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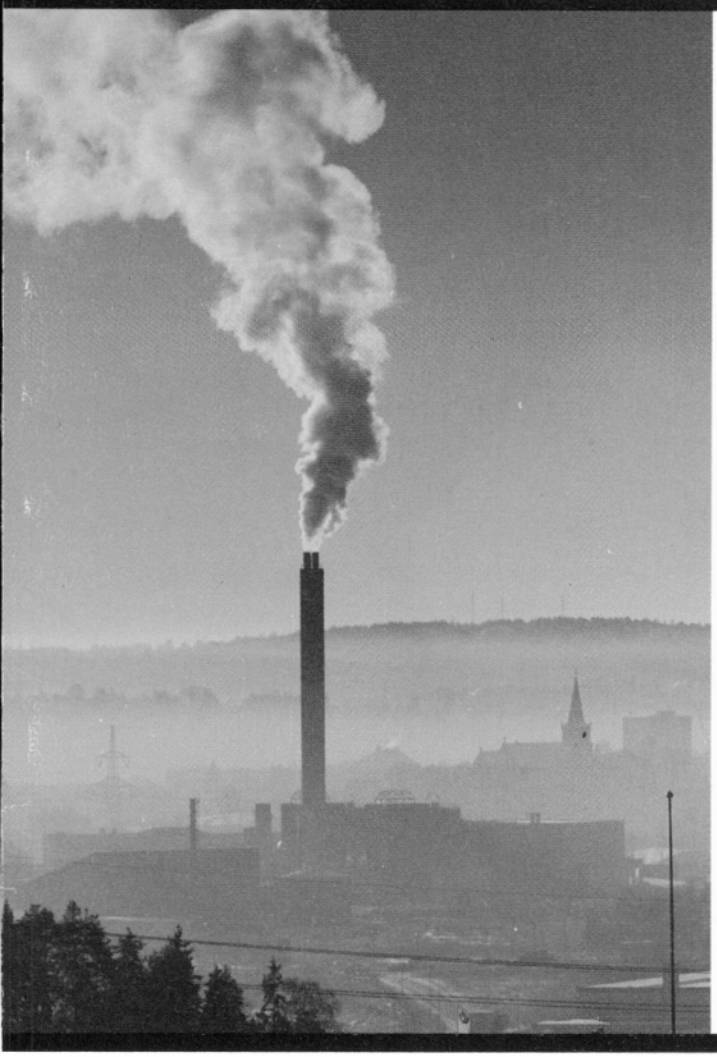

ANTHROPOGENIC EMISSIONS OF THE GREENHOUSE GASES CO_2, CH_4 AND N_2O IN NORWAY

A DOCUMENTATION OF METHODS OF ESTIMATION, ACTIVITY DATA AND EMISSION FACTORS

BY
KRISTIN RYPDAL

STATISTISK SENTRALBYRÅ
CENTRAL BUREAU OF STATISTICS OF NORWAY

Til salgs hos:

Akademika
- avdeling for offentlige publikasjoner
Møllergt. 17
Postboks 8134 Dep
0033 Oslo

Tlf.: 22 11 67 70
Telefax: 22 42 05 51

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By
Kristin Rypdal
Statistics Norway

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EMNEGRUPPE
10 Ressurs- og miljøregnskap og andre generelle ressurs- og miljøemner

EMNEORD
Drivhusgasser
Forurensning
Klimagasser
Luft
Utslipp

Foto: Forside: Frode Brunvoll

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Preface

The methodology for calculating the anthropogenic emissions to air of the greenhouse gases CO_2, CH_4 and N_2O in the Norwegian national emission inventory for 1990 is presented in this report. The emission sources, emission factors, activity data, measurements and other sources for emission estimates are described and the trends in the emissions are discussed.

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

The author is grateful to the following individuals for helpful comments and assistance: Ketil Flugsrud, Lisbet Høgset and Trond Sandmo (Statistics Norway), Audun Rosland (State Pollution Control Authority) and Jon Fredrik Hanssen (Norwegian University of Agriculture).

Statistics Norway, Oslo 6 September 1993

Svein Longva

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1. Introduction

The methodology for estimating anthropogenic emissions of greenhouse gases in Norway in 1990 will be reviewed in this report. The scope is to cover all emissions of CO_2, CH_4 and N_2O. The emission figures are estimated in collaboration between The State Pollution Control Authority (SFT) and Statistics Norway (SN). SFT is responsible for industrial emissions and emission factors generally. SN is responsible for activity data (*e.g.* on energy use), emissions models and calculations.

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 1989 emission methodology was described in the report "Emissions of Greenhouse Gases in Norway -1990. National versus IPCC estimation method (Transparency study)". The current report is an extension of the first half of this report; the combustion emissions of CH_4 and N_2O are described more thoroughly, the trends in emissions are shown and improvements since the 1989 inventory have been taken into account. The documentation of the emission estimates of the pollutants SO_2, NO_X, NMVOC and NH_3 will be published in a separate report.

2. Summary

In the Norwegian emission inventory all emissions are calculated in a four dimensional cube model, with the axes components, technical emission sources, emission carriers (*e.g.* fuels) and economic sectors. Thus, emissions may be listed by a multitude of combinations of fuels, sources and sectors. The combustion emissions are calculated by combining the fuel consumption distributed on 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 special model in a detailed manner. 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. The non-combustion emissions 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 in this century
- A decrease in use of oils for heating the last 15 years
- A decrease in use of gasoline for transport the last few years
- A large increase of natural gas combusted in the North Sea
- A large increase in extraction and transport of crude oil and natural gas
- An increase in landfilled waste in this century
- An increase in use of N-fertilizers in this century
- Increased production of mineral fertilizers
- Measures to reduce emissions: Mainly in the production process of mineral fertilzers and on landfills (incineration of waste and utilization of landfill gas)

The combustion and non-combustion emissions, as estimated in the Norwegian emission

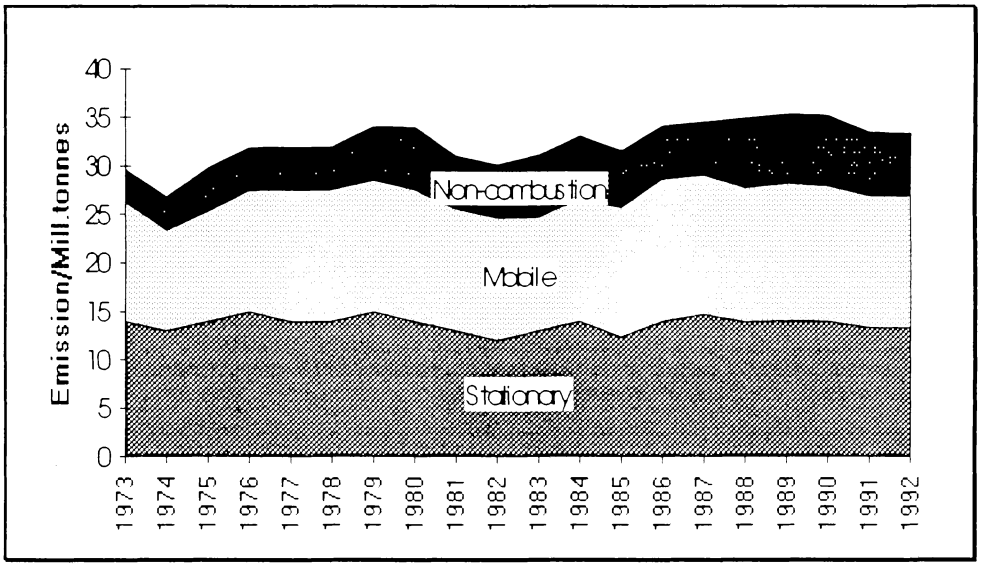
inventory for 1990, are summarized in table 2.1.

Totally 35.2 mill.tonnes CO_2, 281.8 ktonnes CH_4 and 15.6 ktonnes N_2O were emitted in 1990.

The trends in the emissions are shown in figures 2.1, 2.2 and 2.3 for CO_2, CH_4 and N_2O, respectively. The emissions of these greenhouse gases have overall increased in the time periods considered. The emissions of CO_2 have decreased slightly the last few years, mainly due to reduced consumption of heating oils and gasoline in addition to reduced industrial production. The emissions of N_2O have clearly decreased the last three years due to reduced contributions from fertilizer production.

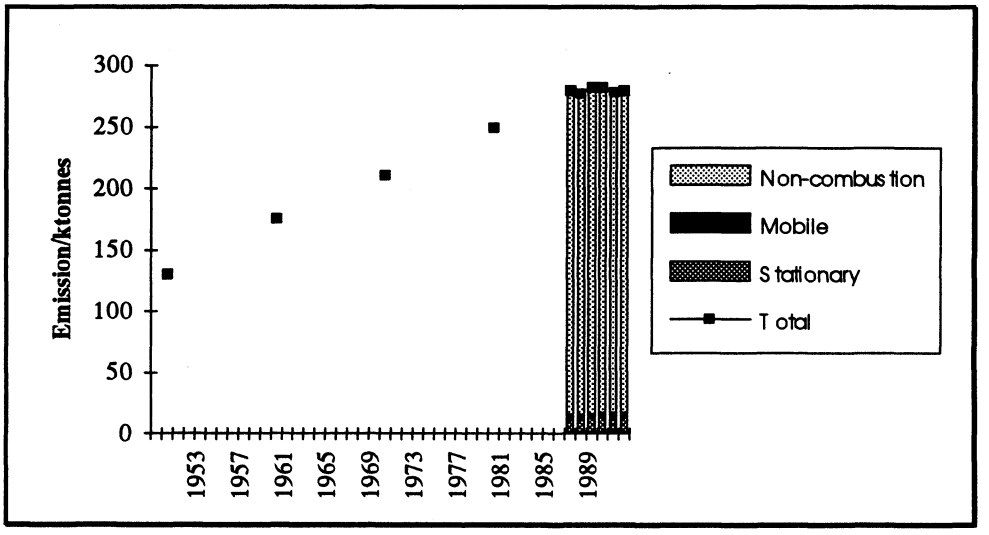
All historical emission figures are updated when emission factors, definitions or methodologies are changed.

