Norway, Svalbard, sea north of 62°N, sea south of 62°N and air space above 1000 metres.

3.1.3. Emission model for road traffic

A model for estimating emissions from road traffic has been developed [7]. The results (as average aggregated emission factors) from this model are given as input to the general emission model.

Choice of model

A fuel-based model has been chosen, where the total consumption of various fuels provides the framework for determining the emissions. The emission factors will depend on the kind of vehicle (weight and type of engine), technology, ageing, fuel type and driving mode. The total number of vehicle-kilometres driven does not enter the calculations directly. However, fractions of it are estimated for the listed parameters in order to distribute the fuel consumption, calibrated against the total fuel consumption, between these parameters. Emission factors may be given as emission per vehicle-kilometre or as emission per unit fuel consumed.

Box 3.2. Sources in the Norwegian emission model. Emission carriers in brackets.

Source	Emission carrier
Stationary combustion	
Direct fired furnaces	[Coal, Coke, Heavy oil, Gas]
Boilers	[Coal, Coke, Fuel oils, Kerosene, Gas, Wood etc.]
Small stoves	[Coal, Gasoline, LPG, Wood]
Gas turbines	[Gas, Marine diesel]
Flares	[Gas]
Fire	[Wood, Waste]
Mobile combustion	
Road traffic (several categories)	[Gasoline, Auto diesel]
Motorcycles	[Gasoline]
Mopeds and snow scooters	[Gasoline]
Two stroke boats	[Gasoline]
Four stroke boats	[Gasoline, Diesel]
Ships	[Marine diesel, Heavy oil]
Railway	[Diesel]
Air traffic (landing/ take-off)	[Jet fuel (kerosene), Aviation gasoline]
Air traffic (cruise)	[Jet fuel (kerosene), Aviation gasoline]
Motorized tools (two stroke)	[Gasoline]
Motorized tools (four stroke)	[Gasoline, Auto diesel]
Non-Combustion	
Oil loading (offshore)	[Crude oil]
Oil loading (on shore)	[Crude oil]
Fertilizer, ammonia and nitric acid production	[Nitrogen compounds/products]
Transformation	[Crude oil, Gas, LPG, Lime and Ca-compounds, Clay, Coal, Waste, Ore]
Bioprocesses	[Nitrogen compounds/products, Animals, Manure, Waste, Food articles]
Liming	[Lime and Ca-compounds]
Extraction	[Crude oil, Natural gas, Coal]
Evaporation	[Solvents, Gasoline]
Boiling	[Sulphur compounds, Ore]
Redox processes	[Sulphur compounds, Ore]
Calcium carbide production	[Petrol coke]
Silicon carbide production	[Petrol coke]

The total emission (Q) of pollutant *j* from combustion of fuel *k* while driving with a warm engine may be calculated from equation 3.2. or 3.3.

(3.2.)

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

(3.3.)

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

Where:
M_k is total fuel consumption
P_{ijk} is the emission factor [g/kg] of pollutant *j* from fuel *k* for the combination *i* of vehicle category/driving pattern
q_{ijk} is emission factor [g/km] of pollutant *j* from fuel *k* for combination *i* of vehicle category/driving pattern
T_{ik}/T_k is the fraction of vehicle-kilometres of fuel *k* for the combination *i* of vehicle category/driving pattern.
l_{ik} is the fuel consumption [kg/km]
l_k is the average fuel consumption (in kg/km) of fuel *k*, and is determined by

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

The fuel based model determines changes in emissions from one year to another from changes in M_k (the total fuel consumption) and changes in

- the number of vehicles in the various categories
- technologies in use
- annual average of kilometres driven per vehicle
- driving modes.

Parameters
The following variables are considered:

- All pollutants in the general Norwegian emission model
- Total fuel used for road traffic the current year. Fuels: Gasoline, diesel, LPG (propane) and natural gas
- Vehicle categories: 15 classes are considered combining fuels, weight and vehicle categories. See box 3.3.

  The number of vehicles in each class aids the distribution of vehicle-kilometres driven between each class.

Box 3.3. Vehicle categories for determining emissions from road traffic

Fuel	Category	Total weight	Duty weight
Gasoline	"Passenger car"	<3.5 t	<760 kg
"	Light duty	<2.7 t	>760 kg
"	Heavy light duty	2.7 - 3.5 t	>760 kg
"	Heavy duty	>3.5 t	..
"	Bus	>3.5 t	..
Diesel	"Passenger car"	<3.5 t	<760 kg
"	Light duty	<2.7 t	>760 kg
"	Heavy light duty	2.7 - 3.5 t	>760 kg
"	Light goods	3.5 - 10 t	..
"	Medium goods	10 - 20 t	..
"	Heavy goods	>20 t	..
"	Bus	>3.5 t	..
LPG	"Passenger car"	<3.5 t	<760 kg
"	Bus	>3.5 t	..
Natural gas	Bus	>3.5 t	..

- Technology classes: Emission estimates are made from the distribution of vehicles between age classes within each vehicle class. The technology class is determined from the year of registration and the vehicle class. It is corrected for changes in emissions due to ageing of the vehicles.
- Average annual mileage for the various vehicle categories: Aids the distribution of vehicle-kilometres driven between the different classes.
- Average annual mileage distributed beween the vehicle age classes within each vehicle class.
- Driving modes: Four ways of driving are considered:

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

  NB! The driving pattern does not tell where the driving actually takes place. E.g. we name it urban driving outside an urban area if the speed limit is less than 50 km/h.

- Fuel consumption factors: The average fuel consumption (per km) depends on vehicle category, technology class, ageing of the vehicle and driving mode.
- Emission factors: Emission factors expressed as g/km or g/kg fuel depend on vehicle category, technology class, ageing of the vehicle and driving pattern.
- Ageing: Emission factors and fuel consumption factors are corrected to take into account that the values will change as the vehicle is ageing.

- Cold start emissions: Driving with a cold engine the emissions, of particularly CO and NMVOC, will in most instances be higher than if it was hot. The difference in emission is called cold start emission. The emissions are calculated as an additional emission contribution per start. Thus, the actual number of trips starting with a cold engine has to be determined. The cold start emissions depend on vehicle category and technology class.
- NMVOC-evaporation from gasoline vehicles: Emissions from running losses, hot soak emissions and daily emissions are taken into account. Average emission factors have been calculated, taking Norwegian climatic conditions into account. The emission factors depend on vehicle category and technology class.

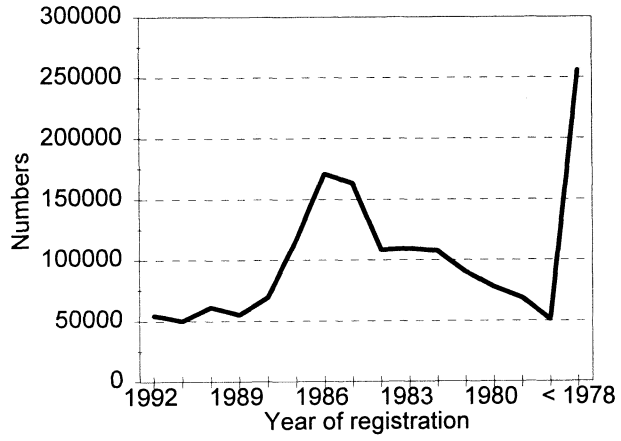
Sources of data

All data are, as far as possible, changed for every year of inventory. Some of them are, however, based on assumptions.

- Total fuel consumption: The total amounts of fuels consumed are corrected for off-road use (small boats, snow scooters, motorized tools etc.). This consumption is estimated either from assumptions on the number of units, annual operation time and spesific fuel consumption or from assumptions and investigations on the fraction of consumption within each sector for non-road traffic applications.
- Number of vehicles: The number of vehicles in the various vehicle categories is taken from the official register in the Norwegian Directorate of Public Roads.
- Average annual mileages for the various vehicle categories: Most are determined from surveys in Statistics Norway or TI (Institute of Transport Economics). In some instances assumptions are needed.
- Ageing: The age of the vehicles is given directly from the vehicle register. The average annual mileage driven will decrease as the vehicle age increases. Surveys from Statistics Norway, combined with some assumptions give this distribution.
- Driving pattern: The Directorate of Public Roads has data on the annual number of vehicle-kilometres driven on national and provincial roads. These data are distributed between speed limits and roughly between vehicle sizes. Similar data exist for municipal roads in the ten largest cities. The same distribution is assumed on the remainder municipal roads.
- Annual number of trips (for the calculation of cold start emissions): TI (Institute of Transport Economics) has determined the number of trips per vehicle. We have assumed that 2/3 of these trips start with a cold engine.
- Average temperature: This parameter is needed for the estimation of emissions from cold starts and NMVOC evaporation. An annual average of 6.0°C has been chosen for Norway.
- Emission factors and fuel use factors: See section 3.2.2.

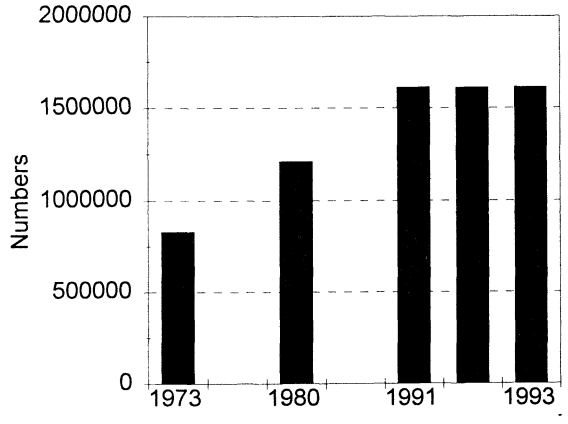
Some basic data applied in the calculations for 1992 are shown in appendix 2. The age profile of the Norwegian passenger cars in 1992 is shown in figure 3.2. The sale of new cars has been quite low the last years. Hence, the percentage of cars equipped with a three way catalyst was relatively low in 1992 (12 percent). However, this fraction had increased to 16 per cent in 1993. The sale of new cars is currently somewhat increasing.

Figure 3.2. Age distribution of passenger cars in 1992.



Source: The Directorate of Public Roads

Figure 3.3. Total number of passenger cars. 1973, 1980 and 1991-1993



Source: The Directorate of Public Roads

3.2. Emissions from combustion

3.2.1. Energy data

Norway has two ways of presenting official energy data. The energy balance shows production, transformation, import, export and consumption of energy in Norway. It has an aggregated classification of energy consumption by purpose. The energy balance follows international guidelines and is reported to OECD and UN. The energy account is based on the energy balance, but the figures are corrected for Norwegian consumption abroad and foreign consumption in Norway; it is supposed to cover Norwegian economical activity. Furthermore all use of energy, also energy for transport, is distributed between the actual consuming sectors. The energy balances and energy accounts for 1992 are shown in appendix 3 and 4, respectively.

The energy figures for calculating emissions to air are based on the energy accounts. Hence, the calculated emissions cover all Norwegian activity. However, the calculated emissions may, if necessary, be corrected to correspond with international guidelines as determined by ECE or IPCC/OECD [8]. E.g. emissions from fuel consumed as bunkers in foreign ship traffic or in air transport abroad are calculated, but are subtracted before reporting. The energy accounts also include fuels consumed as raw materials or reducing agents. This consumption is subtracted before calculating the combustion emissions. Emissions from fuel used as raw materials or reducing agents are treated as non-combustion emissions.

The energy balance and accounts use several data sources. The Norwegian Petroleum Institute (NP) in collaboration with Statistics Norway makes an official sales statistics for liquid commercial fuels. The sales statistics give reliable figures for total consumption in Norway. For some sectors, especially air transport and fishing, the consumption in the energy accounts will diverge from the energy balance and sales statistics. Overall consumption in these sectors has to be determined by special surveys.

About half of the energy consumed for inland use in Norway is electricity made from hydropower. The fractions of various sources of energy used in inland Norway in 1976 and 1992 are shown in figure 3.4.

Solid fuels

Coal or oil fired power plants do not have any importance in Norway. Coal and coke are mainly consumed in manufacturing industries. The most important applications are as reducing agents in metal production and as raw materials in the production of carbides. In addition, there is a small consumption in greenhouses and private households. The figures for these sectors are uncertain. Wood is an important source of energy in Norway. The data for the most important consumers are determined in special investigations. The consumption in private households is determined in yearly sample surveys. About 8 per cent of the energy used in private households is wood. About half of the households has a wood fuel stove and one third an open fireplace. In farmhouses, wood is still the most important source of heating in Norway. The consumption in manufacturing industry is reported from an industry organisation (black liquor) or determined from surveys (wood waste). Waste is partly included in the energy balance and accounts. The mass of waste combusted in large plants is reported to the State Pollution Control Authorities (SFT) and Statistics Norway each year. SFT and Statistics Norway also have made an estimate of the mass combusted in smaller waste combustion plants. A fraction of the methane gas produced from solid waste is utilised as energy or flared.

Gaseous fuels

Gas is burned in the manufacturing industries only. The volume of natural gas utilised and flared in the oil and gas sector is reported to the Norwegian Petroleum Directorate. Most of the energy used in this sector is natural gas, but there is in addition a consumption of diesel for stationary use. The figures include consumption on all platforms in the Norwegian part of the continental shelf and the Norwegian economic part of the platforms shared with the United Kingdom. The oil refineries consume mainly refinery gas. A fraction of this gas is also flared. Some large industrial plants use a petrochemical excess gas which is composed of mainly methane and hydrogen. Liquefied gas is used as raw material for manufacture of plastics and ammonia. A small amount is combusted in private households.

Liquid fuels

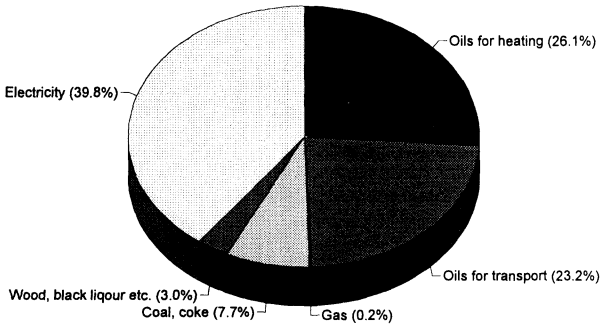
8 per cent of the inland consumption of energy in 1992 was oils for residential, commercial or process heating. Oils for transport amount to a quarter of the inland energy use. The largest fraction of this is marine gas oil (mainly used in ships and fishing vessels), followed by gasoline and diesel for road transport

The figures on production and transformation of commercial fuels are reported to Statistics Norway by the appropriate industry. Production of crude oil and natural gas is reported to the Norwegian Petroleum Directorate. The figures include production on all platforms in the Norwegian part of the continental shelf and the Norwegian economic part of the platforms shared with the United Kingdom. Import, export and changes in stock are taken into account as well to estimate the consumption.

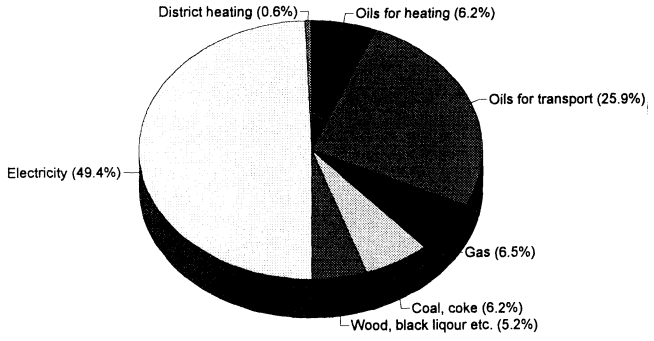
All major manufacturing plants report their consumption of all forms of energy directly to Statistics Norway each year. Energy used as fuel and energy used as raw materials or reducing agents are reported separately.