Figure 2.1. Emissions of CO_2 by source 1973-1992



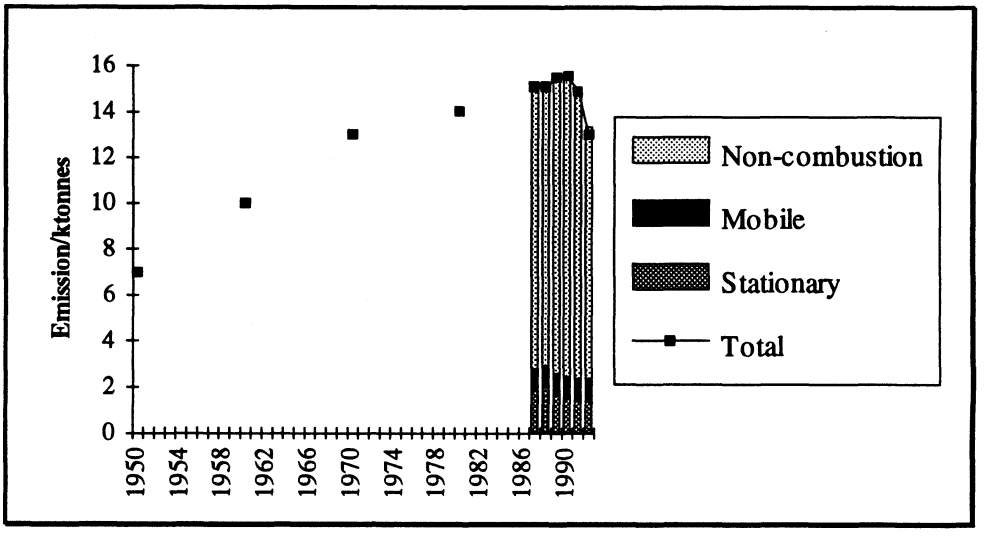
Source: Statistics Norway and the State Pollution Control Authority

Figure 2.2. Emissions of CH_4 by source 1950-1992



Source: Statistics Norway and the State Pollution Control Authority

Figure 2.3. Emissions of N_2O by source 1950-1992



Source: Statistics Norway and the State Pollution Control Authority

The Norwegian national inventory seems to cover all the recognized important sources for the emissions of these three components. 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 recognized uncertainties in many of the emission factors, particularly for the non-combustion emissions of CH_4 and N_2O. Further research is needed in this field to reduce these uncertainties.

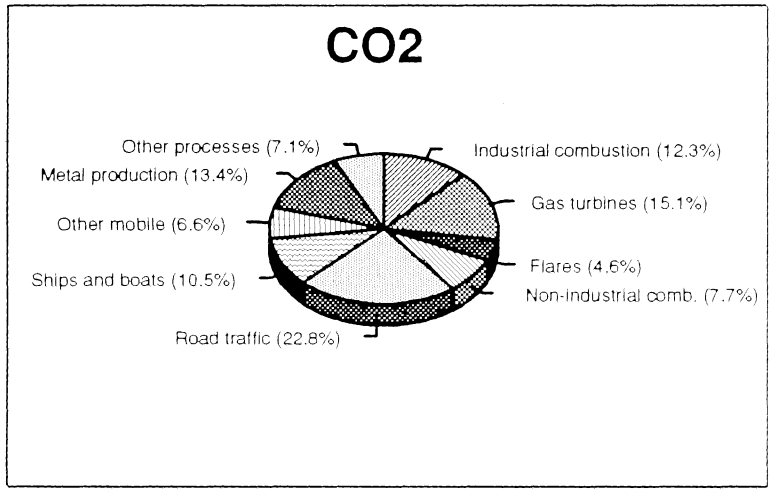
Summary tables of emission factors are given in tables 3.2 (CO_2 from combustion), 3.3. (CH_4 from combustion), 3.4 (N_2O from combustion) and 3.10 (non-combustion).

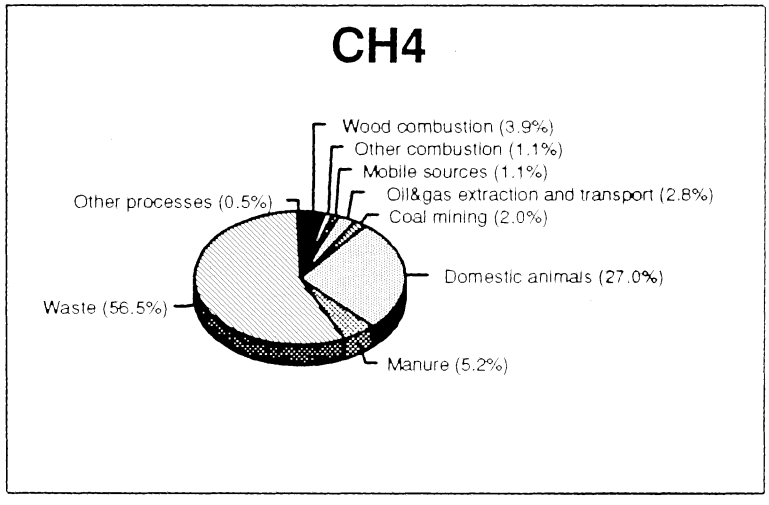
Table 2.1 Emissions of greenhouse gases by source. 1990.
Units: CO_2 in mill. tonnes, CH_4 and N_2O in ktonnes.

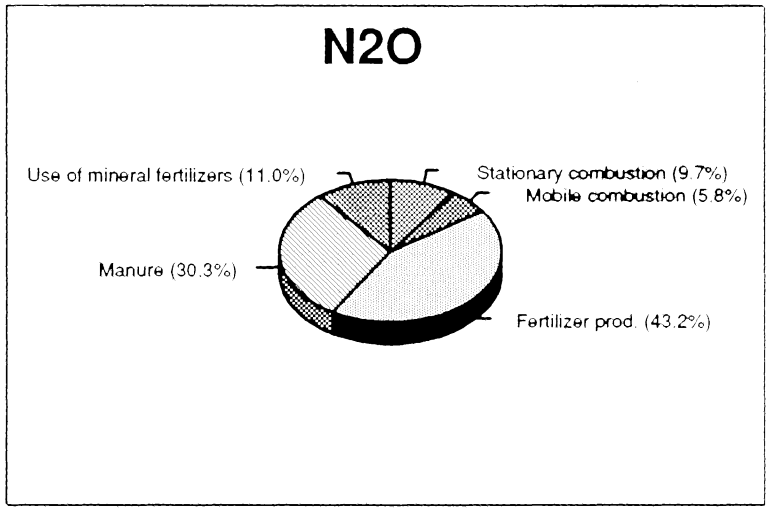
	CO_2	CH_4	N_2O
Total	35.2	281.8	15.6
Stationary combustion	13.9	13.9	1.5
Industrial combustion	4.3	0.4	0.8
Gas turbines	5.3	2.2	0.0
Flares	1.6	0.3	0.0
Non-industrial combustion	2.6	11.0	0.6
Incineration of waste	0.1	0.1	-
Mobile combustion	13.9	3.1	0.9
Road traffic	8.0	1.8	0.6
- Gasoline	5.3	1.7	0.3
- Diesel	2.6	0.1	0.3
Motorcycles, two-stroke engines, tractors and motor-driven tools	0.9	0.2	0.0
Railways	0.1	0.0	0.0
Air traffic	1.3	0.0	0.1
Ships and boats	3.7	1.0	0.2
Non-combustion	7.3	264.8	13.1
Oil & gas extraction and drilling	0.0	5.3	-
Loading of crude oil, offshore	0.2	2.4	-
Loading of crude oil, land	0.1	0.1	-
Coal mining	0.0	5.5	-
Gas terminal	0.0	0.4	-
Cement production	0.7	-	-
Metal production	4.7	-	-
- Ferroalloys	2.8	-	-
- Aluminium	1.6	-	-
- Magnesium	0.1	-	-
- Other metals	0.2	-	-
Carbide production	0.4	1.0	-
Fertilizer production	0.6	-	6.7
Liming	0.2	-	-
- Industrial	0.0	-	-
- Agriculture	0.2	-	-
- Lakes	0.0	-	-
Domestic animals	-	76.2	-
Manure	-	14.8	4.7
Use of mineral fertilizers	-	-	1.7
Waste	0.1	159.2	-

Source: Statistics Norway and the State Pollution Control Authority

Figure 2.4. Emissions of CO_2, CH_4 and N_2O by source. 1990.







Source: Statistics Norway and the State Pollution Control Authority

3 Calculations of emissions to air in Norway

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 calculation methods for the non-combustion emissions are described in section 3.3.

3.1. The Norwegian emission model[1]

3.1.1. Structure

The main activity data for calculating emissions to air is energy use. In the Norwegian energy account 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 (*i.e.* 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 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. A spatial distribution of emissions will introduce another dimension (axis) to this model.

The calculations take place in three steps:

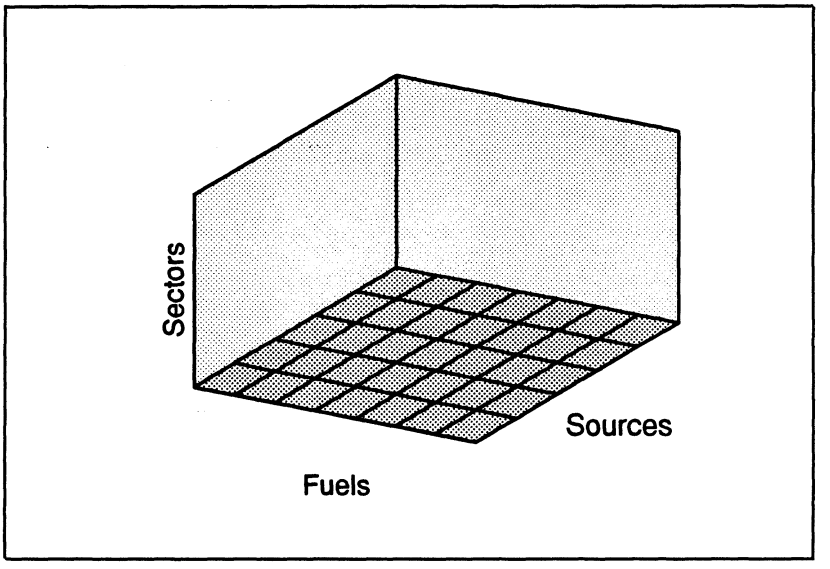
- The combustion emission factors are multiplied by the energy consumption of the energy account, cell by cell, giving the calculated combustion emissions of each pollutant.
- Emissions of some pollutants are measured directly at major manufacturing plants (point sources). When such measured data are available it is possible to replace the calculated values with the measured.
- 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.

---

[1] L. Daasvatn, K. Flugsrud, H. Høie, K. Rypdal and T. Sandmo, Modell for beregning av nasjonale utslipp til luft. Interne notater 92/17. Statistics Norway.

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



$$E_{ijkl} = \left[C_{jkl} - CPS_{jkl}\right] * EF_{ijkl} + EPS_{ijkl} + ENC_{ijkl} \qquad (3.1.)$$

Where

E_{ijkl}	=	Emission of pollutant *i* from combustion of fuel *j* in source *k* in sector *l*.
C_{jkl}	=	Consumption of fuel *j* in source *k* in sector *l*.
CPS_{jkl}	=	Consumption of fuel *j* in source *k* in point sources in sector *l*.
EF_{ijkl}	=	Emission factor for pollutant *i* from combustion of fuel *j* in source *k* in sector *l*.
EPS_{ijkl}	=	Emission of pollutant *i* from combustion of fuel *j* in source *k* in point sources in sector *l*.
ENC_{ijkl}	=	Non-combustion emission of pollutant *i* from emission carrier *j*, source *k* in sector *l*.

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 analysis of origins of emissions are possible, *e.g.* within a certain sector or for a particular pollutant, source or fuel. We have also calculated emission estimates useful for economical analysis without losing the accuracy of more technical approaches.

The main disadvantage is the difficulty in handling several dimensions.

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 and an excess gas (mainly methane and hydrogen) produced and consumed in the chemical industry. These two 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]
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 from a Norwegian economic model called MODIS(IV) (MOdel DISaggregated) which is aggregated from the ISIC classification. This classification is close to the one used in the national accounts. The high number of sectors is an advantage in dealing with important emissions from manufacturing. 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.

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]
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 (onshore)	[Crude oil]
Fertilizer, ammonia and nitric acid prod.	[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	[Petrolcoke]
Silicon carbide production	[Petrolcoke]

Currently ten pollutants are covered by this emission model. In addition to the gases to be discussed in this study (CO_2, CH_4 and N_2O), emissions of SO_2, CO, NOx, Pb, airborne particles, NMVOC and NH_3 are calculated in a uniform manner. This means that the procedure we use for calculating CO_2 emissions is unnecessarily detailed for giving an overall picture. However, nothing is lost in accuracy, and the disaggregation of the various CO_2 sources is important for analysis of the results.

3.1.3. Emission model for road traffic

A model for estimating emissions from road traffic has been developed.[2] The results (as average aggregated emission factors) from this model give input to the general emission model.

Choice of model
A fuel-based model was chosen, where the total consumption of various fuels is the main parameter for determining the emissions. The emission factors will depend on the kind of vehicle, technology, age, fuel type and driving pattern. The total number of vehicle-kilometres driven does not enter the calculations directly, but fractions of it are distributed between the listed parameters. Emission factors may be given as emission per vehicle-kilometres or as emission per unit fuel consumed.

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

$$Q_{jk} = M_k \sum_i p_{ijk} \frac{l_{ik}}{\bar{l}_k} \left(\frac{T_{ik}}{T_k}\right) \qquad (3.2.)$$

$$Q_{jk} = M_k \sum_i q_{ijk} \frac{1}{\bar{l}_k} \left(\frac{T_{ik}}{T_k}\right) \qquad (3.3.)$$

Where:

M_k is total fuel consumption
p_{ijk} is the emission factor [g/kg] for 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]
$\bar{l}_k$ is the average fuel consumption (in kg/km) of fuel k, and is determined by $\sum_k l_{ik} \left(\frac{T_{ik}}{T_k}\right)$

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

- the composition of the vehicle categories
- technologies
- annual average of kilometres driven per vehicle
- driving patterns

[2] J. Bang, E. Figenbaum, K. Flugsrud, S. Larssen, K. Rypdal and C. Torp. Utslipp fra veitrafikken i Norge - Dokumentasjon av beregningsmetode, data og resultater. Statens forurensningstilsyn 93:12.

Parameters
The following variables are considered:

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

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 heavy duty	3.5 - 10 t	..
"	Medium heavy duty	10 - 20 t	..
"	Heavy heavy duty	> 20 t	..
"	Bus	> 3.5 t	..
LPG	"Passenger car"	< 3.5 t	< 760 kg
"	Bus	> 3.5 t	..
Natural gas	Bus	> 3.5 t	..

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

- 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 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 each class.
- Average annual mileage distributed between the age classes within each vehicle category.
- Driving pattern: Three 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 the vehicle category, technology class, ageing of the vehicle and driving pattern.
- 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 the 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 the vehicle category and technology class.

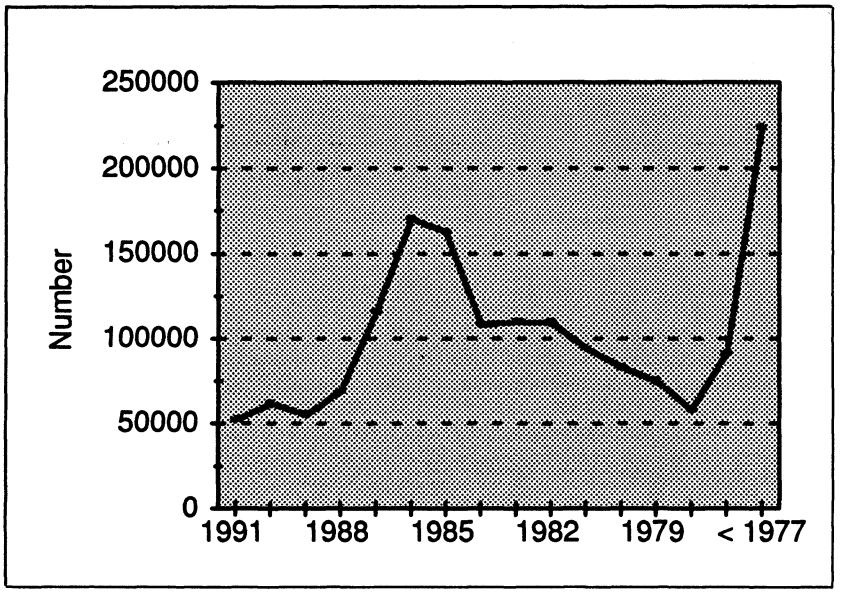
Sources of data

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

- Total fuel consumption: The total amounts of fuels consumed are corrected for off-road use (*e.g.* in small boats, snow scooters, motorized tools etc.). This consumption is estimated from assumptions on the number of units, average use and average fuel consumption or from assumptions 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 by surveys in the Statistics Norway or TØI (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 SN, combined with some assumptions give this distribution.
- Driving pattern: The Directorate of Public Roads have data on the annual number of vehicle-kilometres driven on national and provincial roads. These data are distributed on speed limits and are roughly distributed on vehicle size. Similar data exists for municipal roads in the ten largest cities. The same distribution is assumed on the remainder municipal roads.
- Annual numbers of trips (for the calculation of cold start emissions): TØI has determined the number of trips per vehicle. We have assumed that 2/3 of these trips starts 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. and Appendix 5.

Some basic data applied in the calculation for 1990 are shown in Appendix 2. The age profile of the Norwegian passenger cars in 1991 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 three way catalysts was relatively low in 1990 and 1991.

Figure 3.2. The age distribution of the passenger cars in 1991.



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* analyses 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 made with a much more detailed sector split. It is based on the energy balance, but the figures are corrected for Norwegian consumption abroad and foreign consumption in Norway, *i.e.*, it is supposed to cover Norwegian economical activity. The energy balances and energy accounts for 1990 are shown in appendix 3 and 4, respectively.

The figures reported for emissions to air are based upon 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.[3] *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 (SN) makes an official sales statistics for liquid commercial fuels. The sales statistics give reliable figures for total consumption in Norway. For some sectors, the consumption in the energy accounts will diverge from the energy balance, especially air transport and fishing. Overall consumption in these sectors has to be determined by special investigations.

About half of the energy consumed for inland use in Norway is electricity made from hydro-power. The fractions of various sources of energy used in inland Norway in 1976 and 1991 are shown in figure 3.3.

Solid fuels
Coal or oil fired power plants do not have any importance in Norway. Coal and coke are mainly consumed in manufacturing. 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 industrial consumption is reported directly to SN, but the data for the most important consumers are determined in special investigations. The consumption in private households is more uncertain. It is determined in yearly sample surveys. About 14 percent of the energy used in private households is wood. Three quarters of the households have a wood fuel stove or an open fireplace. In farmhouses, wood is still the most important source of heating in Norway. Waste is partly included in the energy balance and accounts. The amount of waste combusted in large plants is reported to the State Pollution Control Authority (SFT) and SN each year. SFT also has made an estimate of the amount combusted in smaller waste combustion plants. A fraction

[3] Proceedings on the EMEP workshop on emission inventory techniques. Regensburg, Germany. 2-5 july 1991.

of the methane gas produced from solid waste is utilized as energy (section 3.3.4.) or flared. This amount is currently not included in the official energy statistics.

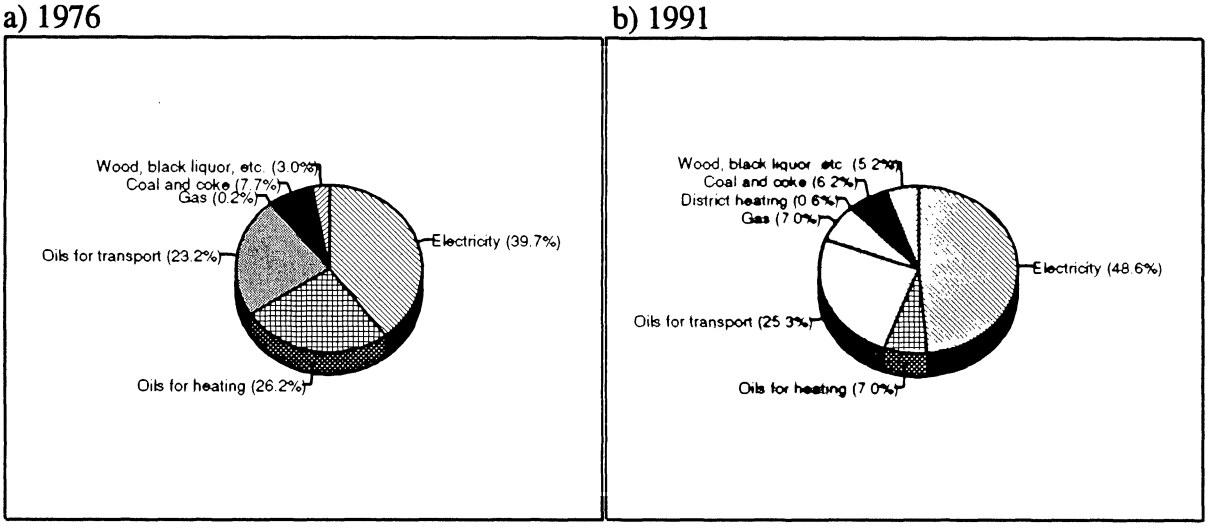
Gaseous fuels

Gas is burned in the manufacturing industries only. The amount of natural gas utilized and flared in the oil and gas sector is reported by 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 Great Britain. 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 a raw material for manufacture of plastics and ammonia. A small amount is combusted in private households.

Liquid fuels

7 per cent of the inland consumption of energy in 1991 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 traffic.

Figure 3.3. Inland energy consumption in Norway (including energy used as raw materials). Distribution on energy source. a) 1976 and b) 1991. The total inland energy consumption was 607 PJ in 1976 and 726 PJ in 1992



Source: Statistics Norway

The figures on production and transformation of commercial fuels are reported to SN by the appropriate industry. Production of crude oil and natural gas is reported by 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 Great Britain. Import, export and changes in stock are taken into account as well.

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

The total consumption from which the emissions in 1990 are calculated and the theoretical energy content of fuels are shown in table 3.1.