Figure 3.4. Inland energy consumption in Norway (including energy used as raw materials). Distribution between energy sources. a) 1976 and b) 1992. The total inland energy consumption was 607 PJ in 1976 and 725 PJ in 1992.

a) 1976



b) 1992



Source: Statistics Norway

The total consumption from which the emissions in 1992 are calculated and the theoretical energy content of fuels are shown in table 3.1.

Due to the increasing level of activity in the North sea (figure 3.5.), the volume of natural gas combusted has increased steadily the last years (figure 3.6.). However, the volume combusted per unit production has decreased. The level of flaring of natural gas has been relatively stable, but decreasing the last years.

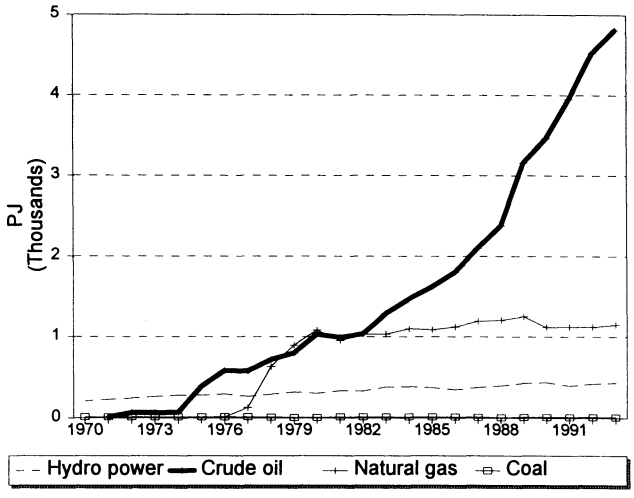
The total inland energy consumption has overall increased the last 20 years. However, since 1987 there has been a slight decrease (figure 3.7.). Throughout the last 20 years consumption of oils has been substituted by consumption of electricity. The reduction in use of

Table 3.1. Energy consumption for calculating emissions to air from combustion. 1992. Energy content of fuels. Net heating values unless otherwise specified.

Energy	Consumed[a]	Unit	Energy content	Unit
Coal[b]	182	ktonnes	28.1	TJ/ktonnes
Coal coke	11	ktonnes	28.5	TJ/ktonnes
Petrol coke	7	ktonnes	35.0	TJ/ktonnes
Wood etc.	2398	ktonnes		
- Fuel wood			16.8	TJ/1000 tonnes[c]
- Black liquor			14.0	TJ/1000 tonnes[c]
- Wood waste			16.8	TJ/1000 tonnes[c]
Waste	411	ktonnes	10.5	TJ/ktonnes
Gasoline, cars	1696	ktonnes	43.9	TJ/ktonnes
Gasoline, aviation	3	ktonnes	43.9	TJ/ktonnes
Kerosene, heating	152	ktonnes	43.1	TJ/ktonnes
Kerosene, jet[d]	337	ktonnes	43.1	TJ/ktonnes
Auto diesel	1162	ktonnes	43.1	TJ/ktonnes
Marine fuel	1056	ktonnes	43.1	TJ/ktonnes
Heating oils, light	603	ktonnes	43.1	TJ/ktonnes
Special distillates	137	ktonnes	43.1	TJ/ktonnes
Heavy oil	242	ktonnes	40.6	TJ/ktonnes
Crude oil	-		43.0	TJ/ktonnes
Refinery gas	630	ktonnes	48.6	TJ/ktonnes
Refinery gas (flaring)	61	ktonnes	48.6	TJ/ktonnes
LPG	55	ktonnes	46.1	TJ/ktonnes
Excess gas	234	ktonnes	56.4	TJ/ktonnes
Natural gas	2585	mill.Sm^3	40.8[e]	TJ/mill.Sm^3
Natural gas (flaring)	308	mill.Sm^3	40.8[e]	TJ/mill.Sm^3
Landfill gas	6.9	ktonnes	50.2	TJ/ktonnes

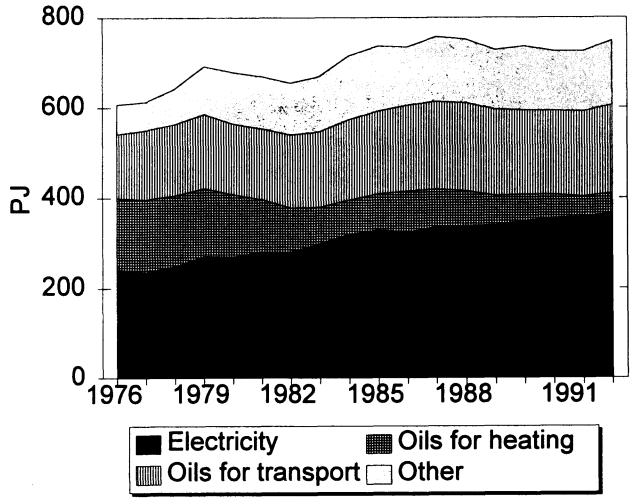
a Combustion only. Excluding bunkers. b Hard coal. c Dry solid fuel. d Consumption of Norwegian aircraft in Norway, all phases of the flight.
e Average gross heating value, 1992

Figure 3.5. Production of energy in Norway. 1970-1993. PJ.



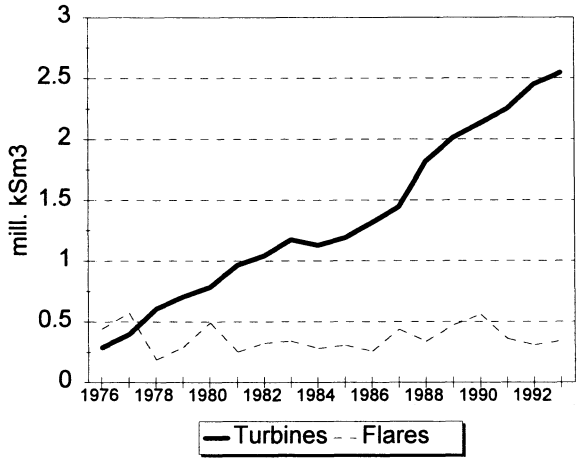
Source: Statistics Norway

Figure 3.7. Inland use of energy in Norway. 1976-1993. PJ.



Source: Statistics Norway

Figure 3.6. Combustion and flaring of natural gas in the Norwegian part of the North Sea. 1976-1993. Billion Sm^3.



Source: Norwegian Petroleum Directorate

oils for heating has been about 70 per cent in the period 1976-1993. Consumption of heavy fuel oil has been reduced as much as 85 per cent in the same period. The consumption of gasoline has decreased since 1989, while there has been an increase in consumption of auto diesel.

In order to calculate the emissions of most pollutants we need to differentiate between various technologies of combustion. Within each economic sector the consumption of each fuel is distributed between the technical sources available in the model. The distribution is based on knowledge of the activities in the sectors or, if necessary and possible, on special calculations or surveys. The fuels gasoline, auto diesel and marine gas oil are generally used for transport. Marine gas oil is also used on drilling and extraction platforms (stationary combustion). The consumption of gasoline and auto diesel has to be distributed between motorized tools and various kinds of road traffic with the aid of calculations (see section 3.1.3). Heavy oil is used in ships in the transport, fishing and extraction sectors. Solid fuels and kerosene are combusted in small stoves in private households. Coal, coke and heavy fuel oil are combusted in direct fired furnaces in certain industries, e.g. metal and cement production. Light fuel oil is generally combusted in boilers.

3.2.2. Emission factors

SO_2

The emission factors used in 1992 are shown in table 3.2. The sulphur content of liquid fuels are collected by the Norwegian Petroleum Institute. All values are updated annually. The sulphur content of most fuels has been reduced the last 20 years (figure 3.8.). For solid fuels (coal, coke or black liquor) used in the major large industrial plants, plant specific average annual values are used. For other use of solid fuels we apply the values in table 3.2. every year. In gases and liquefied gases there are not significant amounts of sulphur. 100% emission is assumed, except in the largest industrial plants and for combustion of coal and coke generally. In these cases the emissions may be reduced due to absorption of sulphur in ash or products, or control. In the production process of cement 98% absorption is assumed, while about 30% is assumed for concrete pumice stone. For use of coal and coke generally (except for manufacture of cement and concrete pumice stone) normally 3% absorption in ash is assumed [9]. Emissions are controlled in some of the larger plants, e.g. paper and pulp industries and refineries. In these cases emission estimates are based on measurements and not on emission factors.

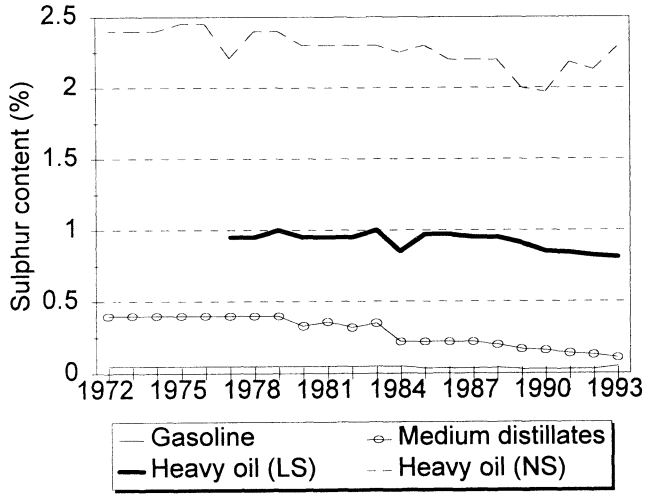
NO_x and NMVOC:

The emission factors will depend on the sector/source combination. The emission factors applied for the year 1992 are shown in tables 3.6. and 3.7. for NO_x and NMVOC, respectively. With a few exceptions, described below, they are taken from reference [9].

Table 3.2. Emission factors, SO_2 from combustion. kg SO_2/tonne fuel. 1992.

	kg SO_2/tonne
Coal, industry	16.0
Coal, private	20.0
Coal coke	18.0
Petrol coke	18.0
Wood	0.37
Waste	1.4
Gasoline	0.6
Gasoline (aviation)	0.4
Kerosene (heating)	0.32
Jet fuel (kerosene)	0.32
Auto diesel	2.6
Marine gas oil	2.6
Light heating oils	2.6
Special distillates	4.4
Heavy oil (LS = Low Sulphur)	16.4
Heavy oil (NS = Normal Sulphur)	42.6
Natural gas	0.0
LPG	0.0
Refinery gas	0.0
Excess gas	0.0
Landfill gas (methane)	0.0

Figure 3.8. Sulphur content of liquid commercial fuels. 1972-1993. Per cent by weight.



Source: Norwegian Petroleum Institute

Oil and gas extraction and drilling

Emission factors have been derived from measurements [10] coordinated by the Norwegian Oil Industry Association (OLF). The sources considered are combustion of natural gas in 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 use of natural gas is not feasible. Gas is flared on production platforms. In well testing, the collected oil and gas will be incinerated due to lack of transport facilities. However, the NO_x emissions from this source were 100 tonnes only and NMVOC emissions ignorable in 1992. The emission factors for all sources are given in table 3.3.

Aviation

Emission factors are derived from a study performed by the Norwegian Institute for Air Research (NILU) [11]. Emissions per unit of fuel consumed are calculated for landing/takeoff (emissions under 1000 metres above the ground) and cruise (over 1000 meters above the

Table 3.3. Emission factors for NO_x and NMVOC from combustion and flaring in the oil and gas extraction sectors.

	Unit	NO_x	NMVOC
Gas turbines-natural gas	kg/kSm^3 gas	6.27	0.23
Gas turbines -diesel	kg/tonne diesel	16.0	0.03
Diesel engines	kg/tonne diesel	70.0	5.00
Flaring	kg/kSm^3 gas	12.0	0.06
Well testing	kg/tonne oil	3.7	0.99

Sources: State Pollution Control Authority, Norwegian Oil Industry Association

Table 3.4. Emission factors for NO_x and NMVOC from aviation. kg/tonne fuel.

	NOx	NMVOC
Landing/takeoff	10.8	3.9
Cruise	8.6	0.6

Sources: NILU, Statistics Norway

ground). The fraction of fuel (jet kerosene) used for landing/takeoff is derived from the same study. The emission factors are shown in table 3.4.

Ships
Emission factors are derived by Marintek [12]. These emission factors are applied for all ships and fishing vessels, regardless of fuel (diesel or heavy oil) and driving mode.

NO_x: 70 kg/tonne fuel
NMVOC: 2.5 kg/tonne fuel

The methodology will be revised in the near future.

Residential fuel wood combustion
The emission factor for NMVOC from residential fuel wood combustion, 6.9 kg NMVOC/tonne wood, has been derived from a study performed by NILU [13]. Formaldehyde is not included in this emission factor.

Two stroke engines
An emission factor of 314 kg NMVOC/tonne gasoline has been derived for all two stroke engines [14].

Offroad machinery
Emission factors have been collected and assessed in [15]. For each sector average emission factors are given as emissions per unit fuel used (table 3.5.). The amount of fuel used has been determined in sample surveys, assumed or calculated from the activity level.

The choice of emission factors and fuel consumption factors for road traffic are explained in reference [7].

Table 3.5. Emission factors for NO_x and NMVOC for offroad machinery. kg/tonne fuel.

	NOx	NMVOC
Agriculture	54	7.2
Forestry	52	5.7
Construction	46	3.8
Mining	48	4.8
Military services	48	4.8
Railway	47	4.0

Sources: State Pollution Control Authority, Technological Institute

Data are determined from driving cycles. Measurements have been performed in Norway, or in Sweden, Germany, EU (Corinair) or USA. NMVOC emission factors are derived from VOC data, applying results from measurements on NMVOC to methane ratios. As far as possible values representative for the situation in Norway have been chosen. Ageing has been taken into account by introducing ageing factors for emission factors and fuel consumption factors. The basic factors are shown in appendix 5.

NH_3:
Except from road traffic, no combustion emissions are estimated.

Table 3.6. NO_x, emission factors, kg/tonne fuel. 1992

Source/Sector	Coal	Coal coke	Petrol coke	Wood etc.	Natural gas	Other gas	LPG	Gasoline (cars)	Gasoline (aviation)	Kerosene (heating)	Kerosene (aviation)	Diesel (road transport)	Marine diesel	Light fuel	Special distillates	Heavy oil
Direct																
Generally		20			7	5.4							70		5	5
Cement	16	20	20												24	24
Brick	16														9.5	9.5
Turbines																
Generally					8.0	8										
Oil and gas extraction					7.4	8							16			
Flaring																
Generally					8.0	7										
Oil and gas extraction					14.1	7										
Refineries						7										
Landfills						0.0										
Boilers																
Generally	3	3		0.9		3				3				2.5	2.5	4.2
Industry	4.5	3.4	3.4	0.9	3	3	2.3			3				3	3	5
Chemical	4.5	3.4	3.4	0.9	3	2.9	2.3			3				3	3	3
Metals	4.5	3.4	3.4	0.9	3	2.9	2.3			3				3	3	3
Private														2.5		4.2
Landfills						0.0										
Small stoves																
Generally	3	3		0.7						2.5				2.5	2.5	
Private	1.4	1.4		0.7			2.3			2.5						
Passenger cars[1]								29.3				11.6				
Vans[1]								36.2				12.1				
Heavy duty[1]								35.5				40.2				
Railway												47				
Aviation, LTO									10.8		10.8					
Aviation, cruise									8.6		8.6					
Motorcycles								7.0								
Mopeds								2.8								
Boat, 2 stroke								1								
Boat, 4 stroke								19								
Ships																
Generally													70	70	70	70
Drilling													70			65
Tools, 2 stroke								2								
Tools, 4 stroke																
Generally								19				50				
Agriculture												54				
Forestry												52				
Mining												47				
Quarrying												48				
Construction												46				
Railway												47				
Military services												48				

[1] Average values

Table 3.7. NMVOC, emission factors, kg/tonne fuel

Source/Sector	Coal	Coal coke	Petrol coke	Wood etc.	Natural gas	Other gas	LPG	Gasoline (cars)	Gasoline (aviation)	Kerosene (heating)	Kerosene (aviation)	Diesel (road transport)	Marine diesel	Light fuel	Special distillates	Heavy oil
Direct																
Generally	0	0	0		0	0							5		0.3	0.3
Cement	0	0	0												0	0
Brick	0														0.9	0.9
Refineries						0.1										
Turbines																
Generally					0.3	0.3										
Oil and gas					0.3	0.3							0.03			
Gas terminal					0.5	0.3										
Flaring																
Generally					2.2	0.3										
Oil and gas					0.0	0.3										
Refineries					2.2	13.5										
Landfills						0.0										
Boilers																
Generally	1.1	0.6		1.3			0.1			0.4				0.4	0.4	0.3
Industry	0.8	0.6	0.6	1.3	0.1	0.1	0			0.4				0.4	0.4	0.3
Paper and pulp	0.8	0.6	0.6	0	0.1	0.1	0			0.4				0.4	0.4	0.3
Chemical	0.8	0.6	0.6	1.3	0.1	0	0			0.4				0.4	0.4	0.3
Metals	0.8	0.6	0.6	1.3	0.1	0	0			0.4				0.4	0.4	0.3
Refineries	0.8	0.6	0.6	1.3	0.1	0.1	0			0.4				0.4	0.4	0.3
Landfills						0.0										
Private														0.6	0.6	0.3
Small stoves																
Generally	1.1	0.6		6.9						0.4				0.4	0.4	
Private	10	0.6		6.9			0.1			0.6						
Passenger cars[1]								43.6				3.6				
Vans[1]								46.4				4.3				
Heavy duty[1]								44.9				5.4				
Railway												4				
Aviation, LTO									3.9		3.9					
Aviation, cruise									0.6		0.6					
Motorcycles								135.8								
Mopeds								376.7								
Boat, 2 stroke								314.3								
Boat, 4 stroke								12				27				
Ships																
Generally													2.5	2.5	2.5	2.5
Drilling													5		6.4	6.4
Tools, 2 stroke								314.3								
Tools, 4 stroke																
Generally								12				6		6		
Agriculture												7.2		7.2		
Forestry												5.7		5.7		
Mining												4		4		
Quarrying												4.8		4.8		
Construction												3.8		3.8		
Railway												4.0		4		
Military services												4.8		4.8		

[1] Average values

3.2.3. Emission rates from combustion

The emissions are calculated as described in section 3.1.1. and 3.1.3. (road traffic). The unit of energy is usually ktonnes, and the unit of emission factors is tonnes emission/tonne fuel. An exception is the combustion of natural gas, for which emissions are calculated from consumption measured in kSm^3. Because of the large consumption of natural gas, small inaccuracies in conversion factors may lead to serious errors. The emissions by fuel, main sector and source are shown in tables 3.8, 3.9, and 3.10, respectively.

Table 3.8. Emissions from combustion by fuel. 1992. ktonnes *

	SO_2	NO_x	NMVOC	NH_3
Total	17.0	213.4	106.6	0.4
Coal	0.9	2.6	0.1	-
Coke from coal	0.1	0.0	0.0	-
Petrol coke	0.0	0.1	0.0	-
Wood, black liquor	1.4	2.0	7.8	-
Waste	0.3	1.2	0.3	-
Natural gas	0.0	19.5	0.6	-
Other gas	0.0	3.6	0.9	-
LPG	0.0	0.1	0.0	-
Gasoline (cars)	1.0	49.1	86.5	0.4
Gasoline (aviation)	0.0	0.0	0.0	-
Kerosene (heating)	0.0	0.4	0.1	-
Kerosene (aviation)	0.1	3.8	0.6	-
Diesel (road)	3.0	43.8	6.1	0.0
Marine fuel	2.8	73.8	3.0	-
Light heating oil	1.8	1.6	0.3	-
Special distillates	0.9	5.6	0.2	-
Heavy oil	4.6	5.9	0.2	-

* Emissions from coal and coke used as reducing agents in metal production are not included

Sources: Statistics Norway and State Pollution Control Authority

Table 3.9. Emissions of SO_2, NO_x, NMVOC and NH_3 from combustion by main sector. 1992. ktonnes

	SO_2	NO_x	NMVOC	NH_3
Stationary combustion	8.3	37.2	10.4	-
Energy sectors	1.1	27.9	2.1	-
Agriculture, forestry and fisheries	0.2	0.1	0.0	-
Manufacturing and mining	5.3	6.9	0.6	-
Services	0.7	0.7	0.1	-
Private households	1.0	1.5	7.5	-
Mobile combustion	8.7	176.2	96.2	0.4
Energy sectors	0.5	10.0	0.5	0.0
Agriculture, forestry and fisheries	1.5	35.8	3.5	0.0
Manufacturing and mining	0.4	10.2	1.2	0.0
Services	5.3	81.7	21.6	0.1
Private households	0.9	38.6	69.4	0.3

Sources: Statistics Norway and State Pollution Control Authority

Table 3.10. Emissions of SO_2, NO_x, NMVOC and NH_3 from combustion by source. 1992. ktonnes.

	SO_2	NO_x	NMVOC	NH_3
Total combustion	17.0	213.4	106.6	0.4
Stationary	8.3	37.2	10.4	-
Oil and gas extraction	0.2	23.4	0.9	-
--Natural gas	0.0	15.4	0.6	-
--Flaring	0.0	3.8	0.0	-
--Diesel	0.2	4.2	0.3	-
Oil refineries/gas terminal	0.1	3.4	0.9	-
Other manufacture	5.8	7.0	0.7	-
Non-manufacture	0.9	0.7	0.1	-
Households	1.0	1.5	7.5	-
Incineration of waste	0.3	1.2	0.3	-
Mobile	8.7	176.2	96.2	0.4
Road traffic	3.3	79.4	76.6	0.4
-Gasoline	1.0	48.9	72.0	0.4
-- Passenger cars	0.9	44.5	66.4	0.4
-- Light duty	0.1	3.9	5.0	0.0
-- Heavy duty	0.0	0.5	0.6	0.0
-Diesel	2.3	30.5	4.6	0.0
-- Passenger cars	0.2	1.0	0.3	0.0
-- Light duty	0.3	1.3	0.5	0.0
-- Trucks and buses	1.8	28.1	3.8	0.0
Motorcycles	0.0	0.1	1.0	0.0
Mopeds, snow scooters	0.0	0.0	4.3	0.0
Leisure boats	0.0	0.0	8.8	-
Motorized tools	0.6	11.9	1.8	0.0
-Diesel	0.6	11.9	1.4	0.0
-Gasoline	0.0	0.0	0.4	-
Railways	0.1	1.5	0.1	-
Aviation	0.1	3.8	0.6	-
- <1000m	0.0	1,0	0.4	-
- >1000m	0.1	2.8	0.2	-
Ships and boats	4.5	79.5	3.1	-
- Coastal traffic	3.1	46.4	1.7	-
- Fishing vessels	1.1	27.7	1.0	-
- Mobile oil drilling	0.2	5.4	0.4	-

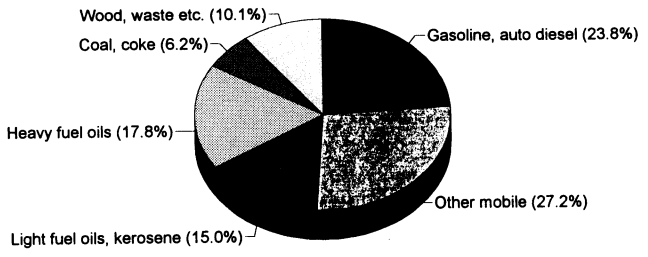
Sources: Statistics Norway and State Pollution Control Authority

Trends in combustion emissions:

The *SO_2* emissions have decreased since 1980 due to less consumption of oils (particularly heavy oil) for heating purposes (increased use of electricity generally, sulphur tax on fuels and mild winters the last few years), reduced sulphur content of fuels, increased use of abatement techniques at industrial plants and close down of some particularly polluting plants.

The *NO_x* emissions have increased since 1973 due to increased road traffic and combustion of natural gas in the North Sea. The last few years, however, catalytic converters in gasoline driven cars, reduced consumption of gasoline and reduced flaring in the North Sea have caused a decrease.

Figure 3.9. Emissions of SO_2 from combustion by fuel. 1992.



Sources: Statistics Norway and State Pollution Control Authority

The *NMVOC* emissions are dominated by the trends in road traffic (gasoline driven cars); an increase since 1973. A decrease in emissions the last few years is mainly caused by control of emissions from gasoline driven cars and decreased consumption of gasoline.

3.3. Non-combustion emissions

The Norwegian emission inventory covers, in addition to SO_2, NO_x, NMVOC and NH_3, emissions of CO_2, CH_4, N_2O, CO, Pb, Cd and airborne particles from extraction of oil, gas and coal, oil refineries, agriculture, liming, municipal solid waste, evaporation of gasoline and solvents, fermentation, ores and manufacture. Emission sources from manufacture include the production processes of fertilizers, plastic, sulphuric acid, paper and pulp, titanium dioxide, silicon carbide, calcium carbide, explosives, mineral wool, cement, concrete pumice stone, prebaked anodes, ferroalloys, silicon metal, aluminium, magnesium, zinc and nickel. The emission sources of relevance for the pollutants considered in this report will be presented in the following sections.

All emissions from use of coal and coke as reducing agents and liquefied gas for ammonia (hydrogen) production are defined as non-combustion emissions.

3.3.1. Oil and gas extraction and drilling

Extraction of crude oil and natural gas is a source of emissions of NMVOC (and methane). NMVOC emissions from turbines and flares are calculated as described in section 3.2.

Test drilling (pre-production), production and transportation are activities that have to be considered. Cold vent is direct, controlled emissions of VOC to the atmosphere. For various reasons these emissions cannot yet be avoided. However, the oil companies will of economic reasons keep these emissions as small as possible when it is possible to sell the natural gas. Natural gas from oil fields without pipelines is mainly flared instead of cold vented. There are also many smaller sources of direct, uncontrolled emissions. We classify these as fugitive emissions. Gas is transported in pipelines. Crude oil may be transported by ships as well. The emissions from pipelines are usually small, and they are included in the fugitive emissions. We do not have any inland pipelines for natural gas in Norway. Loading of crude oil for transportation by ships, offshore and at land terminals, is an important VOC source.

The Norwegian Oil Industry Association (OLF) has made a thorough report on emissions from oil and gas extraction activities [10]. They have included emissions from stationary combustion and non-combustion activities, except parts of the loading of crude oil onshore. The emission estimates presented for 1990 have been evaluated by SFT and the Ministry of Environment, taking information from OLF, SINTEF and other experts into account. The emission estimates in the OLF report are based on data from the oil companies. The cold vent and fugitive emissions are determined by collecting information from the operators through questionnaires and by analysis of process flowsheets provided by the companies. The collected information has been evaluated and analyzed, and specific simulations have been performed to quantify the emissions. 17 different sub-emission sources were quantified. Younger platforms generally emit less than the older (older than 10 years) by a factor of about 50 per cent. The part of the fugitive emissions originating from transportation of natural gas can mainly be located to the gas terminal (only one in Norway). The CH_4/NMVOC ratio of the emissions varies, but average values may be calculated from the available measurements.

The direct emissions estimated from the OLF project for 1990 were 3.6. tonnes NMVOC and 5.1 tonnes methane. The production of crude oil and natural gas, respectively, were 80.6 million tonnes and 37.1 billion Sm^3. About the same quantities were emitted in 1991 and 1992, in spite of an increasing rate of production, due to improvements in technology.

The following emission factors may be derived (tonnes/ktoe produced oil and gas):

NMVOC	0.03
CH_4	0.04

The estimated emission of NMVOC from testing (pre-production) is small (30 tonnes).

The fugitive emissions from *oil loading* are approximately proportional to the mass crude oil transported by ships. Only three fields used this kind of transportation in Norway in 1992: Statfjord, Snorre and Gullfaks.

The mass of crude oil transported is assumed equal to the production at these fields. The VOC evaporation rates have been estimated by the relevant operators from measurements at the fields, and include emissions from all stages of the process (loading and washing of tanks). The methane content of the VOC, which varies from field to field, also has been measured. The evaporation rate will depend heavily upon recovery systems and crude oil washing procedures. E.g. the specific VOC-emissions from this source were reduced by 15% from 1989 to 1990 in Norway due to changes in the crude oil washing and loading procedures. Installing recovery systems may reduce these emissions by as much as 70%.

The calculation methodology is to calculate a total VOC evaporation from the estimated evaporation rate combined with the mass of crude oil transported. The total estimated VOC evaporated from each field is distributed between methane and NMVOC from the measured methane/NMVOC ratio. The calculation is shown in table 3.11.

A similar method is used for calculating the emissions from loading of crude oil at land terminals. There are two relevant terminals in Norway, Sture and Mongstad. The mass of crude oil loaded at these terminals is reported to Statistics Norway.

The evaporation rate is estimated to be less than for offshore loading. Reduced movements of the ships in port favour smaller evaporation rates than offshore. In addition, some volatile components have already evaporated during transport to the onshore terminals. The methane content of the VOC is estimated to be 0.55% at both terminals. The calculation is shown in table 3.12.

The gas terminal at Kårstø receives natural gas from pipelines. There is a fairly constant level of fugitive emissions from various processes in this terminal. The emission estimate is based on measurements. The emissions were estimated to 0.8 ktonnes of NMVOC and 0.4 ktonnes of methane in 1992.

A summary of the NMVOC emission estimates from oil and gas extraction activities is given in table 3.13.

The Norwegian production of oil and gas has increased as shown in figure 3.5. The NMVOC emissions from oil and gas extraction activities, and particularly from crude oil loading, have also increased the last years (figure 3.10).

Table 3.11. Emissions from oil loading offshore. 1992

Field	Evaporation rate (%)	Production (Mtonnes)	Methane content (%)	NMVOC ktonnes	Methane ktonnes
Statfjord*	0.2	32.1	1.2	63.5	0.8
Gullfaks	0.07	21.9	17.2	12.7	2.6
Total				76.1	3.4

* Including Snorre

Sources: Statistics Norway and State Pollution Control Authority

Table 3.12. Emissions from oil loading on shore. 1992

Terminal	Evaporation rate (%)	Loaded (Mtonnes)	Methane content (%)	NMVOC ktonnes	Methane ktonnes
Terminal 1	0.006	9.7	0.55	0.6	0.0
Terminal 2	0.11	25.6	0.55	28.0	0.2
Total				28.6	0.2

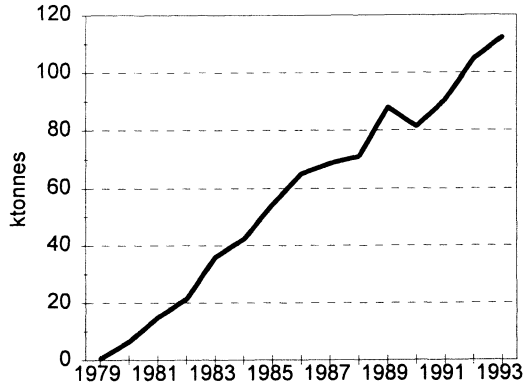
Sources: Statistics Norway and the State Pollution Control Authority

Table 3.13. NMVOC emissions from oil and gas extraction activities. 1992. ktonnes.