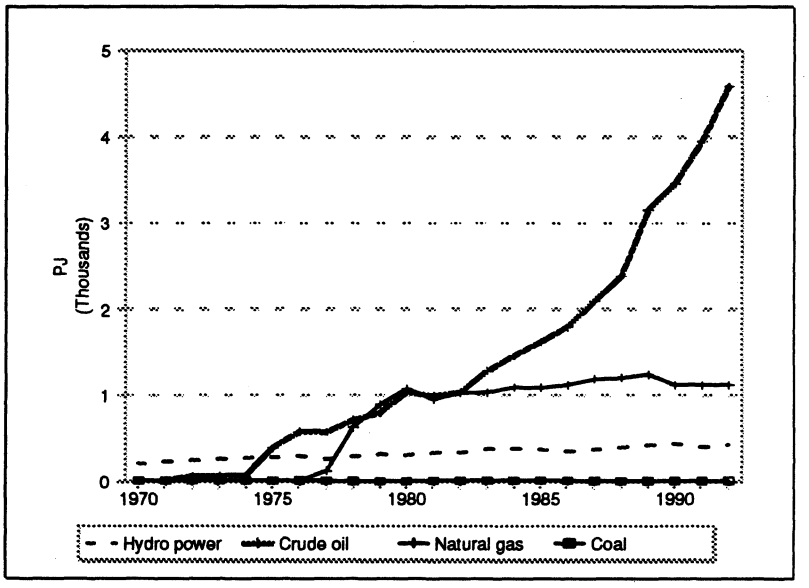
Table 3.1. Energy consumption for calculating emissions from combustion to air, 1990. Energy content of fuels.

Energy	Consumed[a]	Unit	Energy content	Unit
Coal[b]	180	ktonnes	28.1	TJ/ktonnes
Coal coke	15	ktonnes	28.5	TJ/ktonnes
Petrol coke	10	ktonnes	35.0	TJ/ktonnes
Wood etc.	859	ktoe		
- Fuelwood			16.8	TJ/1000 tonnes[c]
- Black liquor			12.6-15.5	TJ/1000 tonnes[c]
- Wood waste			15.0-18.5	TJ/1000 tonnes[c]
Waste	398	ktonnes	10.5	TJ/ktonnes
Gasoline, cars	1,789	ktonnes	43.9	TJ/ktonnes
Gasoline, aviation	3	ktonnes	43.9	TJ/ktonnes
Kerosene, heating	159	ktonnes	43.1	TJ/ktonnes
Kerosene, jet[d]	409	ktonnes	43.1	TJ/ktonnes
Auto diesel	1,067	ktonnes	43.1	TJ/ktonnes
Marine fuel	1,060	ktonnes	43.1	TJ/ktonnes
Heating oils, light	904	ktonnes	43.1	TJ/ktonnes
Heavy oil	477	ktonnes	40.6	TJ/ktonnes
Crude oil	-		39.8-46.2	TJ/ktonnes
Refinery gas	554	ktonnes	48.6	TJ/ktonnes
Refinery gas (flaring)	54	ktonnes	48.6	TJ/ktonnes
LPG	29	ktonnes	46.1	TJ/ktonnes
Excess gas	85	ktonnes	40.0	TJ/ktonnes
Natural gas	2,258	mill.Sm^3	40.5[e]	TJ/mill.Sm^3
Natural gas (flaring)	556	mill.Sm^3	40.5[e]	TJ/mill.Sm^3
Landfill gas	0.8	ktonnes		

a Combustion only. Excluding bunkers.
b Hard coal
c Dry solid fuel
d Consumption of Norwegian aircarft in Norway, all phases of the flight.
e Average 1990. Upper heating value

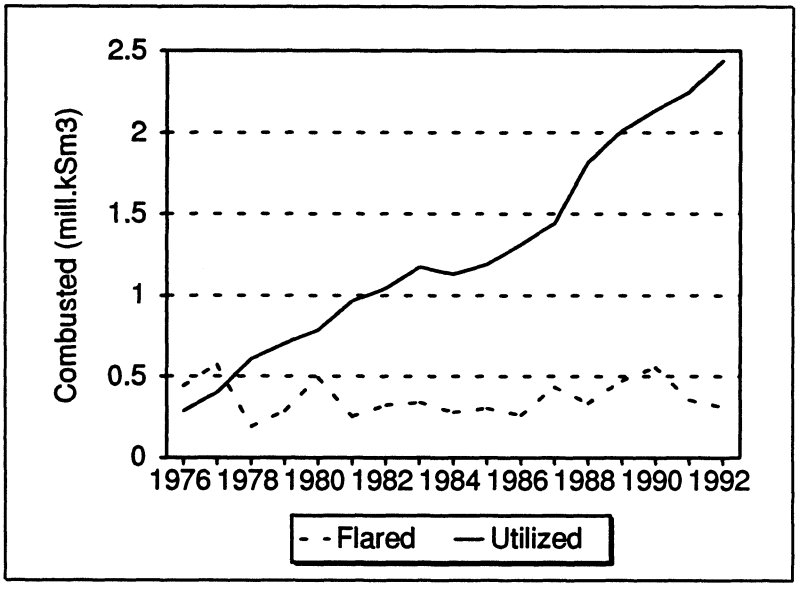
Due to the increasing level of activity in the North sea (figure 3.4.), the amount combusted has increased steadily the last years (figure 3.5.). However, the amount combusted per unit production has decreased. The level of flaring of natural gas has been relatively stable.

Figure 3.4. Production of energy in Norway. 1970-1992. PJ.



Source: Statistics Norway

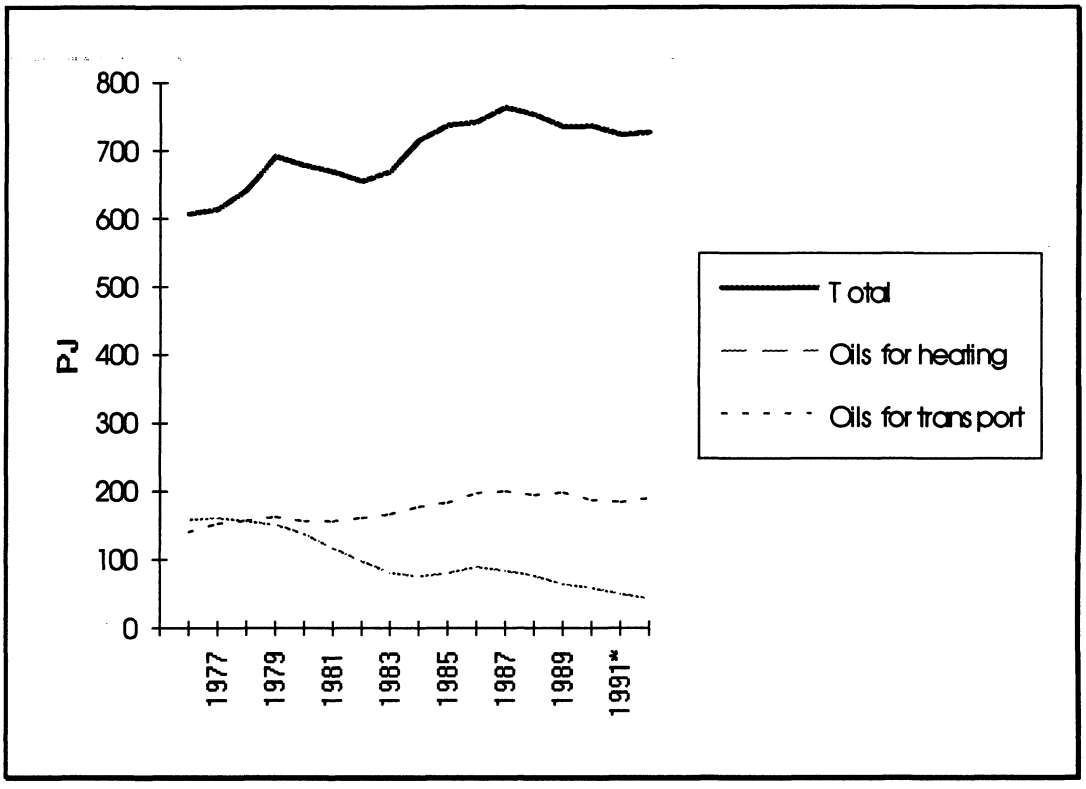
Figure 3.5. Combustion of natural gas in the Norwegian part of the North Sea. 1976-1992. Gas turbines and flares. Billion Sm^3.



Source: Norwegian Petroleum Directorate

The total inland energy consumption has overall increased the last 20 years. However, since 1987 there has been a decrease (figure 3.6.). Throughout the last 20 years the consumption of oils have been substituted by the consumption of electricity. The reduction in use of heating oils has been more than 70 per cent in the period 1976-1992. The consumption of gasoline has decreased since 1989, while the increase in the consumption of auto diesel has stopped.

Figure 3.6. Inland use of energy in Norway. 1976-1992. PJ.



Source: Statistics Norway

In order to calculate the emissions of CH_4 and N_2O we need to differentiate between sources of combustion. Within each economic sector the consumption of each fuel is distributed between the sources available in this model. The distribution is based on knowledge of the activities in the sectors or, if necessary, on special calculations or surveys. The fuels gasoline, auto diesel and marine fuels are generally used for transport. Marine diesel 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. 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

CO_2

For liquid fuels, coal and coke we generally use internationally accepted emission factors reflecting the average carbon content.[4] We do not usually consider net CO_2 emissions from wood/biomass burning since these are regarded as renewable sources of energy. This assumption is appropriate in Norway as the amount of forest is net increasing corresponding to a sink of about 8 million tonnes of CO_2 each year, or about 22 per cent of the total national anthropogenic emission.[5] However, emissions from wood/biomass will be calculated here for comparison. The CO_2 emission factors for combustion of waste and methane from landfills include only the fossil part of the emissions (assumed to be 10 per cent). The CO_2 emission factors for combustion of gases and the gas densities presented in this study have been calculated for the year 1989 from the average chemical compositions of these gases in Norway. Carbon emitted in compounds other than CO_2, *e.g.* as CO, CH_4 and NMVOC, is included in the CO_2 emission estimates. The emission factors applied for the year 1990 are shown in table 3.2.

Table 3.2. Emission factors, CO_2 from combustion. tonnes CO_2/tonne energy and tonnes CO_2/TJ energy.

	tonnes CO_2/tonne	tonnes CO_2/Sm^3	tonnes CO_2/TJ
Coal	2.42		86.1
Coal coke	3.19		111.9
Petrol coke	3.59		102.6
Wood, black liquor etc.	0.0 (1.8)		0.0 (96)
Waste[1]	0.3		28.6
Gasoline	3.13		71.3
Gasoline (aviation)	3.13		71.3
Kerosene (heating)	3.15		73.1
Jet fuel (kerosene)	3.15		73.1
Auto diesel	3.17		73.5
Marine diesel	3.17		73.5
Light heating oils	3.17		73.5
Heavy oil	3.20		78.8
Natural gas	2.75	2.34	57.7
Natural gas (flaring)	2.86	2.43	-
LPG	3.00		65.1
Refinery gas	2.80		57.6
Excess gas	2.50		62.5
Landfill gas (methane)[1]	0.27		

[1] Only taking into account fossil carbon (plastic, rubber, PVC, polyethylene etc.)