Total	109.1
Venting and fugitive	3.6
Oil loading, offshore	76.1
Oil loading, on shore	28.6
Pre-production	0.0
Gas terminal	0.8

Sources: The State Pollution Control Authority, the Norwegian Oil Industry Association, Statistics Norway

Figure 3.10. NMVOC emissions from crude oil loading offshore and on shore. 1979-1992.



Sources: Statistics Norway and the State Pollution Control Authority.

3.3.2. Distribution of gasoline

Three sub-sources are included in the estimates: loading of tanker, loading of tanks at gasoline stations and loading of cars. The emissions in 1989 were estimated by the State Pollution Control Authority (SFT) [14]. A certain amount of recovery is included in these estimates. Since 1989 more gasoline is recovered and less gasoline is sold. The emissions are reduced by 6 per cent from 1989 to 1992, the gasoline consumption by 5 per cent (table 3.14.). Emission from loading of storage tanks are reduced by an order of magnitude, while emissions from loading tanker trucks are halved and emissions from loading of tanks at gasoline stations are reduced by 7.5 per cent if recovery systems are installed.

The total emissions from gasoline distribution were estimated to 8.8 ktonnes in 1992.

Table 3.14. NMVOC emissions from gasoline distribution. ktonnes

	1989	1992
Gasoline sold (ktonnes):	1783	1696
Loading of ships at refineries	0.4	0.4
Loading of storage tanks	0.8	0.7
Loading of tanker trucks	1.7	1.6
Loading of tanks at gasoline stations	2.4	2.2
Loading of cars	4.1	3.9
Total	9.4	8.8

Sources: Statistics Norway and State Pollution Control Authority

3.3.3. Solvent losses

We have developed a methodology [16] to estimate emissions from use of solvents and products containing solvents. This methodology gives independent emission estimates for each year of inventory and covers in principle all fugitive sources.

The methodology is based on a solvent balance approach. The mass of consumed solvents will either be imported to the country or be produced in the country. Most of the consumed solvents will sooner or later evaporate to air. Solvents not emitted within the country are either exported, used as feedstock, incinerated or broken down in water. This solvent balance follows the flow of solvents from import and export, via transformation, to incineration or consumption.

The equation applied for the solvent balance is:

Emissions =
(Production + Import - Export - Destruction - Feedstock)
**Solvent_content *Fraction_emitted*
+ Emissions_from_certain_industrial_processes.

The solvent balance is based on the commodities in the statistics of foreign trade that either are pure solvents or contain solvents. Important examples are white spirits and paint based on solvents. Each of these commodities is followed through the balance - the equation is applied for each commodity and the total emission is the sum of emissions from each.

The following data are of main importance for the solvent balance:

- *Import and export* of the various commodities as determined by Statistics Norway in collaboration with the customs authorities.
- *Production in Norway* of the commodities is based on statistics from Statistics Norway as determined in annual surveys covering all main manufacturers.
- *Destruction* of solvent waste and paint is given by official statistics on waste delivered and incinerated. In addition, the State Pollution Control Authority has information about the incineration in plants with permissions to incinerate.
- Solvents used as *feedstock*: In certain industrial processes chemical substances usually considered as solvents are used for other purposes than solvents. Important examples in Norway are styrene used for producing polystyrene and chlorinated hydrocarbons used for manufacture of PVC. In other processes, e.g. production of paint and glue, solvents are used to produce solvent containing products. These products may either be exported or used within the country. To avoid double counting of emissions, the amount of solvents used for producing these products must be estimated and subtracted from the balance. Emissions are, in the current methodology, counted when and where the products (commodities) are used. Statistics Norway has statistics on the amount of feedstock used in industrial processes.
- *Solvent content:* Commodities that are not pure solvents have to be multiplied by a solvent content in order to estimate the potential emission. We have determined the solvent content from several sources. The most important source has been the Norwegian product register. Here, products with possible harmful environmental or health effects are registered - the mass imported or produced, the main consumers and the chemical composition. The average solvent content is determined from the average chemical composition of the product category. The solvent contents of the remaining commodities are, with a few exceptions, taken from investigations for other countries.
- *Fraction emitted:* Not all solvents consumed will evaporate to air. Some will be emitted to water. The solvents emitted to water may partly evaporate to air and partly be broken down. For each commodity a fraction emitted to air is assumed. Generally, this fraction is higher for products that are not water soluble than for those who are.

- Emissions from particular *industrial processes*: In plants where solvents are used as feedstock, fractions of this feedstock may evaporate to air. Emissions from these plants have been added to the solvent balance where data have been available. The emission estimates or emission factors are delivered by the State Pollution Control Authority. Furthermore, it is possible to make corrections in the model if emissions from certain plants or sectors are well known.

Emissions are roughly distributed between main *sectors* utilising information about kind of commodity, feedstock statistics from Statistics Norway, data from the Product register and data on expenditures in the National accounts.

The speciation, distribution of the emissions between groups of chemical substances, has been done for each commodity utilising e.g. data from the Product register. These groups of NMVOCs may again be classified according to the photochemical oxidant formation potential: Very important, less important and least important.

CFCs and halons are not included in the solvent balance.

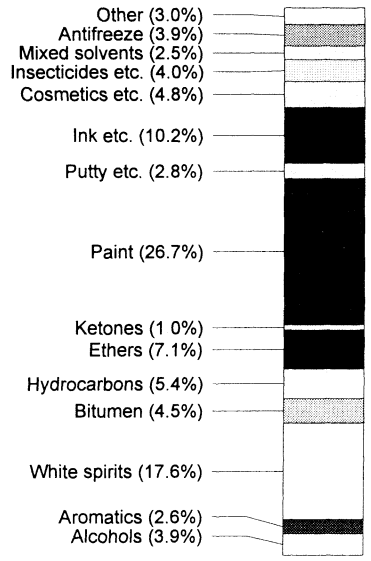
Use of paint is the most important source of solvent emissions in Norway (figure 3.11). This source accounts for about a quarter of the total emission. Use of white spirits and other petroleum products as solvents is another source of importance. Other main sources are ink (mainly in the printing industry), use of antifreeze and household products. Emissions from use of chlorinated solvents are 2-3 ktonnes per year only.

Earlier this was somewhat different: Use of white spirits and other petroleum products as solvents was the most important source and use of paint the second most important source. In addition to use of aromatic compounds as solvents and creosote, use of insecticides and herbicides were also among the main sources in 1976.

The total emission was 61 ktonnes in 1976 and about 43 ktonnes each year in the period 1988-1992. The reduction in emission has been 18 ktonnes, or about 30 per cent, in the period 1976 to 1992 (figure 3.12.). However, most of this reduction was achieved between 1976 and 1988. In the period 1988 to 1992 the emissions have been relatively stable from one year to another. The main cause of the reduced emissions in the period 1976-1988 is reduced consumption of white spirits, aromatic compounds, mixed thinners and herbicides, insecticides etc.

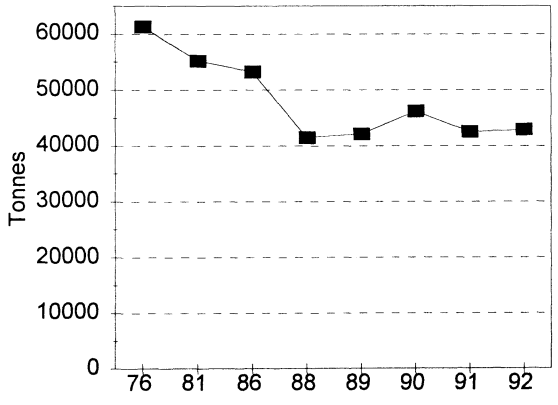
The consumption of many solvent containing commodities has followed the economic development: An increase until late in the 1980 decade and a decrease or stable consumption later. For other commodities the

Figure 3.11. Solvent losses by source. 1988-1992 (average)



Sources: Statistics Norway and State Pollution Control Authority

Figure 3.12. Solvent losses 1976-1992. Tonnes.



Sources: Statistics Norway and State Pollution Control Authority

consumption has changed due to environmental concern or regulations. The reduction in emissions from use of paint has not been very high in this period. There has been an increase in the total consumption of paint. More use of water based paint and less organic solvents in water based paints has only partly been able to make up for this.

The last years there has been an increase in the mass registered of solvents and solvent containing products incinerated or regenerated. Without this incineration the emissions in 1988 would have been about 5 per cent higher.

About 40 % of the emissions in Norway are from manufacturing industry. The main sectors are the graphical, wood, mechanical and chemical industries. Use of ink,

paint and white spirits are the main emission sources in the manufacturing industry. The construction industry is the most important emitter in Norway. Nearly a quarter of the emissions originate from this sector. About half of this is due to use of paint. The household sector contributes to 15 % of the total emission. Use of paint is the main source.

3.3.4. Fermentation processes

Fermentation processes will lead to emissions of NMVOC (ethanol). We consider the production processes of bread (and other similar yeast products) and beer. The emission factors are taken from [17]. The volume of production is in both cases estimated from data reported to Statistics Norway. The mass produced of bread is quite uncertain. The calculation for 1992 is shown in table 3.16.

3.3.5. Agriculture

Two sources are identified: emissions from animal waste and emissions from use of mineral fertilizers.

Emissions of ammonia from *animal waste* will depend on several factors, e.g. on animal type, nitrogen content of food, manure storage, climate, spread of manure, agriculture practices and properties of the soil. Asman has developed aggregated emission factors from the current knowledge [18]. Emission factors for reindeer have been estimated by scaling the factors for sheep by the animal weights. They are, however, made from data on Dutch conditions and agricultural practise. The number of animals are taken from Statistics Norway - agricultural statistics [19]. The emission estimate is 34.9 ktonnes for 1992, and has been fairly stable the last years. The calculation is shown in table 3.17.

Table 3.15. NMVOC from solvents by industry and commodity. 1988. ktonnes

	Manufacture									Other			
Commodity / Industry	Chemical	Graphical	Furniture and textiles	Plastic	Pharmaceutical	Ship and offshore	Mechanical	Other	Sum	Car painting etc.	Construction	Private	Other
Ethanol	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1
Aromates	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
White spirit and other pet. products	0.5	1.0	0.3	0.6	0.0	0.3	0.2	0.2	3.1	0.6	2.2	1.2	0.4
Bituminous mixtures (asphalt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.2
Hydrocarbones	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Halogenated hydrocarbones	0.0	0.0	0.0	0.1	0.0	0.0	1.6	0.0	1.7	0.0	0.1	0.0	0.4
Alcohols	0.0	0.3	0.0	0.1	0.3	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.7
Ethers etc.	0.3	0.0	0.0	0.2	0.0	0.1	0.4	0.1	1.2	0.0	0.3	0.0	0.1
Aldehydes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1
Ketones with derivates	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Paint etc.	0.0	0.0	1.3	0.0	0.0	0.7	1.1	0.1	3.1	0.3	6.1	1.1	1.8
Putty etc	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.4	0.0	0.0
Ink	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.1	0.3
Oils and cosmetics	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.1
Lubricants and polishing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.0
Glue	0.0	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.1	0.0	0.0
Terpentine etc.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0
Insect- and herbicides	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.3
Mixed solvents and thinners	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.1	0.4	0.2	0.1
Mixed alkylbenzenes etc.	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0
Antifreeze	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.0	1.0	0.6
Total	0.9	5.5	2.7	1.7	0.4	1.2	3.9	0.7	17.0	1.5	10.8	6.2	6.0

Sources: Statistics Norway and State Pollution Control Authority

Table 3.16. NMVOC emissions from fermentation processes. 1992.

	Production	Emission factor	Emission (ktonnes)
Bread	298 ktonnes	0.003 tonne/tonnes	893
Beer	227 mill. litres	0.2 g/litre	45
Total			938

Sources: Statistics Norway and State Pollution Control Authority

The emissions from application of mineral fertilizers will depend on fertilizer type, climate, agricultural practices and properties of the soil. The emissions in Norway have been estimated by Asman [18]. The composition of the mineral fertilizer consumption in Norway is taken into account, but the emission factors for each fertilizer type are derived from European conditions generally (and not particularly the Norwegian). Mainly NPK-fertilizer is consumed in Norway, it has a share of about three quarters of the amount of nitrogen sold. Calcium ammonium nitrate has a share of about 13 per cent. 110-111 ktonnes of nitrogen are applied as mineral fertilizers in Norway each year [19].

The emission was estimated to 5.0 ktonnes per year, and is fairly constant.

The total emissions from agriculture add up to 40 ktonnes each year.

The methodology and emission factors are currently being revised by the Norwegian University of Agriculture on behalf of the Ministry of Agriculture. Preliminary results indicate that the actual emissions are lower than estimated by the current methodology and that they have decreased due to changed feeding of cattle.

3.3.6. Paper and pulp industries

We consider emissions of SO_2 from the production processes of chemical pulp. All SO_2-emissions from the five relevant producers are measured continuously and emission estimates are made from these measurements. The total emission in 1992 was 876 tonnes. The emissions from this source have been reduced considerably since the early eighties due to the introduction of control technologies (figure 3.13.). In addition, increasing use of hydropower has lead to lower emissions from combustion.

3.3.7. Manufacture of nitric acid

Nitric acid is mainly produced in Norway as a step in the fertilizer production. Norsk Hydro, the only producer in Norway, has estimated the emissions of NO_x from the three relevant plants from measurements. The emissions were 998 tonnes in 1992. They have been reduced considerably the last ten years (figure 3.14.).

Table 3.17. Emissions of ammonia (NH_3) from animal waste. 1992.

	Number (thousands)	Emission factor (tonne/animal/year)	Emission (ktonnes)
Cattle	984	0.023	22.6
Sheep	2363	0.0017	4.0
Goat	89	0.0017	0.1
Reindeer	217	0.005	1.1
Horse	207	0.012	0.2
Swine	766	0.0054	4.1
Fox (fur)	681	0.0027	0.2
Mink (fur)	40	0.0017	0.1
Poultry	9334	0.00025	2.3
Total			34.9

Sources: Statistics Norway and State Pollution Control Authority

These reductions are due to installations of abatement techniques in two plants.

NH_3 is emitted from two plants producing N-fertilizers. The emission estimates are made from measurements. However, these measurements are not very accurate. The emissions added up to 353 tonnes in 1992. These emissions have been quite stable the last years.

3.3.8. Refineries

Refining of crude oil

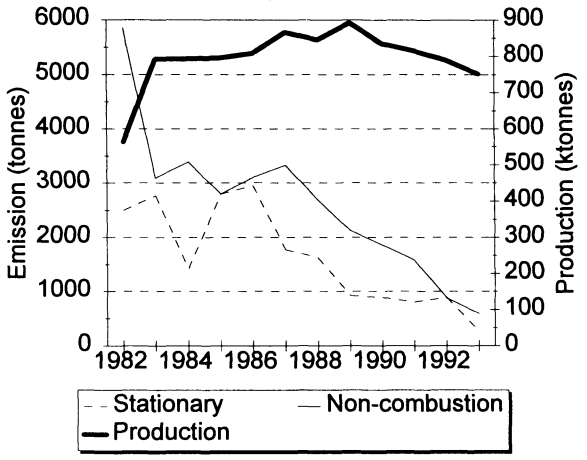
SO_2 is emitted from the production processes in refineries. NMVOC is emitted from the production processes and from various fugitive sources. There are four refineries in Norway.

The SO_2 emissions are measured and reported from the refineries to SFT annually. Totally, 2.5 ktonnes SO_2 were emitted in 1992. The emissions have been reduced the last 10 years due to increased control, in spite of increased production (figure 3.15.).