[4] Klimagassregnskap, Beskrivelse av utslippsmengder, drivhusstyrke og utslippsfaktorer. Statens forurensningstilsyn 1990. Some of the emission factors have been slightly revised according to information from the Norwegian Petroleum Institute.

[5] A. Lunnan, S. Navrud, P.K. Rørstad, K. Simensen and B. Solberg, Skog og skogproduksjon i Norge som virkemiddel mot CO_2-opphopning i atmosfæren. Skogforsk nr. 6, 1991.

CH_4 and N_2O:
The emission factors applied will in principle depend on the sector/source combination. Unfortunately, the knowledge about the N_2O and CH_4 emission factors is limited and we have not been able to apply a very differentiated set. The emission factors applied for the year 1990 are shown in tables 3.3 and 3.4 for CH_4 and N_2O, respectively. Most of the emission factors for combustion are taken from reference [6]. The emission factor for methane from fuel wood has been derived from a study by NILU.[7] Emission factors for methane from combustion and flaring of natural gas are taken from the OLF study presented in section 3.3.1.

The choice of emission factors and fuel consumption factors for road traffic are explained in reference [8]. Data are determined from driving cycles. Measurements have been performed in Norway, or in Sweden, Germany, EC (CORINAIR) or USA. Methane 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.

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[6] Klimagassregnskap, Beskrivelse av utslippsmengder, drivhusstyrke og utslippsfaktorer. Statens forurensningstilsyn 1990. Some of the emission factors have been slightly revised according to information from the Norwegian Petroleum Institute.

[7] O.A. Braathen, N. Schmidbauer and O. Hermansen, Utslipp av metan og hydrokarboner fra vedfyring. NILU ok28/91 ref:o-89 93. April 1991.

[8] J. Bang, E. Figenbaum, K. Flugsrud, S. Larssen, K. Rypdal and C. Torp. Utslipp fra veitrafikken i Norge - Dokumentasjon av beregningsmetode, data og resultater. Statens forurensningstilsyn 93:12.

Table 3.3 CH_4, 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 oil	Heavy oil
Direct	Generally		0.0				0.1							0.8		0.04
	Structural clay	0.03	0.0	0.0		0.0	0									0.04
	Refineries						0.1									
Turbines	Generally					0.5	0.5									
	Oil and gas extraction					1.1	0.5							0.9		
	Gas terminal					0.8	0.5									
Flaring	Generally					4.2	4.2									
	Oil and gas extraction					0.3	4.2									
	Refineries					4.2	1.5									
Boilers	Generally	0.05	0.05	0.05	0.2	0.1	0.1	0.1			0.1				0.1	0.1
	Industry	0.05	0.05	0.05	0.2	0.1	0.1	0.1			0.1				0.1	0.1
	Private										0.1				0.1	0.1
Small stoves	Generally				9.0						0.1				0.1	
	Private	0.3	0.3	0.05	9.0	0.1	0.1	0.1			0.1					
Passenger cars[1]									1.0				0.2			
Vans[1]									1.0				0.2			
Heavy duty[1]									0.7				0.1			
Railway													0.1			
Aviation, LTO										0.1		0.1				
Aviation, cruise										0.1		0.1				
Motorcycles									5.0							
Mopeds									6.0							
Boat, 2 stroke									1.7							
Boat, 4 stroke									1.7				0.1			
Ships	Generally													0.9	0.9	0.9
	Drilling													0.8		1.9
Tools, 2 stroke									1.7							
Tools, 4 stroke	Generally								1.7				0.3			
	Agriculture/forestry								1.7				0.3			

[1] Average values

Table 3.4 N_2O, 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 oil	Heavy oil
Direct	Generally		0.0				0.2							0.02		0.6
	Structural clay	0.0	0.0	0.0		0.2	0.2									0.6
Turbines	Generally					0.2								0.02		
Flaring	Generally					0.2	0.2							0.02		
Boilers	Generally	0.4	0.4	0.4	0.3	0.2	0.2	0.2			0.6				0.6	0.6
	Industry	0.4	0.4	0.4	0.3	0.2	0.2	0.2			0.6				0.6	0.6
	Private														0.6	0.6
Small stoves	Generally										0.6				0.6	
	Private	0.4	0.4		0.1			0.2			0.6					
Passenger cars [1]									0.1				0.2			
Vans [1]									0.1				0.2			
Heavy duty [1]									0.03				0.4			
Railway													0.2			
Aviation, LTO										0.2		0.2				
Aviation, cruise										0.2		0.2				
Motorcycles									0.05							
Mopeds									0.06							
Boat, 2 stroke									0.04							
Boat, 4 stroke									0.04				0.8			
Ships	Generally													0.2	0.2	0.2
	Drilling													0.02		
Tools, 2 stroke									0.04							
Tools, 4 stroke	Generally								0.04				0.2			
	Agriculture/forestry								0.04				0.2			

[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 ktonne, 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 source, fuel and main sector are shown in tables 3.5, 3.6, and 3.7, respectively.

The gross CO_2 emission from combustion of wood, wood waste, and black liquor was approximately 4.2 mill. tonnes in 1990. The bio mass part of the CO_2 emissions from incineration of waste was about 1100 ktonnes.

Table 3.5 Emissions of greenhouse gases *from combustion* by source. 1990. Units: CO_2 in mill. tonnes, N_2O and CH_4 in ktonnes.

Source	CO_2	CH_4	N_2O
Total combustion	27.8	17.0	2.4
Stationary	13.9	13.9	1.5
Oil and gas extraction	6.6	2.2	0.1
--Natural gas	5.0	1.9	0.0
--Flaring	1.4	0.2	0.0
--Diesel	0.2	0.1	0.0
Oil refineries/gas terminal	2.0	0.2	0.1
Other industry	2.6	0.3	0.7
Non-industry	2.6	11.0	0.6
Incineration of waste	0.1	0.1	-
Mobile	13.9	3.1	0.9
Road traffic	8.0	1.8	0.6
-Gasoline	5.4	1.7	0.3
-- Passenger cars	5.0	1.6	0.2
-- Light duty	0.4	0.1	0.0
-- Heavy duty	0.1	0.0	0.0
-Diesel	2.6	0.1	0.3
-- Passenger cars	0.2	0.0	0.0
-- Light duty	0.3	0.0	0.0
-- Trucks	1.6	0.0	0.2
-- Buses	0.5	0.0	0.0
Motorbikes	0.0	0.0	0.0
Mopeds, snow scooters	0.0	0.1	0.0
Leisure boats	0.1	0.0	0.0
Motorized tools	0.7	0.1	0.0
Railways	0.1	0.0	0.0
Aviation	1.3	0.0	0.1
Ships and boats	3.7	1.0	0.2
- Coastal traffic	1.9	0.5	0.1
- Fishing vessels	1.5	0.4	0.1
- Mobile oil drilling	0.2	0.1	0.0

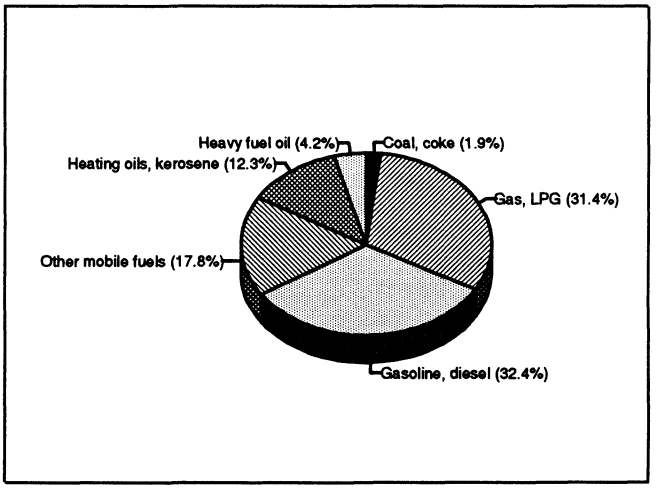
Source: Statistics Norway and State Pollution Control Authority

Table 3.6 Emissions of CO_2 from combustion by fuel. 1990. Mill. tonnes

Total	27.9
Coal	0.4
Coke from coal	0.0
Petrolcoke	0.0
Wood, black liquor	-
Waste	0.1
Natural gas	6.7
Other gas	1.9
LPG	0.1
Gasoline (cars)	5.6
Gasoline (aviation)	0.0
Kerosene (heating)	0.5
Kerosene (aviation)	1.3
Diesel (road)	3.4
Marine fuel	3.4
Light heating oil	2.8
Heavy oil	1.6

Source: SN and SFT

Figure 3.7. Emissions of CO_2 from combustion by fuel. 1990.



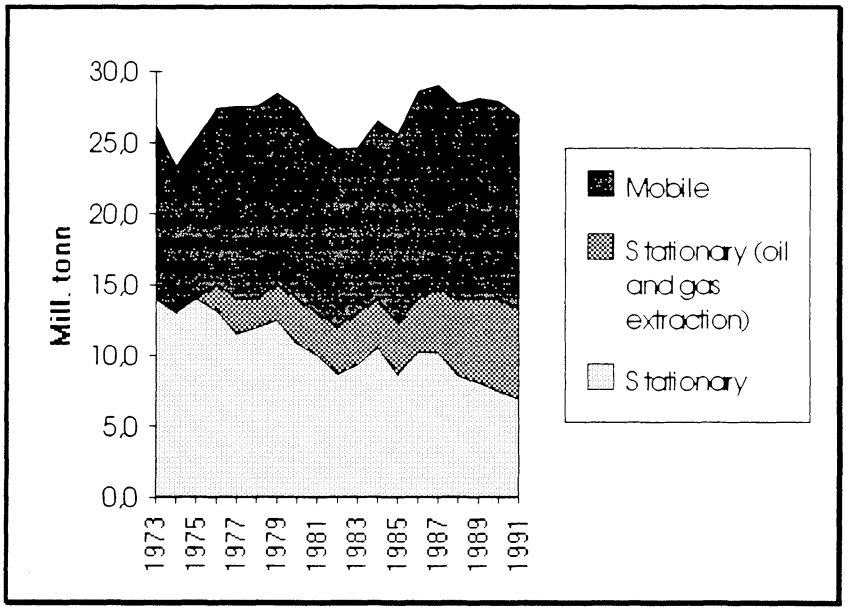
Source: SN and SFT

Table 3.7 Emissions of greenhouse gases from combustion by main sector. 1990. Units: CO_2 in mill. tonnes, N_2O and CH_4 in 1 000 tonnes

	CO_2	CH_4	N_2O
Stationary combustion	13.9	13.9	1.5
Energy sectors	8.8	2.6	0.2
Agriculture, forestry and fisheries	0.2	0.0	0.0
Manufacturing and mining	2.6	0.3	0.7
Services	1.0	0.0	0.2
Private households	1.4	11.0	0.4
Mobile combustion	13.9	3.1	0.9
Energy sectors	0.7	0.2	0.0
Agriculture, forestry and fisheries	2.0	0.5	0.1
Manufacturing and mining	0.4	0.1	0.0
Services	6.4	0.9	0.5
Private households	4.5	1.5	0.2

Source: Statistics Norway and State Pollution Control Authority

Figure 3.8. CO_2 from combustion. 1973-1991. Stationary sources (except oil and gas extraction), Oil and gas extraction (stationary), Mobile sources. Million tonnes



Source: Statistics Norway and State Pollution Control Authority

3.3. Non-combustion emissions

The Norwegian emission inventory covers emissions of SO_2, CO, NO_x, Pb, airborne particles, NMVOC and NH_3, in addition to CO_2, CH_4 and N_2O, 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 sources of relevance for greenhouse gas emissions will be presented in the following sections.

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

3.3.1. Methane from oil and gas extraction and drilling

Extraction of crude oil and natural gas is a source of emissions of methane (and non-methane VOC). Methane 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 methane to the atmosphere. For various reasons these emissions cannot yet be avoided. However, the 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 diffuse emissions. Gas is transported in pipelines. Crude oil is transported on pipelines or by ships. The emissions from pipelines are usually small, and they are included in the diffuse 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 methane source.

The Norwegian oil industry association (OLF) has made a thorough report on emissions from oil and gas extraction activities.[9] 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 was evaluated and analyzed, and specific simulations 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 diffuse emissions originating from transportation of natural gas may mainly be located to the gas terminal (only one in Norway). From measurements this methane emission may be estimated to 0.5 ktonnes in 1990. The CH_4/NMVOC ratio of the emissions varies, but average values may be calculated from the available measurements.

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[9] OLF, Environmental Programme, Emissions to air, Report Phase II

The direct emissions estimated from the OLF project for 1990 were 5.1 tonnes methane and 3.6 tonnes NMVOC. 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	0.031
CH_4	0.044

The estimated emission of methane from testing (pre-production) is 160 tonnes.

The diffuse emissions from oil loading are approximately proportional to the amount crude oil transported by ships. Only two fields use this kind of transportation in Norway, Statfjord and Gullfaks. The amount of crude oil transported is equal to the production at these fields. The VOC evaporation rates have been estimated by the relevant operators from measurements at the two 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 are reduced by 15% from 1989 to 1990 in Norway due to changes in the crude oil washing procedure. Installing recovery systems may reduce these emissions by 70%. However, recovery systems will probably not reduce the methane emissions to any considerable extent.

The calculation methodology is to calculate a total VOC evaporation from the estimated evaporation rate combined with the amount of crude oil transported. The total estimated VOC evaporated from each field is distributed between methane and NMVOC from the measured methane/NMVOC ratio. Calculation of emissions from offshore loading of crude oil:

Field	**Evaporation rate (%)**	**Production (Mtonnes)**	**Methane content (%)**	**tonnes NMVOC**	**tonnes methane**
Statfjord	0.2	32.9*	1.2	65,010	790
Gullfaks	0.07	13.0	17.2	7,535	1,565
Total				72,545	2,355

* Total production at Statfjord (Norwegian *and* British share), because everything is loaded at Norwegian installations.

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 amount of crude oil loaded at these terminals is reported to SN.

The evaporation rate is estimated to be 0.11%. Reduced movements of the ships in port favour smaller evaporation rates than offshore. The methane content of the VOC is estimated to 0.55% at both terminals. The calculation of emissions from crude oil terminals:

	Evaporation rate (%)	Loaded (Mtonnes)	Methane content (%)	tonnes NMVOC	tonnes methane
Total	0.11	23.1	0.55	25,270	140

NMVOC and methane emitted (from non-biological sources) may be considered as indirect CO_2-emissions. These species will be oxidized to CO_2 in the atmosphere. The indirect CO_2-emissions from oil loading amount to 0.3 mill. tonnes.

The gas terminal at Kårstø receives natural gas from pipelines. There is a fairly constant amount of diffuse emissions from various processes in this terminal. The emission estimate is based on measurements. The emissions were estimated to 410 tonnes of methane and 1,580 tonnes of NMVOC in 1990.

A summary of the methane emission estimates from oil and gas extraction activities is given in table 3.8.

Table 3.8. Methane emissions from oil and gas extraction activities. 1990. Tonnes.

Total	**8,165**
Venting and fugitive	5,100
Oil loading, offshore	2,355
Oil loading, on shore	140
Pre-production	160
Gas terminal	410

The Norwegian production of oil and gas has increased as shown in figure 3.4. The methane emissions from oil and gas extraction activities have also increased the last years.

3.3.2. Methane from coal mining

Norway produces coal at Svalbard. The emissions of methane from the mining process are unknown due to lack of relevant measurements. For 1990 we used the IPCC/OECD method for estimating the emission.[10] The amount of coal produced is chosen as activity rate in the report. The emission factors will depend upon several variables. The report recommends to calculate them from the methane content of the coal. The methane content of the Svalbard coal has been measured by "Store Norske Spitsbergen Kulkompani". However, this methane content, about 10% by weight, is extremely high compared with the typical values suggested in the IPCC report. We believe that the scientific definition of "methane content" is unclear.

The Svalbard mines are underground, the coal is hard, although young. We chose to apply the standard method outlined for underground mines in the IPCC report, using the factor 27.1 m^3 CH_4 per tonne coal produced.

[10] OECD. Estimation of greenhouse gas emissions and sinks. Final report. Prepared for IPCC. August 1991.

Production (tonnes)	Coefficient (tonne/tonne)	*Emission* (tonnes)
302,804	0.018	5,450.5

We have not made any attempts to estimate emissions from the degasification system or from post-mining activities.

The activities at Svalbard include Norwegian and Russian extraction of coal. Only the Norwegian emissions are included in our estimates. However, it is not evident that emissions from Svalbard should be included in the Norwegian emission inventory. Emissions at Svalbard are not controlled by Norwegian Authority.

3.3.3. Methane from domestic animals and manure

Domestic animals, especially ruminants, emit CH_4. Although these emissions depend on several factors and vary from individual to individual within one species, we have chosen to apply average emission factors for each species. The chosen emission factors are in reasonable agreement with, although somewhat lower than, those applied in Denmark, the Netherlands and Canada. The emission factor for reindeer has been estimated by scaling the factor for sheep by the animal weights. The appropriate activity data are the average numbers of individuals of each species for a given year. SN publishes official statistics on agriculture each year. The data are based upon sample surveys. The number of animals is recorded at a selected date (1st of July), and does not necessarily equal the yearly average.

Calculation:

Species	Number:	Emission factor (tonne/animal/year)	Emission (tonnes)
Cattle	953,100	0.055	
Sheep	2,231,200	0.008	
Goats	91,500	0.008	
Reindeer	231,501	0.015	
Horses	18,000	0.018	
Pigs	709,700	0.0015	
Humans	4,241,473	$5.0*10^{-5}$	
Hens	3,763,400	$2.0*10^{-5}$	
Chickens	1,659,200	0	
Duck	500	0	
Turkey	30,000	$1.0*10^{-5}$	
Total			76,151

Source: Statistics Norway

Organic material in the manure is transformed to methane with the aid of microbiological processes. Emissions from cattle are most important in Norway. The emissions from manure also depend on several factors; kind of animal, feeding, manure managing, manure storing and the climatic conditions (temperature and humidity).

The emissions are estimated from equation 3.4.

$$Emission = GM * \%VS * B_0 * \%MCF * \rho_{methane} \quad (3.4)$$

Where:

GM	=	Annual production of manure
%VS	=	Fraction volatile solids
B_0	=	Maximum theoretical methane production(m^3 methane/kg-VS)
%MCF	=	Fraction of theoretical potential emitted
$\rho_{methane}$	=	Density of methane

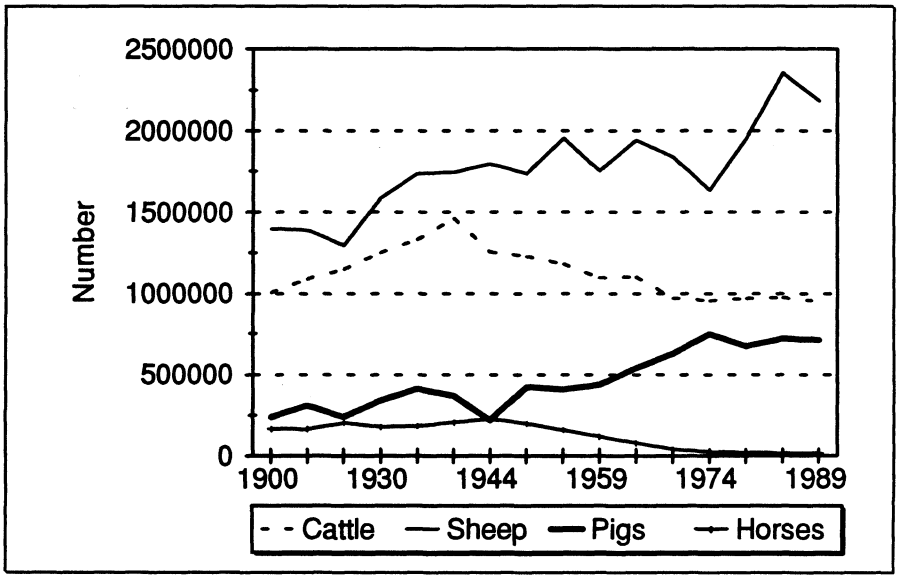
The number of animals is taken from SN's Agricultural Statistics. The values of the other parameters in the calculation have been determined in co-operation with Jon Fredrik Hanssen at the Norwegian University of Agriculture. The values chosen are, as far as possible, corresponding to Norwegian climatic conditions and agricultural procedures. The main uncertainty in this calculation lies in the %MCF (the fraction of the theoretical methane production actually emitted).