The NMVOC emissions are calculated from the throughput of crude oil as reported to Statistics Norway from the refineries. The emission factor, 0.06%, is based on measurements at one of the Norwegian refineries, but is applied to all. More measurements are currently performed to improve these estimates. This emission factor covers fugitive emissions from the production process, storage and handling. The crude oil and light distillates are stored in floating roof tanks. About 60 per cent of the emissions in the refineries are from storage. The emissions have been steadily increasing due to increased production.

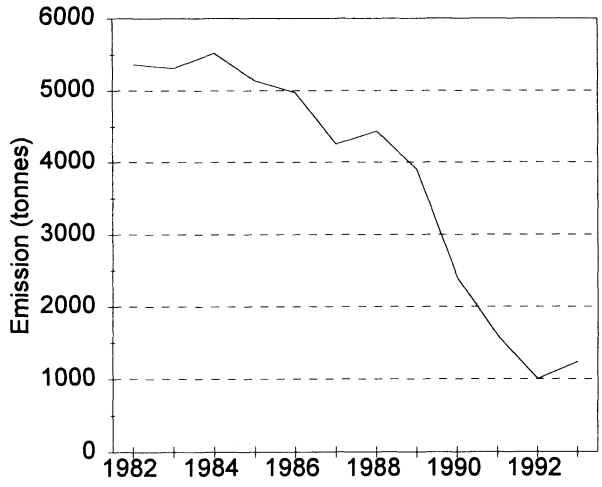
The throughput of crude oil was 13.5 million tonnes in 1992, and about 8 ktonnes NMVOC was emitted.

Figure 3.13. Emissions of SO_2 from pulp production. Stationary combustion and non-combustion. Production of pulp. 1982-1993.



Sources: State Pollution Control Authority and Statistics Norway

Figure 3.14. Non-combustion emissions of NO_x from the production of mineral fertilizers (all steps in the production process). 1982-1993.



Source: State Pollution Control Authority

Gas terminal
Natural gas is received, treated and distributed at the gas terminal at Kårstø in Rogaland. All these processes lead to fugitive emissions of VOC. The NMVOC emission in 1992 has been estimated from measurements to 756 tonnes by SFT. The production at Kårstø started in 1985. The emissions have been quite stable since.

3.3.9. Other petrochemical industry

NGL is the raw material for the production of propene and ethene at the Norsk Hydro plant at Rafnes. Plastic is produced from these gases at the Statoil plant at Bamble. NMVOC is emitted from both plants. The estimates are made from measurements. 0.9 ktonnes were emitted in 1992. The emissions have decreased since the early eighties due to control of diffuse and controlled emissions. Leakages are detected by routine and a program of maintenance is followed. Controlled emissions are as far as possible avoided.

3.3.10. Carbide production

Silicon carbide and calcium carbide are produced in Norway.

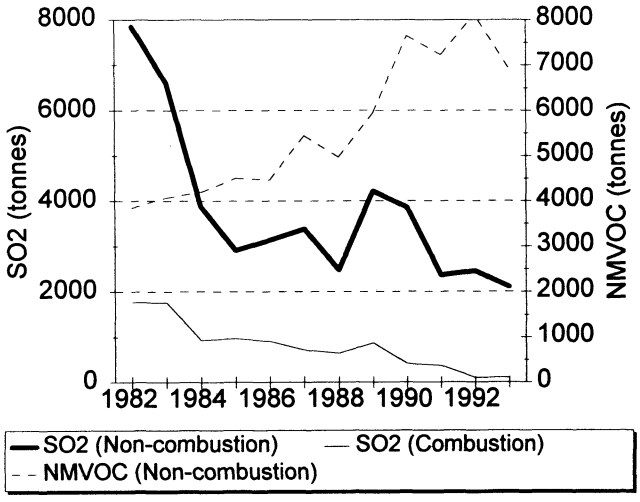
Silicon carbide is produced from quartz. Petrol coke is used as a carbon source and reducing agent.

$$SiO_2 + 3C \rightarrow SiC + 2\,CO \rightarrow 2CO_2$$

All sulphur in the petrol coke is assumed emitted to air as SO_2. Thus, the emissions are calculated from the sulphur content of coke and consumption of petrol coke as reported annually to SFT. There are three relevant plants in Norway.

3.6 ktonnes SO_2 were emitted in 1992. The emissions have increased slightly the last 10 years, but decreased

Figure 3.15. Emissions of SO_2 and NMVOC from oil refineries. 1982-1993.

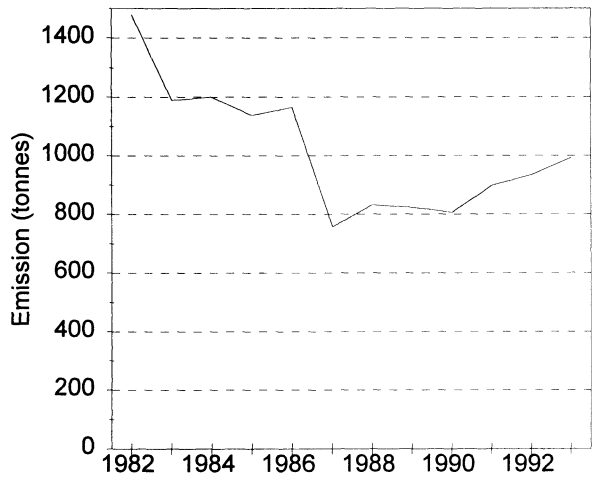


Sources: State Pollution Control Authority and Statistics Norway

the last few years due to decreased production (figure 3.17.).
Calcium carbide is made by heating of calcium carbonate, and reduction of the CaO with carbon as petrol coke.

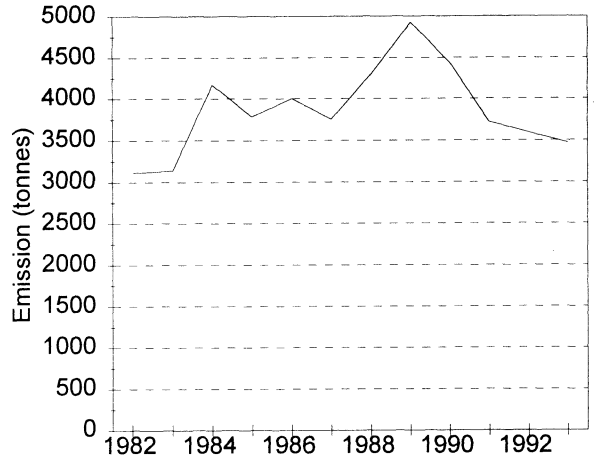
$$CaCO_3 \rightarrow CaO + CO_2,$$
$$CaO + C \text{ (petrol coke)} \rightarrow CaC_2 + CO\ (\ CO_2)$$

Figure 3.16. Emissions of NMVOC from petrochemical industry. 1982-1993.



Source: State Pollution Control Authority

Figure 3.17. Non-combustion emissions of SO_2 from silicon carbide production.1982-1993.



Source: State Pollution Control Authority

Sulphur in coke is a potential source of SO_2. However, no SO_2 is emitted as near 100% of the sulphur from the petrol coke will be sequestered in the product.

3.3.11. Manufacture of other inorganic chemicals

Manufacture of sulphuric acid
Emissions for one plant are reported to SFT. The emission has been estimated from measurements to 1.1 ktonnes in 1992. There has been a slight, but clear, decrease in emissions since the early eighties.

Manufacture of titanium dioxide
Emissions for one plant are reported from calculations to SFT. The estimate was 0.4 ktonnes for 1992. There has been a slight, but clear, decrease in emissions since the early eighties.

3.3.12. Manufacture of explosives

The production process of explosives will lead to emissions of NO_x. Emissions are reported from one particular plant. The emissions were 12 tonnes in 1992, estimated from measurements. There has been a slight reduction in these emissions since 1985.

3.3.13. Mineral production

Cement
The emissions of SO_2 from manufacture of cement are estimated from measurements at two (currently) plants and reported to SFT. The level of production of cement has been quite low in the early nineties after an increase during the eighties. The emissions have decreased steadily. The emissions in 1992 add up to 0.2 ktonnes SO_2.

Concrete pumice stone
The non-combustion emissions originate from the clay used in the production process. 0.2 ktonnes SO_2 were reported to SFT from measurements in 1992.

3.3.14. Metal production

Norway produces ferroalloys, aluminium, nickel, zinc and magnesium. The level of production has varied (figure 3.19.). Coal, coke and/or prebaked anodes are used as reducing agents. SO_2 emissions originate from sulphur in reducing agents and ores. In addition, depending on the process conditions, NO_x and VOC may be emitted.

Manufacture of prebaked anodes
Prebaked anodes and coal electrodes are an alternative to use of coal and coke as reducing agents in the metal production processes of aluminium and ferroalloys. The anodes and coal electrodes are produced from coal and coke. The production process of such anodes and coal electrodes leads to emissions of SO_2. However, the emissions from the metal production will be lowered. Four plants are producing prebaked anodes and coal electrodes in Norway. The emissions, partially estimated from measurements, were 0.4 ktonnes in 1992. These emissions have been steadily increasing due to an increasing amount of metals produced from prebaked anodes and coal electrodes rather than coal and coke.

Ferroalloys
There are 16 plants in Norway. The SO_2 emissions are estimated from the consumption and sulphur content of the reducing agents as reported to SFT. Some of the sulphur will be trapped in the products. For production of ferromanganese and silicon manganese 98-99% of

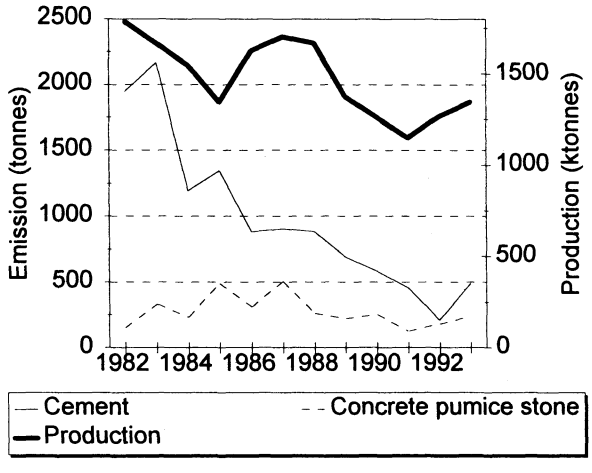
the sulphur will be trapped, for the rest of the ferroalloys about 5% is assumed. The emissions in 1992 add up to 7.3 ktonnes SO_2. The emissions increased until 1984, were stable 1984-1988, increased 1989-90, but decreased in 1991 and 1992 due to reduced production (figure 3.20.). In 1993 the emissions will increase due to increased production.

Emissions of NO_x originate from production of ferrosilicon and siliconmetal. The level of production, as reported to Statistics Norway, is chosen as activity statistics. The emission factor of 11.7 kg NO_x/tonne ferroalloy has been estimated from measurements at two Norwegian ferroalloy plants. This emission factor is, however, rather uncertain. 5.1 ktonnes NO_x were emitted in 1992. In 1991-1992 there has been a decrease in the production of ferrosilicon, and hence also the emissions, after an increase 1980-1990. The calculation is shown in table 3.16. The emission factors and methodology will be revised in the near future.

NMVOC emissions originate from use of coal and coke in the production processes. The emissions are estimated from the consumption of coal and coke, as reported to Statistics Norway. An emission factor of 1.7 kg NMVOC/tonnes coal or coke has been applied [20]. 1.3 ktonnes NMVOC were emitted in 1992. The emissions have followed the increase in production from 1980, and the decrease since 1990. The calculation is shown in table 3.17.

Iron and steel
SO_2 emissions are estimated from measurements at the only plant in Norway. This plant produces iron from ilmenite and coal. The emissions were 2 tonnes SO_2 and 218 tonnes NO_x in 1992.

Figure 3.18. Emissions of SO_2 from cement and concrete pumice stone manufacture. Production of cement. 1982-1993.



Sources: State Pollution Control Authority and Statistics Norway

Until 1988 there were also SO_2 emissions from Norsk Jernverk. These emissions decreased in the period 1982-1988.

Aluminium
The production process will lead to emissions of SO_2 and NO_x. Aluminium is manufactured by two main processes in Norway, the traditional Søderberg method (direct use of coal and coke) and with prebaked anodes. About 35% of the total production is by the Søderberg method (1991). The fraction produced by this method is steadily decreasing. There are 7 plants producing aluminium in Norway. The aluminium production increased until 1989, and has decreased 1990-1992.

The SO_2 emissions are estimated from measurements at each plant as reported to SFT. They add up to 3.0 ktonnes in 1992. These emissions have decreased steadily since 1982 due to control (figure 3.20.).

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. The emission factor is, however, rather uncertain. 0.6 ktonnes NO_x were estimated emitted in 1992.

There has not been measured significant VOC emissions from this source.

Other metals
The SO_2 emissions from the only nickel producing plant are estimated from weekly measurements to be 197 tonnes in 1992.

17 tonnes SO_2 were emitted from the only zinc plant in 1992. The emissions are estimated from infrequent measurements combined with calculations. These emissions have been slightly reduced since 1982.

Magnesium is produced from dolomite ($MgCa(CO_3)_2$). Coke is used as an anode in the production process. The SO_2 emissions are estimated from the consumption of coke. The emissions from the only relevant plant are reported to be 139 tonnes by Norsk Hydro to SFT in 1992.

Metal mines
The treatment of ores will lead to emissions of SO_2. Before 1987 emissions from melting at Sulitjelma (copper mine) were relatively high (figure 3.20). This plant was closed in 1987. In 1992 emissions from one mine has been estimated to 330 tonnes.

Table 3.16. Emissions of NO_x from manufacture of ferro-alloys. 1992.

	Production (ktonnes)	Emission factor (tonne/ktonne produced)	Emission (ktonnes)
FeSi	365.8	11.7	4.3
Si-Metal	72.8	11.7	0.9
Total			5.1

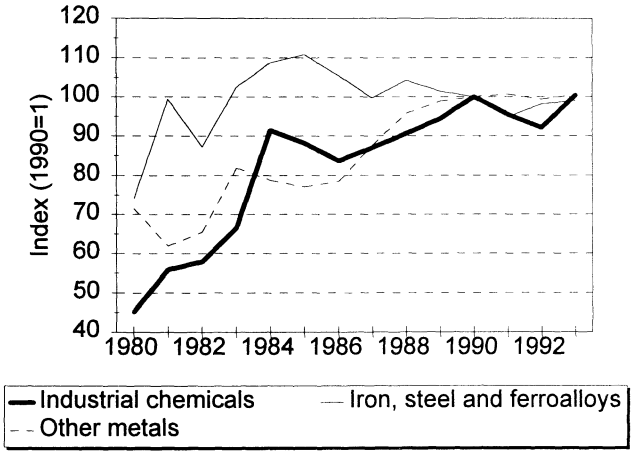
Sources: State Pollution Control Authority and Statistics Norway

Table 3.17. Emissions of NMVOC from manufacture of ferro-alloys. 1992.