Calculation:

	Number	Production	VS	B_0	Max prod.	MCF	Emission
		kg/animal/day	%	m^3/kg-VS	Tonnes	%	Tonnes
Horse	18,000	25.5	16.4	0.21	3,820	8	306
Cattle							10,306
-Ox < 1 year	175,200	15	9.2	0.21	12,268	8	981
-Heifer < 1 year	176,900	15	9.2	0.21	12,387	8	991
-Ox > 1 year	95,000	45	9.2	0.21	19,957	8	1,597
-Heifer > 1 year	172,500	30	9.2	0.21	24,158	8	1,933
-Dairy cow	333,500	45	9.2	0.18	60,051	8	4,804
Sheep							1,404
-< 1 year	1,326,100	1	19.5	0.19	11,872	5	594
-> 1 year	905,100	2	19.5	0.19	16,206	5	810
Goat							74
-Dairy	61,000	1.8	23	0.19	1,159	5	58
-Other	30,500	1	23	0.19	322	5	16
Pig							1,729
-> 6 months.	87,500	9	9.5	0.21	3,796	10	380
-For slaughter	622,200	4.5	9.5	0.21	13,497	10	1,350
Poultry							904
-Hen	3,763,400	0.16	15.6	0.3	6,809	10	681
-Chicken	1,659,200	0.085	19.4	0.3	1,983	10	198
-Duck	500	0.17	16	0.3	1	10	0
-Turkey	30,000	0.7	16	0.3	244	10	24
Reindeer, domestic	231,501	2	19.5	0.19	4,145	2	83
Total					192,675		14,805

During this century the numbers of cattle and horses have decreased, while the numbers of sheep and pigs have increased (figure 3.9.). Another important factor is that the size and feeding of animals also have changed. Thus, the emission per animal per year has probably increased.

Figure 3.9. Numbers of selected domestic animals. 1900-1989



Source: Statistics Norway

3.3.4. Methane and CO_2 from landfills

The biological destruction of waste contributes to emissions of CH_4 and CO_2. This transformation of organic matter takes place in several steps, and the process may last 50-100 years or more. The actual emissions depend on several factors. We use an estimate of 159 ktonnes of CH_4 and 79 ktonnes of CO_2 emitted in 1990.

These values are based on a study made by Berdal Strømme for the State Pollution Control Authority (SFT).[11] Their calculation of emissions are based on several assumptions. Various sources suggest that the theoretical maximum production of gas from waste is approximately 400 Nm^3/tonne waste. A more realistic value for Norway will lay in the interval 100-300 Nm^3/tonne waste. 250 Nm^3/tonne waste has been chosen. The composition of the emitted gas will vary throughout the transformation. As average values 55% methane and 45% CO_2 was chosen. The gas emission reaches its maximum value the first year after deposition. The next 20-30 years the production of gas will be lower and fairly constant. Although the emissions may last 50-100 years or more, it is assumed that the average "lifetime" of gas production is 40 years. The amount of waste deposited is currently approximately 0.5 tonne/citizen each year, but it was lower earlier in the century. An increasing amount of combusted waste has been taken into account. The yearly emissions are estimated to 160,000 tonnes of CH_4 and 36,000 tonnes of CO_2 from the described assumptions and data.

The actual calculated CO_2 emission is 360 ktonnes each year. However, based upon the composition of Norwegian municipal solid waste, it was assumed that only 10% was from fossil carbon. In addition, the methane emitted is a source of indirect CO_2-emissions, as the

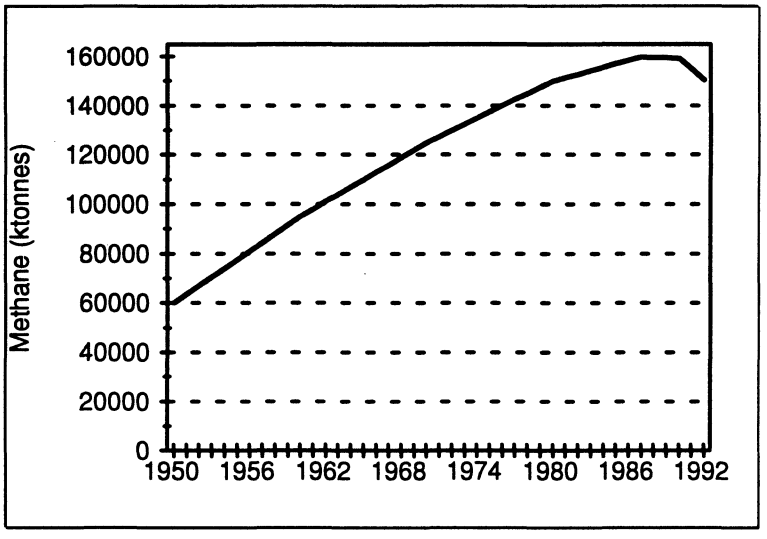
[11] Berdal Strømme, Gass fra avfallsfyllinger i Norge. SFT 1990.

methane will be oxidized in the atmosphere. The fossil part of the indirect emissions amounts to 43,000 tonnes CO_2.

800 tonnes of the methane produced were combusted in 1990. This amount is expected to increase the next years.

The emissions have increased substantially the last 40 years due to the increased amount of waste landfilled. However, utilization of the methane has caused a decrease the last few years (figure 3.10).

Figure 3.10. Methane from landfills. 1950-1992. ktonnes



Source: State Pollution Control Authority

Preliminary estimates of emissions from waste water treatment indicate that these are small in Norway.

3.3.5. Nitrous oxide from use of N-fertilizers and manure

Microbiological processes in soil lead to emissions of N_2O. The man-made part of these emissions is usually considered as proportional to the use of nitrogen fertilizers and manure.

The consumption of mineral fertilizers in Norway for a given year is published in the Agricultural Statistics from SN. In 1990 this consumption was 110,600 ktonnes N. The consumption of manure has been estimated to approximately 100,000 tonnes N each year by the SFT.

The denitrification rate leading to N_2O has been studied by Bakken at the Norwegian University of Agriculture. His results are in good agreement with a Swedish study.[12]

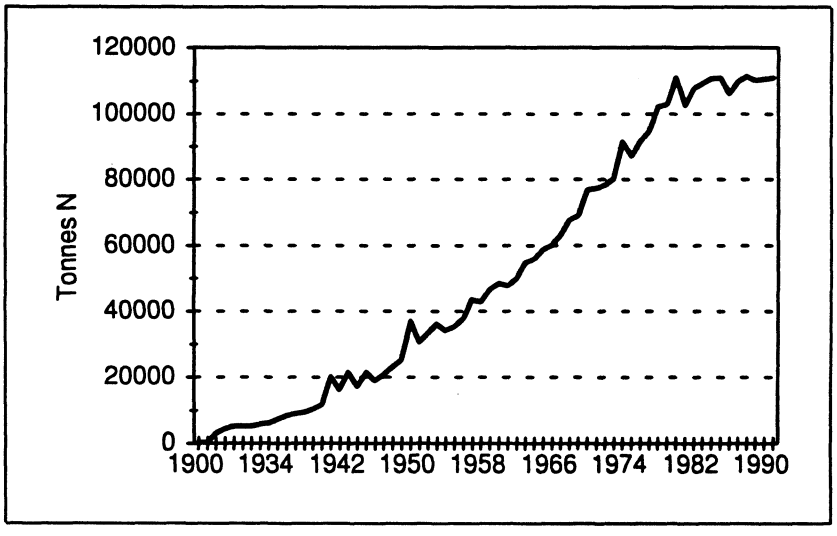
[12] K. Robertsson, Emissions of N_2O in Sweden - Natural and anthropogenic sources, AMBIO, vol 20, 3-4 may 1991, p 151-155.

However, both the emission factors and methods of estimation are highly uncertain. More research is needed in this field.

For 1990 the calculations are:

	% loss as N_2O-N	Consumption (ktonnes N)	Emission N_2O-N (ktonnes)	Emission N_2O (ktonnes)
N-fertilizers:	1	110	1.1	1.7
Manure:	3	100	3.0	4.7
Total:				6.4

Figure 3.11. Application of mineral fertilizers. 1900-1990. Tonnes N



Source: Statistics Norway

3.3.6. Nitrous oxide from 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 in 1990 from measurements. In the newest plants emissions are measured continuously. These measurements show that the N_2O emissions vary considerably from plant to plant and also within one plant. However, as the reported emission estimate is based on many representative measurements, we believe it is reasonable accurate. The emissions were approximately 6,650 tonnes in 1990. The emissions were reduced from this level in 1991, and particularly in 1992.

3.3.7. CO_2 from production of fertilizers

Hydrogen for the ammonia production is produced from hydrocarbon gases (LPG), and CO_2 is emitted. All consumption of gas in this production process is considered as non-energy use. The total amount of gas consumed is known. The chemical composition of this gas is, however, uncertain. We have chosen an average emission factor of 3.0 tonnes CO_2/tonne LPG.

650 ktonnes of CO_2 were emitted in 1990.

The emissions from this source has increased steadily as ammonia earlier was manufactured without use of gas.

3.3.8. CO_2 from cement production

Calcium carbonate, a raw material in the cement production, is transformed to lime and CO_2 during the process. An emission factor has been calculated assuming a CaO content of 63% (by weight) in the cement produced. This gives an emission factor of 0.5 tonne CO_2/tonne produced cement. The production of cement is known from national statistics (SN, manufacturing statistics). For 1990 we calculated:

Production (tonnes)	**Factor (tonnes/tonne)**	***Emission* (ktonnes)**
1,380,143	0.5	690

3.3.9. CO_2 from metal production

Norway has production of ferroalloys, aluminium, nickel, zinc and magnesium. The level of production of iron, steel and ferroalloys has decreased the last few years (figure 3.12.). Coal, coke and/or prebaked anodes are used as reducing agents, and CO_2 is emitted. There are at least two appropriate activity data: The amount of reducing agents consumed or the volume of production. Norway has relatively good data on the volume of production and on consumption of coal and coke as reducing agents. On the other hand, statistics on the use of prebaked anodes is lacking.

For *ferroalloys* the volume of production is the best activity rate, as there is a consumption of prebaked anodes. SINTEF has estimated emission factors for the SFT.[13] The actual emission factor will depend on the kind of ferroalloy produced.

[13] SINTEF- Avd. for metallurgi, Ferrolegeringer og CO_2, STF 34 A 91056.

	Production (tonne)	Factor (tonnes/tonne)	Emission (ktonnes)
Ferrosilicon	4,604,31	3.93	1,809
Silicon metal	79,348	4.27	339
Ferromanganese	174,193	1.57	273
Silicon manganese	193,411	1.71	331
Ferrochromium	73,725	1.31	97
Total:			2,849

CO_2 from processes in the *iron and steel industry* is estimated from the use of coal and coke for non-energy purposes as reported to SN. The calculation in 1990 was:

	Non-energetic use (tonnes)	Factor (tonnes/tonne)	Emission (ktonnes)
Coal	70,300	2.42	170
Coal coke	0	3.19	0
Petrol coke	0	3.59	0
Total			170

Also for *aluminium* manufacturing the volume of production seems to be the best activity rate for estimating the CO_2 emissions. The amount produced is known from the manufacturing statistics (SN). Aluminium is manufactured by two main processes in Norway, the traditional Søderberg method (direct use of coal and coke) and with prebaked anodes. The latter method has lower emission per unit of aluminium produced. However, the manufacturing of prebaked anodes from coal or coke leads to additional CO_2 emissions. About 37% of the total production is by the Søderberg method (1990). The fraction produced by this method is steadily increasing.