	Consumption (ktonnes)	Emission factor (kg NMVOC/tonne)	Emission (ktonnes)
Coal	357.0	1.7	0.6
Coke	409.3	1.7	0.7
Petrol coke	7.2	1.7	0.0
Total			1.3

Sources: State Pollution Control Authority and Statistics Norway

Figure 3.19. Production indexes. 1980-1993. 1990=1



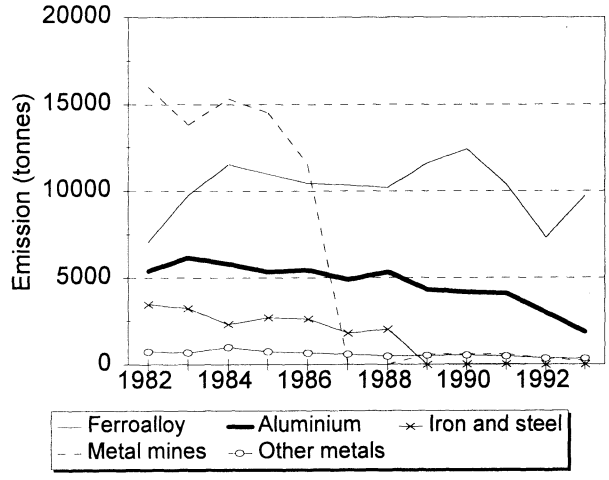
Source: Statistics Norway

3.3.15. Summary, non-combustion emissions

The complete Norwegian source list and emissions calculated as outlined in section 3.3 are summarized in table 3.18., the most important emission factors are shown in table 3.19.

The SO_2 emissions have decreased substantially the last 20 years. A reduction has been achieved for most sources, but particularly the close down of a metal mine plant has been important. Control technologies have been installed in many plants. The NO_x and NH_3 non-combustion emissions have been quite stable. The NMVOC emissions have increased substantially. This is particularly due to increased loading of crude oil to ships.

Figure 3.20. Non-combustion emissions of SO_2 from manufacture of metals. 1982-1993



Source: State Pollution Control Authority

Table 3.18. Non-combustion emissions of SO_2, NO_x, NMVOC and NH_3 by source. 1992. ktonnes

Source	SO_2	NO_x	NH_3	NMVOC
Total	20.2	7.0	40.3	172.2
Oil and gas extraction and drilling	-	-	-	3.6
Loading of oil, offshore	-	-	-	76.1
Loading of oil, land	-	-	-	28.6
Solvents	-	-	-	42.9
Gasoline distribution	-	-	-	8.9
Fermentation	-	-	-	0.9
Gas terminal	-	-	-	0.8
Refineries	2.5	-	-	8.1
Other petrochemical production	-	-	-	0.9
Silicon carbide production	3.6	-	-	-
Calcium carbide production	0.0	-	-	-
Sulphuric acid production	1.1	-	-	-
TIO_2 production	0.4	-	-	-
Explosives production	-	0.0	-	-
Paper and pulp production	0.9	-	-	-
Fertilizer production	0.0	1.0	0.4	-
Cement production	0.2	-	-	-
Other mineral production	0.2	-	-	-
Metal production	11.1	6.0	-	1.3
- Anode production	0.4	-	-	-
- Ferroalloys	7.3	5.1	-	1.3
- Aluminium	3.0	0.6	-	-
- Iron and steel	0.0	0.2	-	-
- Magnesium	0.1	-	-	-
- Other metals	0.2	0.0	-	-
- Mines	0.3	-	-	-
Domestic animals	-	-	34.9	-
Use of mineral fertilizers	-	-	5.0	-

Sources: Statistics Norway and the State Pollution Control Authority

Table 3.19. Selected emission factors. Non-combustion emissions. 1992.

Source	SO_2	NO_x	NH_3	NMVOC
Oil and gas extraction/drilling	-	-	-	0.031 tonne/ktoe oil and gas
Loading of oil, offshore	-	-	-	1.41 ktonnes/Mtonne oil
Loading of oil, land	-	-	-	0.81 ktonnes/Mtonne oil
Solvents	-	-	-	10 kg/capita
Gasoline distribution				
- Loading of ships at refineries	-	-	-	0.2 kg/tonne gasoline
- Loading of storage tanks	-	-	-	0.1-0.3 kg/tonne gasoline
- Loading of tanker trucks	-	-	-	0.2-0.7 kg/tonne gasoline
- Loading of tanks at gasoline stations	-	-	-	0.2-1.1 kg/tonne gasoline
- Loading of cars	-	-	-	2.3 kg/tonne gasoline
Fermentation				
- Bread	-	-	-	3 kg/tonne bread
- Beer	-	-	-	0.2 g/l beer
Gas terminal	-	-	-	Measured
Refineries	Measured	-	-	0.06% of crude oil throughput
Other petrochemical prod.	-	-	-	Measured
Cement production	Measured	-	-	-
Other mineral production	Measured	-	-	-
Anode production	Measured	-	-	-
Metal production				
- Ferroalloys				
-- FeSi	Measured	11.7 kg/tonne FeSi	-	1.7 kg/tonne coal/coke
-- SiMetal	Measured	11.7 kg/tonne Si-metal	-	"
-- Other	Measured	0.0	-	"
- Aluminium	Measured	0.71 kg/tonne Al	-	0
- Iron and steel	Measured	-	-	-
- Magnesium	Measured	-	-	-
Silicon carbide production	Sulphur% of coal or coke	-	-	-
Calcium carbide production	0	-	-	-
Sulphuric acid production	Measured	-	-	-
TIO_2 production	Calculated	-	-	-
Explosives production	-	Measured	-	-
Paper and pulp production	Measured	-	-	-
Fertilizer production	-	Measured	Measured	-
Domestic animals				
- Cattle	-	-	0.023 tonne/animal	-
- Sheep	-	-	0.0017 tonne/animal	-
- Swine	-	-	0.0054 tonne/animal	-
- Poultry	-	-	0.00025 tonne/animal	-
Use of N fertilizers	-	-	45.4 kg/tonne N	-

Appendix 1. Economic sectors in the Norwegian emission model

Agriculture and forestry

230100 Agriculture
0140 Services related to agriculture and forestry
0200 Forestry and logging

Fishing

0510 Fishing
0520 Operation of fish farms

Energy sectors

1000 Coal mining
1110 Extraction of crude petroleum and natural gas
1200 Mining of uranium and thorium ores
2320 Manufacture of refined petroleum products
2330 Processing of nuclear fuel
2340 Gas terminal
4010 Production of electricity
4020 Distribution of electricity
4030 Manufacture and distribution of gas
4040 Steam and hot water supply

Mining/manufacturing

1120 Oil drilling
1300 Mining of metal ores
1400 Other mining and quarrying
1510 Production, processing and preserving of meat and meat products
1520 Processing and preserving of fish and fish products
1530 Processing and preserving of fruit and vegetables
1540 Manufacture of vegetable and animal oils and fats
1550 Manufacture of dairy products
1560 Manufacture of grain mill products, starches and starch products
1570 Manufacture of prepared animal feeds
1580 Manufacture of other food products
1590 Manufacture of beverages
1600 Manufacture of tobacco products
1700 Manufacture of textiles and textile products
1810 Manufacture of leather clothes
1820 Manufacture of other wearing apparel and accessories
1830 Dressing and dyeing of fur, manufacture of articles of fur
1910 Tanning and dressing of leather, manufac ture of luggage, handbags, saddlery and harness
1930 Manufacture of footwear
2010 Sawmilling and planing of wood, impregnation of wood
2020 Manufacture of particle board, fibre board and other panels and boards
2030 Manufacture of builders' carpentry and joinery
2040 Manufacture of other products of wood
2110 Manufacture of pulp
2120 Manufacture of paper and paperboard
2130 Manufacture of articles of paper and paperboard
2210 Publishing
2220 Printing and service activities related to printing
2230 Reproduction of recorded media
2310 Manufacture of coke oven products
2411 Manufacture of industrial gases
2412 Manufacture of dyes and pigments and other inorganic basic chemicals
2415 Manufacture of fertilizers, nitrogen compounds and pesticides
2416 Manufacture of plastics and synthetic rubber in primary forms, manufacture of other organic basic chemicals
2430 Manufacture of paints and varnishes, printing ink and mastics
2440 Manufacture of basic pharmaceutical products and pharmaceutical preparations
2450 Manufacture of soap and detergents and toilet preparations
2460 Manufacture of other chemical products
2470 Manufacture of man-made fibres
2500 Manufacture of rubber and plastic products
2610 Manufacture of glass and glass products
2620 Manufacture of ceramic goods
2640 Manufacture of other mineral products
2650 Manufacture of cement, lime and plaster
2710 Manufacture of basic iron and steel
2720 Manufacture of ferro-alloys
2730 Aluminium production
2740 Other non-ferrous metal production
2750 Casting of metals
2810 Manufacture of fabricated metal products, except machinery and equipment
2860 Manufacture of cutlery, tools and general hardware
2870 Manufacture of other metal products
2910 Manufacture of general purpose machinery
2930 Manufacture of special purpose machinery
2960 Manufacture of weapons and ammunition
2970 Manufacture of domestic appliances
3000 Manufacture of office machinery and computers
3110 Manufacture of electric motors, generators and transformers, manufacture of electricity distribution and control apparatus

3130 Manufacture of insulated wire and cable
3140 Manufacture of other electrical apparatus and equipment
3210 Manufacture of electronic components and television and radio transmitters
3230 Manufacture of television and radio receivers, sound or video recording apparatus
3310 Manufacture of medical and precision instruments
3340 Manufacture of optical instruments, photographic equipment, watches and clocks
3400 Manufacture of motor vehicles and parts and accessories for motor vehicles
3510 Building and repair of ships and boats
3520 Building and repair of oil platforms
3530 Manufacture and repair of railway and tramway locomotives and rolling stock
3540 Manufacture and repair of aircraft and spacecraft
3550 Manufacture of other transport equipment
3610 Manufacture of furniture
3620 Manufacture of jewellery and related articles
3630 Other manufacturing
3710 Recycling of metal waste and scrap
3720 Recycling of non-metal waste and scrap

Water supply
4100 Collection, purification and distribution of water

Construction
4500 Construction

Wholesale and retail trade/hotels and restaurants
5000 Wholesale and retail trade, repair of motor vehicles and personal and household goods
5500 Hotels and restaurants

Transport etc.
6010 Transport via railways
6020 Tramway and suburban transport, other scheduled passenger land transport
6030 Taxi operation
6040 Other land passenger transport, freight transport by road
6080 Transport via pipelines
6110 Ocean transport, sea and coastal transport in Europe
6130 Inland and coastal water transport
6200 Air transport
6300 Supporting and auxiliary transport activities
6400 Post, telecommunications

Financing, insurance, real estate and business services
6500 Financial intermediation, insurance
7000 Real estate activities
7100 Renting of machinery and equipment
7200 Computer and related activities
7300 Reasearch and development
7400 Other business activities
8000 Education
8500 Health and social work
9000 Sewage and refuse disposal, sanitation and similar activities
9100 Activities of membership organizations
9200 Recreational, cultural and sporting activities
9300 Other service activities
9500 Private households with employed persons

Central government
246300 Supporting and auxiliary transport activities
7300 Research and development
7400 Other business activities
7510 Public administration
7520 Defence
8000 Education
8500 Health and social work
9200 Other service activities

Local government
257510 Public administration
8000 Education
8500 Health and social work
9000 Sewage and refuse disposal, sanitation and similar activities
9200 Other service activities

Private households
330000 Private households

Appendix 2. Background data for estimating emissions from road traffic

Number of vehicles (see section 3.1.3 for definition of categories)

	1993	1992	1991	1990	1989	1987	1986	1980	1973
Passenger cars, gasoline	1,612,477	1,610,706	1,612,508	1,613,992	1,618,593	1,604,769	1,544,831	1,210,384	831,225
Light duty, gasoline	91,873	92,748	94,571	95,902	95,951	90,813	83,364	56,182	70,416
Heavy light duty, gasoline	7,473	7,003	6,511	6,063	5,712	4,876	4,449	2,015	681
Heavy duty, gasoline	3,899	3,975	4,273	4,605	4,919	5,456	5,667	6,041	12,429
Heavy buses, gasoline	287	274	271	277	278	300	295	33	114
Passenger cars, diesel	82,201	72,973	66,769	61,774	58,203	55,289	53,218	23,426	5,630
Light duty, diesel	67,928	63,917	60,983	58,309	55,726	47,508	40,107	6.706	1,206
Heavy light duty, diesel	18,791	14,866	12,224	9,385	7,180	5,451	4,626	1,781	443
Light heavy duty, diesel	34,882	34,253	33,451	32,545	31,762	30,064	28,587	22,430	14,124
Medium heavy duty, diesel	19,395	20,184	20,983	21,961	22,632	24,506	24,719	27,374	23,341
Heavy heavy duty, diesel	20,786	21,444	21,843	22,131	22,350	21,149	19,209	10,815	2,910
Heavy buses, diesel	13,022	12,334	11,011	10,507	10,193	10,119	9,879	7,961	6,599
Sum	1,973,014	1,954,677	1,945,396	1,937,448	1,933,499	1,900,297	1818951	1,375,148	969,116

Source: Directorate of Public Roads

Average annual mileage (km per vehicle)

	1993	1992	1991	1990	1989	1987	186	1980	1973
Passenger cars, gasoline	14,207	14,558	14,486	13,918	13,796	13,616	13,506	13,100	13,200
Light duty, gasoline	14,207	14,558	14,486	13,918	13,796	13,616	13,506	13,100	13,200
Heavy light duty, gasoline	14,207	14,558	14,486	13,918	13,796	13,616	13,506	13,100	13,200
Heavy duty, gasoline	16,157	16,121	15,506	15,881	16,000	16,127	15,054	23,819	23,819
Heavy buses, gasoline	40,902	40,902	40,902	41,940	43,099	41,134	40,068	42,591	36,099
Passenger cars, diesel	19,844	19,962	19,240	20,105	19,631	19,810	20,093	18,704	27,220
Light duty, diesel	16,738	16,738	16,189	17,123	17,160	17,196	17,299	13,526	13,526
Heavy light duty, diesel	16,738	16,738	16,189	17,123	17,160	17,196	17,299	13,526	13,526
Light heavy duty, diesel	16,157	16,121	15,506	15,881	16,000	16,127	15,054	23,819	23,819
Medium heavy duty, diesel	16,626	16,609	15,962	16,103	16,124	16,120	15,875	18,723	18,723
Heavy heavy duty, diesel	34,903	33,815	31,770	31,483	32,368	33,776	34,716	40,164	40,164
Heavy buses, diesel	40,902	40,902	40,902	41,940	43,099	41,134	40,068	42,591	36,099

Sources: Institute of Transport Economics, Statistics Norway

Distribution of vehicle-kilometres on driving pattern. 1980-1993

	Urban ≤50 km/h	Rural 60-70 km/h	Rural 80 km/h	Highway 90 km/h
Light	23.6%	22.9%	44.8%	8.7%
Heavy	19.5%	21.4%	48.6%	10.5%

Sources: Norwegian Institute for Air Research, Directorate of Public Roads and Statistics Norway

Distribution of vehicle-kilometres. Percentage of each fuel.

	1993	1992	1991	1990	1989	1987	1986	1980	1973
Passenger cars, gasoline	93.9	93.9	93.8	93.7	93.7	94.0	94.2	94.6	89.9
Light duty, gasoline	5.3	5.4	5.5	5.6	5.6	5.3	5.1	4.4	7.6
Heavy light duty, gasoline	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.1
Heavy duty, gasoline	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.9	2.4
Heavy buses, gasoline	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0
Passenger cars, diesel	31.2	29.8	28.8	28.2	26.8	27.3	28.7	18.5	11.7
Light duty, diesel	21.8	21.9	22.1	22.6	22.4	20.3	18.6	3.8	1.2
Heavy light duty, diesel	6.0	5.1	4.4	3.7	2.9	2.3	2.1	1.0	0.5
Light heavy duty, diesel	10.8	11.3	11.6	11.7	11.9	12.1	11.5	22.5	25.8
Medium heavy duty, diesel	6.2	6.8	7.5	8.0	8.7	9.8	10.5	21.6	33.5
Heavy heavy duty, diesel	13.9	14.8	15.5	15.8	17.0	17.8	17.9	18.3	9.0
Heavy buses, diesel	10.2	10.3	10.1	10.0	10.3	10.4	10.6	14.3	18.3
Sum gasoline	100	100	100	100	100	100	100	100	100
Sum diesel	100	100	100	100	100	100	100	100	100

Source: Statistics Norway

Annual number of cold starts

	1993	1992	1991	1990	1989	1987	1986	1980	1973
Number of cold starts	657	657	667	681	681	686	682	567	571

Source: Statistics Norway

Fuel for road traffic (tonnes)

	1993	1992	1991	1990	1989	1987	1986	1980	1973
Gasoline									
Total consumption	1,682,960	1,696,983	1,736,578	1,789,172	1,782,733	1,758,066	1,696,000	1,391,143	1,088,484
Non-road traffic consumption	37,902	37,815	37,790	37,825	37,680	39,156	38,781	37,405	37,324
Road traffic consumption	1,645,058	1,659,168	1,698,788	1,751,347	1,745,052	1,718,910	1,657,218	1,353,738	1,051,160
Diesel									
Total consumption	1,300,496	1,160,553	1,079,940	1,066,710	1,051,969	1,102,472	1,057,000	740,279	574,871
Non-road traffic consumtion	252,499	251,840	247,736	253,344	226,429	240,303	252,056	184,644	137,969
Road traffic consumption	1,047,997	908,713	832,204	813,366	825,540	862,169	804,944	555,635	436,902

Source: Statistics Norway

Appendix 3. Balance sheets of energy for Norway. 1992

a) Physical units

	Coal	Coke	Fuel-wood, black liquor, garbage	Crude oil	Gaso-line	Kero-sene	Medi-um distil-lates	Heavy fuel oil	Lique-fied gas	Natu-ral gas	Other gases [1]	Elec-tricity	Dis-trict heat-ing
	1000 tonnes	1000 tonnes	1000 toe	1000 tonnes	1000 tonnes	1000 tonnes	1000 tonnes	1000 tonnes	1000 tonnes	Million Sm^3	1000 toe	GWh	GWh
1. Production	359	166	972	105744	4446	1048	6367	1712	1174	28711	1105	117506	1551
1.1. Prod. of primary energy sources	359	.	972	105744	[3] 212	.	.	.	[3] 951	28711	.	[2]	.
1.2. Prod. of secondary energy sources	.	166	.	.	4233	1048	6367	1712	222	.	1105	117506	1551
2. Imports	617	788	1	1120	390	150	610	639	972	-	-	1380	-
3. Exports	168	111	-	92568	2852	345	3839	1444	1181	25721	-	10109	-
4. Bunkering [4]	-	-	-	-	-	-	211	280	-	-	-	.	-
5. Changes in stocks (+ net decrease, - net increase)	-155	15	..	-595	20	-13	-3	0	-7	.	-	.	.
6. Gross inland availabilities (1+2-3-4+5)	653	858	973	13702	2003	840	2925	628	959	2991	1105	108777	1551
8. Energy converted	27	16	100	13519	218	37	62	714	5	-	2	383	-
8.1. In blast furnaces	-	16	-	-	-	-	-	-	-	-	-	-	-
8.2. In crude petroleum refineries	-	-	-	13519	218	37	59	714	5	-	-	-	-
8.3. In thermal power plants	-	-	-	-	-	-	1	0	-	-	-	-	-
8.4. In power plants for combined generation of electric energy and heat	27	-	48	-	-	-	-	-	-	-	-	-	-
8.5. In district heating plants	-	-	52	-	-	-	1	0	-	-	2	383	-
9. Consumption by energy producing industries	-	-	-	-	4	0	89	6	-	2893	782	2196	-
9.1. Crude petroleum and natural gas production	-	-	-	-	-	-	76	2	-	2893	-	140	-
9.2. Coal mines	-	-	-	-	0	0	4	-	-	-	-	23	-
9.3. Petroleum refineries	-	-	-	-	0	-	2	4	-	-	781	472	-
9.4. Pumping storage power plants	-	-	-	-	-	-	-	-	-	-	-	558	-
9.5. Hydro electric power plants	-	-	-	-	4	0	7	0	-	-	-	938	-
9.6. Thermal power plants	-	-	-	-	-	-	-	-	-	-	-	25	-
9.7. Power plants for combined generation of electric energy and heat	-	-	-	-	-	-	0	-	-	-	-	14	-
9.8. District heating plants	-	-	-	-	-	-	-	0	-	-	-	27	-
10. Consumption for non-energy purposes	.	.	.	.	-	-	-	-	670	-	-	-	-
10.1. In chemical industry	.	.	.	.	-	-	-	-	670	-	-	-	-
10.2. In other industry	.	.	.	.	-	-	-	-	-	-	-	-	-
11. Losses in transport and distribution	..	..	..	..	..	..	..	..	..	..	0	8294	482
12. Statistical differences (6-8-9-10-11-13)	-33	3	0	182	87	155	-83	-404	228	98	-	-1479	0
13. Net inland consumption	659	840	872	-	1695	648	2857	312	55	-	323	99383	1068
14. Industry, mining and quarrying	648	838	461	-	9	1	292	247	53	-	315	44378	221
14.1. Mining and quarrying	-	-	-	-	0	0	10	17	0	-	-	672	-
14.2. Manuf. of paper and paper prod.	9	-	360	-	0	0	3	58	0	-	-	6252	-
14.3. Manuf. of industrial chemicals	-	152	-	-	0	-	3	32	3	-	291	4744	89
14.4. Manuf. of iron, steel and ferro-alloys	417	401	0	-	0	0	4	12	0	-	8	7201	2
14.5. Manuf. of aluminium and other non-ferrous metals	-	158	-	-	0	-	38	17	6	-	15	16421	-
14.6. Other manufacturing industries	223	126	102	-	9	0	235	112	43	-	-	9087	129
15. Transport	-	-	-	-	1683	497	1562	58	-	-	-	670	-
15.1. Railways and subways	-	-	-	-	-	-	33	-	-	-	-	670	-
15.2. Air transport	-	-	-	-	3	497	-	-	-	-	-	-	-
15.3. Road transport	-	-	-	-	1681	-	967	-	-	-	-	-	-
15.4. Coastal shipping	-	-	-	-	-	-	561	58	-	-	-	-	-
16. Fishing	-	-	-	-	3	-	368	3	-	-	-	-	10
17. Agriculture	6	-	-	-	-	1	176	1	-	-	-	678	6
18. Households	5	2	411	-	-	140	167	0	3	-	-	32650	273
19. Other consumers	-	-	-	-	-	10	292	2	-	-	8	21007	558

[1] Includes blast furnace gas, refinery fuel and fuel gas.
[2] Of which electricity produced in thermal power plants, 441 GWh.
[3] Condensate from crude oil and natural gas production.
[4] Delivery to ocean ship traffic, regardless of nationality.

Source: Statistics Norway

b) Energy units, PJ.[1]

	Coal	Coke	Fuel-wood, black liquor, garbage	Crude oil	Petro-leum pro-ducts	Natural gas and other gases	Water-fall energy [2]	Elec-tricity	District heating	Total
1.1. Production of primary energy sources	10	.	42	4547	53	1172	496	-	.	6320
2. Imports	17	25	0	48	121	-	-	5	-	216
3. Exports	5	4	-	3980	419	1050	-	36	-	5494
4. Bunkering	-	-	-	-	20	-	-	-	-	20
5. Changes in stocks (+ net decrease, - net increase)	-4	0	..	-26	0	.	-	.	.	-30
7. Net inland availabilities (1.1+2-3-4+5)	18	21	42	589	-265	122	496	-31	-	992
8. Energy converted	1	0	4	581	43	0	496	1	-	1127
1.2. Production of derived energy sources	.	6	-	.	585	48	-	423	6	1067
9. Consumption by energy producing industries	-	-	-	-	4	152	-	8	-	164
10. Consumption for non-energy purposes	.	.	.	-	31	-	-	-	-	31
11. Losses in transport and distribution	..	..	..	..	..	0	-	30	2	32
12. Statistical differences (7-8+1.2-9-10-11-13)	-1	0	-	8	1	4	-	-5	-	7
13. Net inland consumption	19	26	38	-	241	14	-	358	4	699
13.1. Industry, mining and quarrying	18	26	20	-	26	14	-	160	1	264
13.2. Transport	-	-	-	-	165	-	-	2	-	167
13.3. Other consumers	0	0	18	-	50	0	-	196	3	267
14. Calculated energy consumption [3]	15	21	24	-	99	13	-	358	4	534
14.1. Industry, mining and quarrying	14	21	13	-	22	13	-	160	1	244
14.2. Transport	-	-	-	-	42	-	-	2	-	45
14.3. Other consumers	0	0	11	-	35	0	-	196	3	246
15. Energy losses in final consumption (13-14)	4	5	13	-	142	1	-	-	-	164
15.1. Industry, mining and quarrying	4	5	7	-	4	1	-	-	-	21
15.2. Transport	-	-	-	-	123	-	-	-	-	123
15.3. Other consumers	0	0	6	-	15	0	-	-	-	21

[1] The energy balance has been derived from the energy balance of energy sources.

[2] Electricity is treated as secondary energy. Waterfall energy is the primary energy source for the electricity produced in hydro power stations. It is estimated that 15 per cent, in average, 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 with thermal efficiency coefficients.

Source: Statistics Norway

Appendix 4. Energy accounts. 1992

a) Energy sectors, physical units[1]

	Coal	Coke[2]	Fuel-wood, wood waste, waste	Crude oil	Natural gas	Other gases, liquefied gas	Gasoline	Kerosene	Medium distillates	Heavy fuel oil	Electricity	District heating
	1000 t	1000 t	1000 toe	1000 t	Mill. Sm^3	1000 toe	1000t	1000t	1000t	1000t	GWh	GWh
Extraction of energy sources	359	-	-	105744	28711	1020[3]	212[4]	-	-	-	117062	-
Energy use in extraction sectors	-	-	-	-	-2893[5]	-	-4	-10	-220	-2	-1659	-
Imports and Norwegian purchases abroad	617	788	1	1120	-	1042	419	249	1989	2632	1380	-
Exports and foreign purchases in Norway	-168	-111	0	-92568	-25721	-1266	-2881	-425	-3879	-1520	-10109	-
Stocks (+ Decrease, - Increase)	-155	15	.	-594	.	-7	20	-13	-3	0	.	.
Primary supply	653	693	1	13702	98	789	-2234	-199	-2113	1111	106674	-
Petroleum refineries	-	166	-	-13519	-	233	3969	1010	6305	946	-472	-
Other energy sectors, other supply	-27	-	871	-	-	315	47	1	-3	47	-5	1551
Registered losses, statistical errors	33	-3	-	-182	-98	-245	-87	-155	83	404	-6814	-482
Registered use outside energy sectors	659	855	872	-	-	1092	1695	657	4273	2509	99383	1068

[1] Including energy goods used as raw materials. [2] Including petrol coke. [3] Natural gas liquids from Kårstø. [4] Condensate from Kårstø.
[5] Including gas terminal.

Source: Statistics Norway

b) Outside the energy sectors. Physical units[1]

	Coal	Coke[2]	Fuel-wood, wood waste, waste	Other gases liquefied gas	Gasoline	Kerosene	Medium distillates	Heavy fuel oil	Electricity
	1000 t	1000 t	1000 toe	1000 toe	1000 t	1000 t	1000 t	1000 t	GWh
TOTAL	659	855	872	1092	1695	657	4273	2509	99383
PRODUCTION SECTORS, ESTABLISHMENTS									
Agriculture and fishery	6	-	-	-	16	1	568	4	678
Agriculture	6	-	-	-	12	1	160	1	678
Forestry	-	-	-	-	1	-	16	-	-
Fishery	-	-	-	-	3	-	392	3	-
Mining	-	-	-	0	0	0	35	17	672
Metal ore mining	-	-	-	0	0	0	9	16	461
Other mining	-	-	-	0	0	0	26	1	212
Manufacturing	648	854	461	1081	9	0	349	231	43706
Manufacturing of food, beverages etc.	1	-	0	6	3	0	94	66	2903
Manufacturing of textiles, leather etc.	-	-	-	0	0	0	5	2	210
Manufacturing of wood and wood products	-	-	100	0	0	0	13	4	738
Manufacturing of paper and paper products	9	-	360	0	0	0	5	58	6252
Printing, publishing etc.	-	-	-	2	1	0	2	0	427
Manufacture of industrial chemicals	-	152	-	1012	0	-	7	32	4744
Manufacture of other chemical products, petroleum, coal, rubber and plastic products	88	110	-	3	0	-	29	15	1028
Manufacture of cement and lime	121	7	-	0	-	-	3	2	226
Manufacture of other mineral products	13	9	-	8	0	0	18	19	744
Manufacture of iron and steel	60	1	-	0	0	-	2	12	681
Manufacture of ferro-alloys	357	416	0	0	0	0	4	-	6520
Manufacture of aluminium	-	144	-	1	0	-	34	4	14306
Manufacture of other metals	-	14	-	20	0	-	8	13	2115
Rolling and founding of metals	-	-	0	0	0	0	3	-	189
Manufacture of fabricated metal products, machinery and equipment, other manufacturing industries	-	0	1	8	3	0	47	3	2621
Oil drilling	-	-	-	-	-	-	77	-	-
Construction	-	-	-	-	7	1	148	-	430
Wholesale and retail sale, hotels and restaurants	-	-	-	-	194	3	167	0	5263
Wholesale and retail sale	-	-	-	-	192	3	156	0	3986
Hotels and restaurants	-	-	-	-	2	-	11	-	1277
Transport, storage and communication	-	-	-	-	61	421	2588	2255	1523
Railway, tramway, subway and scheduled motor bus	-	-	-	-	0	-	150	-	670
Taxi and other unscheduled passenger transport by road	-	-	-	-	13	-	18	-	-
Other land transport	-	-	-	-	9	-	528	-	-
Ocean transport	-	-	-	-	-	-	1525	2197	-
Coastal and inland water transport	-	-	-	-	-	-	345	58	-
Air transport	-	-	-	-	3	421	-	-	-
Supporting transport activities	-	-	-	-	3	-	17	-	298
Post and telecommunications	-	-	-	-	32	-	5	-	555
Financial institutions, insurance, real estate and business services	-	-	-	-	53	0	16	-	1844
Other private service industries	-	-	-	-	30	5	46	0	2964
PRODUCTION SECTORS, GENERAL GOVERNMENT	-	-	-	8	4	85	144	1	9653
Public administration except defence	-	-	-	-	2	-	11	-	1832
Education and research	-	-	-	-	-	-	15	-	2512
Health, social work, veterinary services	-	-	-	-	-	0	36	1	3852
Other public services	-	-	-	8	2	85	82	-	1457
PRIVATE HOUSEHOLDS	5	2	411	3	1321	140	213	0	32650

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

[2] Including petrol coke.

Source: Statistics Norway

c) Outside the energy sectors. Energy units (PJ)[1]

	Coal	Coke[2]	Fuel-wood, wood waste, waste	Crude oil	Natural gas	Other gases, liquefied gas	Gasoline	Kerosene	Medium distillates	Heavy fuel oil	Electricity	District heating	Total
Extraction of energy sources	10	-	-	4547	1172	44[3]	9[4]	-	-	-	421	-	6204
Energy use in extraction sectors	-	-	-	-	-118[5]	-	0	0	-9	0	-6	-	-134
Imports and Norwegian purchases abroad	17	25	0	48	-	45	18	11	86	107	5	-	362
Exports and foreign purchases in Norway	-5	-4	-	-3980	-1050	-54	-126	-18	-167	-62	-36	-	-5503
Stocks (+ Decrease, - Increase)	-4	0	.	-26	.	0	1	-1	0	0.	.		-30
Primary supply	18	21	0	589	4	34	-98	-9	-91	45	384	-	898
Petroleum refineries	-	6	-	-581	-	10	174	44	272	38	-2	-	-39
Other energy sectors, other supply	-1	-	38	-	-	14	2	0	0	2	0	6	60
Registered losses, statistical errors	1	0	-	-8	-4	-11	-4	-7	4	16	-25	-2	-38
Registered use outside energy sectors	19	27	38	-	-	47	74	28	184	102	358	4	880
Ocean transport	-	-	-	-	-	-	-	-	66	89	-	-	155
Domestic use	19	27	38	-	-	47	74	28	118	13	358	4	725
Agriculture and fishery	0	-	-	-	-	-	1	0	24	0	2	0	28
Energy intensive manufacturing	12	23	0	-	-	44	0	0	2	2	102	0	186
Other manufacturing and mining	7	4	20	-	-	2	0	0	14	8	58	1	113
Other industries	-	-	-	-	-	0	15	22	68	2	78	2	189
Private households	0	0	18	-	-	0	58	6	9	0	118	1	210

1 Including energy goods used as raw materials.
2 Including petrol coke.
3 Natural gas liquids from Kårstø.
4 Condensate from Kårstø.
5 Including gas terminal.

Source: Statistics Norway

Appendix 5. Basic emission factors for road traffic

The original reference to all factors may be found in the report *Emissions from road traffic in Norway - Method for estimation, input data and emission estimates*, State Pollution Control Authority 93:02.

Light vehicles

Cold start emissions (20°C)

Technology	Model year	NO_x g/start	NMVOC g/start	Consumption l/start
Passenger cars, gasoline				
Pre ECE	-74	-1,0	5,34	0,12
ECE 15.00	74-77	-1,0	4,17	0,11
ECE 15.02	78-79	-0,8	4,17	0,10
ECE 15.03	80-84	-0,9	4,17	0,10
ECE 15.03/04	85-88	-0,9	3,78	0,09
US-83	89-92	1,1	1,94	0,07
Passenger cars, LPG	92-	1,1	0,58	0,10
Passenger cars, diesel				
No control	-91	0,2	0,29	0,06
US-87	91-	0,2	0,16	0,06
Light duty, gasoline				
L2				
Pre ECE	-74	-1,2	6,11	0,14
ECE 15.00	74-77	-1,2	4,85	0,13
ECE 15.02	78-79	-0,9	4,85	0,12
ECE 15.03	80-84	-1,0	4,85	0,12
ECE 15.03/04	85-92	-1,0	4,37	0,10
US-90	93-	2,0	3,88	0,08
L3				
Pre ECE	-74	-1,3	7,08	0,16
ECE 15.00	74-77	-1,3	5,53	0,15
ECE 15.02	78-79	-1,1	5,53	0,13
ECE 15.03	80-84	-1,2	5,53	0,13
ECE 15.03/04	85-92	-1,2	5,04	0,12
US-90	93-	2,0	3,88	0,09
Light duty, LPG				
L2	93-	2,0	1,16	0,10
L3	93-	2,0	1,16	0,11
Light duty, diesel				
L2				
No control	-93	0,30	0,44	0,08
US-87	93-	0,30	0,31	0,08
L3				
No control	-93	0,30	0,44	0,09
US-87	93-	0,30	0,31	0,09

Urban emissions

Technology	Model year	NO_x g/km	NMVOC g/km	Consumption l/10 km
Passenger cars, gasoline				
Pre ECE	-74	1,9	3,10	1,35
ECE 15.00	74-77	1,9	2,43	1,25
ECE 15.02	78-79	1,6	2,43	1,15
ECE 15.03	80-84	1,7	2,43	1,15
ECE 15.03/04	85-88	1,8	2,23	1,05
US-83	89-92	0,10	0,02	1,0
Passenger cars, LPG	92-	0,09	0,02	1,3
Passenger cars, diesel				
No control	-91	0,6	0,19	0,7
US-87	91-	0,6	0,11	0,7
Light duty, gasoline				
L2				
Pre ECE	-74	2,2	3,59	1,55
ECE 15.00	74-77	2,2	2,81	1,44
ECE 15.02	78-79	1,8	2,81	1,32
ECE 15.03	80-84	2,0	2,81	1,32
ECE 15.03/04	85-92	2,1	2,62	1,21
US-90	93-	0,18	0,03	1,15
LPG	93-	0,18	0,03	1,50
L3				
Pre ECE	-74	2,5	4,17	1,80
ECE 15.00	74-77	2,5	3,20	1,66
ECE 15.02	78-79	2,1	3,20	1,53
ECE 15.03	80-84	2,3	3,20	1,53
ECE 15.03/04	85-92	2,4	3,01	1,40
US-90	93-	0,18	0,03	1,33
LPG	93-	0,18	0,03	1,73
Light duty, diesel				
L2				
No control	-93	0,90	0,29	0,91
US-87	93-	0,80	0,21	0,91
L3				
No control	-93	1,0	0,29	1,05
US-87	93-	0,9	0,21	1,05

Rural 50-70 km/h. Assumed average speed 60 km/h.

Technology	Model year	NO_x g/km	NMVOC g/km	Consumption l/10 km
Passenger cars, gasoline				
Pre ECE	-74	2,5	1,75	0,90
ECE 15.00	74-77	2,5	1,36	0,70
ECE 15.02	78-79	2,2	1,36	0,68
ECE 15.03	80-84	2,3	1,36	0,68
ECE 15.03/04	85-88	2,4	1,16	0,61
US-83	89-92	0,14	0,03	0,60
LPG	92	0,12	0,03	0,78
Passenger cars, diesel				
No control	-91	0,60	0,19	0,50
US-87	91-	0,55	0,10	0,50
Light duty, gasoline				
L2				
Pre ECE	-74	2,9	2,04	1,04
ECE 15.00	74-77	2,9	1,55	0,81
ECE 15.02	78-79	2,5	1,55	0,78
ECE 15.03	80-84	2,7	1,55	0,78
ECE 15.03/04	85-92	2,8	1,36	0,70
US-90	93-	0,25	0,07	0,69
LPG	93-	0,25	0,07	0,90
L3				
Pre ECE	-74	3,3	2,33	1,2
ECE 15.00	74-77	3,3	1,84	0,93
ECE 15.02	78-79	3,0	1,84	0,90
ECE 15.03	80-84	3,1	1,84	0,90
ECE 15.03/04	85-92	3,2	1,55	0,81
US-90	93-	0,25	0,07	0,80
LPG	93-	0,25	0,07	1,04
Light duty, diesel				
L2				
No control	-93	0,80	0,25	0,65
US-87	93-	0,70	0,19	0,65
L3				
No control	-93	0,90	0,29	0,75
US-87	93-	0,80	0,19	0,75

Rural/highway, speed 80-90 km/h.

Technology	Model year	NOx g/km	NMVOC g/km	Consumption l/10 km
Passenger cars, gasoline				
Pre ECE	-74	2,5	1,46	0,90
ECE 15.00	74-77	2,4	1,16	0,70
ECE 15.02	78-79	2,5	0,97	0,68
ECE 15.03	80-84	2,8	0,87	0,68
ECE 15.03/04	85-88	2,7	0,82	0,61
US-83	89-92	0,14	0,02	0,60
LPG	92	0,11	0,02	0,78
Passenger cars, diesel				
No control	-91	0,5	0,13	0,5
US-87	91-	0,5	0,05	0,5
Light duty, gasoline				
L2				
Pre ECE	-74	2,9	1,65	1,04
ECE 15.00	74-77	2,8	1,36	0,81
ECE 15.02	78-79	2,9	1,16	0,78
ECE 15.03	80-84	3,2	0,97	0,78
ECE 15.03/04	85-92	3,1	0,97	0,70
US-90	93-	0,25	0,05	0,69
LPG	93-	0,25	0,05	0,90
L3				
Pre ECE	-74	3,3	1,94	1,2
ECE 15.00	74-77	3,2	1,55	0,93
ECE 15.02	78-79	3,3	1,26	0,90
ECE 15.03	80-84	3,7	1,16	0,90
ECE 15.03/04	85-92	3,6	1,07	0,81
US-90	93-	0,25	0,05	0,80
LPG	93-	0,25	0,05	1,04
Light duty, diesel				
L2				
No control	-93	0,65	0,17	0,65
US-87	93-	0,65	0,10	0,65
L3				
No control	-93	0,75	0,20	0,75
US-87	93-	0,75	0,10	0,75

Factors for correcting cold start emissions for temperatures other than 20°C

Cold start emission(t)= Cold start emission(20°C)*(1+20°C-t)*factor

Technology	Model year	NO_x	NMVOC	Consumption
Passenger cars, gasoline				
Pre ECE	-74	-0,05	0,09	0,05
ECE 15.00	74-77	-0,05	0,09	0,05
ECE 15.02	78-79	-0,05	0,09	0,05
ECE 15.03	80-84	-0,05	0,09	0,05
ECE 15.03/04	85-88	-0,05	0,09	0,05
US-83	89-92	0,1	0,13	0,08
LPG	92	0,1	0,13	0,08
Passenger cars, diesel				
No control	-91	0,18	0,26	0,04
US-87	91-	0,18	0,26	0,04
Light duty, gasoline				
L2				
Pre ECE	-74	-0,05	0,09	0,05
ECE 15.00	74-77	-0,05	0,09	0,05
ECE 15.02	78-79	-0,05	0,09	0,05
ECE 15.03	80-84	-0,05	0,09	0,05
ECE 15.03/04	85-92	-0,05	0,09	0,05
US-90	93-	0,1	0,13	0,08
LPG	93-	0,1	0,13	0,08
L3				
Pre ECE	-74	-0,05	0,09	0,05
ECE 15.00	74-77	-0,05	0,09	0,05
ECE 15.02	78-79	-0,05	0,09	0,05
ECE 15.03	80-84	-0,05	0,09	0,05
ECE 15.03/04	85-92	-0,05	0,09	0,05
US-90	93-	0,1	0,13	0,08
LPG	93-	0,1	0,13	0,08
Light duty, diesel				
L2				
No control	-93	0,18	0,26	0,04
US-87	93-	0,18	0,26	0,04
L3				
No control	-93	0,18	0,26	0,04
US-87	93-	0,18	0,26	0,04

Factors for correcting ageing

Emission (X(10 000 km) = Emission factor* (1 + X*ageing factor))

Technology	Model year	NO_x	NMVOC	Consumption
Passenger cars, gasoline				
Pre ECE	-74	-0,007	0,02	0,003
ECE 15.00	74-77	-0,007	0,02	0,003
ECE 15.02	78-79	-0,007	0,02	0,003
ECE 15.03	80-84	-0,007	0,02	0,003
ECE 15.03/04	85-88	-0,007	0,02	0,003
US-83	89-92	0,17	0,12	0,002
LPG	92	0,17	0,12	0,002
Passenger cars, diesel				
No control	-91	0	0	0,001
US-87	91-	0	0	0,001
Light duty, gasoline				
L2				
Pre ECE	-74	-0,007	0,02	0,003
ECE 15.00	74-77	-0,007	0,02	0,003
ECE 15.02	78-79	-0,007	0,02	0,003
ECE 15.03	80-84	-0,007	0,02	0,003
ECE 15.03/04	85-92	-0,007	0,02	0,003
US-90	93-	0,01	0,035	0,001
LPG	93-	0,01	0,035	0,001
L3				
Pre ECE	-74	-0,007	0,02	0,003
ECE 15.00	74-77	-0,007	0,02	0,003
ECE 15.02	78-79	-0,007	0,02	0,003
ECE 15.03	80-84	-0,007	0,02	0,003
ECE 15.03/04	85-92	-0,007	0,02	0,003
US-90	93-	0,01	0,035	0,001
LPG	93-	0,01	0,035	0,001
Light duty, diesel				
L2				
No control	-93	0	0	0,001
US-87	93-	0	0	0,001
L3				
No control	-93	0	0	0,001
US-87	93-	0	0	0,001

Correction factors for speeds more than 77 km/h:

Technology	Model year	NO_x	Consumption
Passenger cars, gasoline			
Pre ECE	-74	0,01	0,01
ECE 15.00	74-77	0,01	0,01
ECE 15.02	78-79	0,01	0,01
ECE 15.03	80-84	0,01	0,01
ECE 15.03/04	85-88	0,01	0,01
US-83	89-92	0,01	0,01
LPG	92	0,01	0,01
Passenger cars, diesel			
No control	-91	0,014	0,015
US-87	91-	0,014	0,015
Light duty, gasoline			
L2			
Pre ECE	-74	0,01	0,01
ECE 15.00	74-77	0,01	0,01
ECE 15.02	78-79	0,01	0,01
ECE 15.03	80-84	0,01	0,01
ECE 15.03/04	85-92	0,01	0,01
US-90	93-	0,01	0,01
LPG	93-	0,01	0,01
L3			
Pre ECE	-74	0,01	0,01
ECE 15.00	74-77	0,01	0,01
ECE 15.02	78-79	0,01	0,01
ECE 15.03	80-84	0,01	0,01
ECE 15.03/04	85-92	0,01	0,01
US-90	93-	0,01	0,01
LPG	93-	0,01	0,01
Light duty, diesel			
L2			
No control	-93	0,014	0,015
US-87	93-	0,014	0,015
L3			
No control	-93	0,014	0,015
US-87	93-	0,014	0,015

Heavy vehicles

	Speed	Fuel consumption	Fuel consumption	NO_x	NMVOC
	km/h	g/kWh	kg/km	g/kg	g/kg
Heavy duty, diesel					
Total weight 3,5-10 t					
Before 93					
Urban	32	321	0,22	39	9,2
Rural	60	320	0,18	34	5,7
Highway	75	250	0,17	39	6,9
After 93					
Urban	32	302	0,21	37	4,9
Rural	60	314	0,17	32	3,0
Highway	75	245	0,17	37	3,6
Total weight 10-20 t					
Before 93					
Urban	32	300	0,33	44	8,5
Rural	60	310	0,28	46	5,7
Highway	75	245	0,25	45	6,3
After 93					
Urban	32	294	0,32	26	4,5
Rural	60	304	0,27	27	3,0
Highway	75	240	0,25	27	3,3
Total weight >20 t					
Before 93					
Urban	32	295	0,34	46	8,6
Rural	60	305	0,33	45	5,5
Highway	75	240	0,26	47	6,1
After 93-					
Urban	32	289	0,34	29	4,8
Rural	60	299	0,32	28	3,1
Highway	75	235	0,25	29	3,4
Heavy duty, gasoline					
Total weight >3,5 t					
Urban	32	417	0,225	20	30,5
Rural	60	368	0,15	50	35,9
Bus, diesel					
Total weight >3,5 t					
Before 93					
Urban	23	280	0,40	44	6,4
Rural	60	229	0,25	44	4,0
After 93					
Urban	23	274	0,39	37	3,2
Rural	60	224	0,25	37	2,0
CNG/LNG/ Methane/ Waste gas, city bus		270	0,40	10	2,5
LPG city bus, with TWC*		292	0,42	20	3,6

*Three way catalyst

Ageing factors for heavy duty vehicles (HDV)

Emission (X(10 000 km) = Emission factor* (1 + X*ageing factor))

	Fuel consumption	NO_x	NMVOC
All HDV diesel	0,001	-0,003	-0,005
All HDV gasoline	0,002	-0,007	0,020
from 93 with TWC*	0,002	0,010	0,035
All HDV gas	0,002	-0,007	0,020

* Three way catalyst

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