The emission factors have been estimated by SFT:

Søderberg	1,850 kg CO_2/tonne Al	37% of production
Prebaked	1,540 kg CO_2/tonne Al	
	230 Baking	
	1,770 kg CO_2/tonne Al	63% of production
Average	1,800 kg CO_2/tonne Al	

This leads to an average CO_2 emission factor of 1.80 tonnes CO_2/tonne aluminium produced.

Production (tonnes)	Factor (tonne/tonne)	*Emission* (ktonnes)
867,061	1.7996	1,560

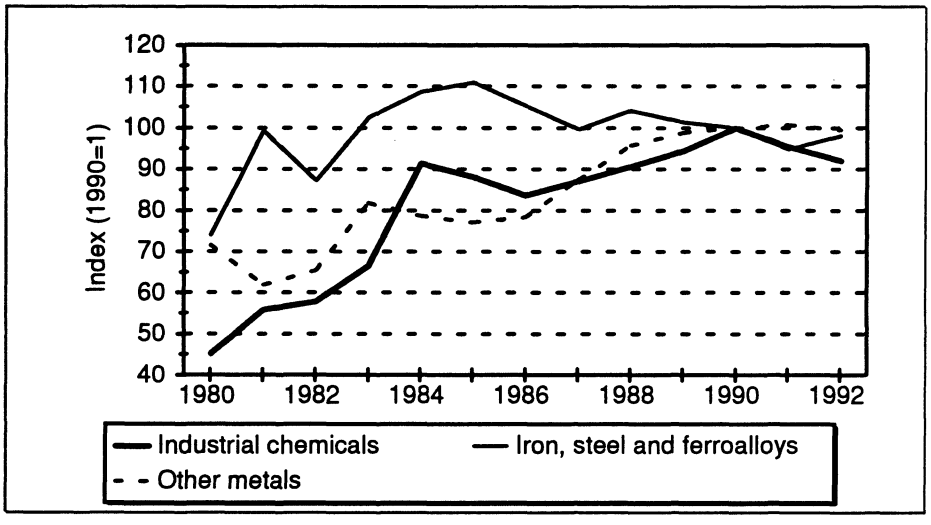
Magnesium is produced from dolomite ($MgCa(CO_3)_2$). Coke is used as an anode in the production process. Carbon in carbonate and coke is emitted as CO_2. The consumption of coke may be chosen as the activity rate in the calculation of the emission from the reduction step. This consumption is reported to the SN and the SFT. The standard CO_2 emission factor for coke from coal, 3.19 tonne CO_2 per tonne coal, is used. 45 ktonnes were emitted from this step in 1990.

The total CO_2 emissions from manufacture of magnesium, reported by Norsk Hydro to SFT, add up to 139 ktonnes in 1990.

The production process of *nickel* and *zinc* does not lead to significant amounts of CO_2. Nickel and zinc are produced by electrolyte electrolysis without use of coal or coke.

The production of ferroalloys has decreased since 1985. The aluminium production has increased until 1989, and decreased since. Although the emissions are not directly proportional to the production they have developed in approximately the same manner.

Figure 3.12. Production indexes. 1980-1992. 1990=100



Source: Statistics Norway

3.3.10. CO_2 and CH_4 from carbide production

Silicon carbide and calcium carbide are produced in Norway.

In the manufacturing of *silicon carbide*, CO_2 is a by-product from a reaction between quartz and carbon as petrol coke. The consumption of petrol coke in the relevant industries, reported to SN, has been chosen as the appropriate activity rate. The following reaction may be assumed:

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

Some carbon, about 35%, is sequestered in the product for a long period of time. If the

average carbon content of the petrol coke is 97% (by weight), an emission factor of 2.3 tonnes CO_2/tonne petrol coke may be calculated.[14]

The emission of CO_2 was estimated to 230 ktonnes in 1990.

In addition, there is an emission of methane in this process. CH_4 may be emitted from the petrol coke in parts of the process. The emission factor has been estimated to 10 kg/tonne petrol coke.[15]

This leads to an emission of 999 tonnes CH_4.

Calcium carbide is made by heating of calcium carbonate, and reduction of the CaO with carbon as petrol coke. Both steps lead to emissions of CO_2. Some of the carbon from petrol coke will be sequestered in the product, but not permanently. Thus, this carbon is included in the emission estimate. The amount of calcium carbide produced each year is the best activity rate in this case. This production is reported to SN. The emission factor has been estimated to 1.8 tonnes/tonne calcium carbide produced.[16]

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

The emission of CO_2 was estimated to 206.6 ktonnes in 1990.

3.3.11. CO_2 from liming

Industry
Sulphuric acid waste from a particular plant is neutralized with limestone. From the equation of reaction an emission factor of 0.45 tonne CO_2/tonne sulphuric acid may be calculated. Approximately 40,000 tonnes sulphuric acid are neutralized each year. This gives an emission of 20 ktonnes CO_2 each year.

Agriculture
Liming of lakes and soil is carried out in Norway in order to reduce the damage from acidification and unbalanced soil. Application of $CaCO_3$ gives rise to emissions of CO_2. The emission factor will theoretically be 0.44 tonne CO_2/tonne calcium carbonate applied. It is however uncertain if all of this is to be considered as a net emission source.

SFT has estimated the consumption of calcium carbonate in agriculture to be approximately 400,000 tonnes each year. About 20,000 tonnes are used in the lakes.

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[14] Ola Kaaness, SINTEF avd. for metallurgi, Silisiumkarbid og CO_2, STF 34 A 91134.
[15] Ola Kaaness, SINTEF avd. for metallurgi, Silisiumkarbid og CO_2, STF 34 A 91134.
[16] Sverre E. Olsen, SINTEF avd. for metallurgi, Kalsiumkarbid og CO_2, STF 34 A91142.

	Consumption (tonnes)	Factor (tonnes/tonne)	Emission (tonnes)
Agriculture	400,000	0.44	176,000
Lakes	20,000	0.44	8,800
Total:			184,800

3.3.12. Summary, non-combustion emissions

The complete Norwegian source list and emissions calculated as outlined in section 3.3 are summarized in table 3.9, the most important emission factors are shown in table 3.10.

Table 3.9. Non-combustion emissions of greenhouse gases by source. 1990. ktonnes

Source	CO_2	CH_4	N_2O
Total	7,265	264.8	13.1
Oil and gas extraction and drilling	25	5.3	-
Loading of oil, offshore	224	2.4	-
Loading of oil, land	76	0.1	-
Coal mining	15	5.5	-
Gas terminal	6	0.4	-
Cement production	690	-	-
Metal production	4,719	-	-
- Ferroalloys	2,849	-	-
- Aluminium	1,560	-	-
- Iron and steel	170	-	-
- Magnesium	139	-	-
Silicon carbide production	230	1.0	-
Calcium carbide production	207	-	-
Fertilizer production	646	-	6.7
Liming	205		
- Industrial	20	-	-
- Agriculture	176	-	-
- Lakes	9	-	-
Domestic animals	-	76.2	-
Manure	-	14.8	4.7
Waste	79	159.2	-
Use of N fertilizers	-	-	1.7
Other indirect	146	-	-

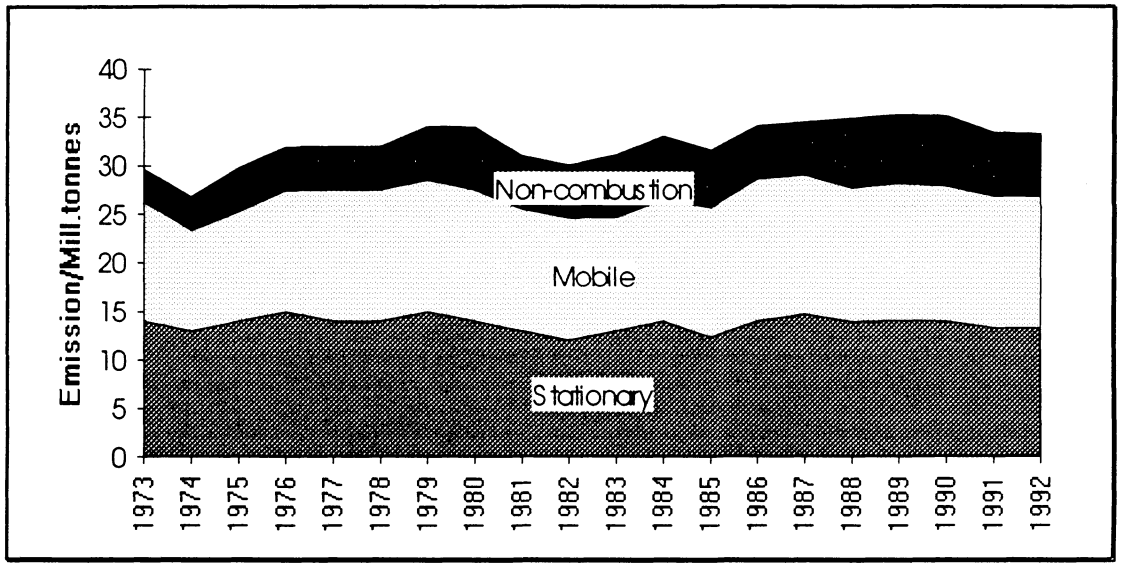
Source: Statistics Norway and the State Pollution Control Authority

Table 3.10. Selected emission factors. Non-combustion emissions. 1990

Source	CO_2	CH_4	N_2O
Oil & gas extraction and drilling	IE	0.044 tonne/ktoe oil and gas	-
Loading of oil, offshore	IE	24-120 tonnes/Mtonne crude oil	-
Loading of oil, land	IE	6 tonnes/Mtonne crude oil	-
Coal mining	IE	0.018 tonne/tonne coal	-
Gas terminal	IE	Measured	-
Cement production	0.5 tonne/tonne cement	-	-
Metal production		-	-
- Ferroalloys	1.3-4.3 tonnes/tonne ferroalloy	-	-
- Aluminium	1.8 tonnes/tonne Al	-	-
- Iron and steel	2.42 tonnes/tonne coal	-	-
- Magnesium		-	-
Silicon carbide production	2.3 tonnes/tonne petrol coke	10 kg/tonne petrol coke	-
Calcium carbide production	1.8 tonnes/tonne calcium carbide	-	-
Fertilizer production	3.0 tonnes/tonne LPG	-	Measured
Liming	0.44 tonne/tonne $CaCO_3$	-	-
Domestic animals			
- Cattle	-	0.055 tonne/animal/year	-
- Pigs	-	0.0015 tonne/animal/year	-
- Sheep	-	0.008 tonne/animal/year	-
Manure			
- Cattle	-	0.011 tonne/animal/year	0.047 tonne/tonne N
- Pigs	-	$2.4*10^{-3}$ tonne/animal/year	0.047 tonne/tonne N
- Sheep	-	$6.3*10^{-4}$ tonne/animal/year	0.047 tonne/tonne N
Waste	0.019 tonne/citizen/year	0.038 tonne/citizen/year	-
Use of N fertilizers	-	-	0.015 tonne/tonne N

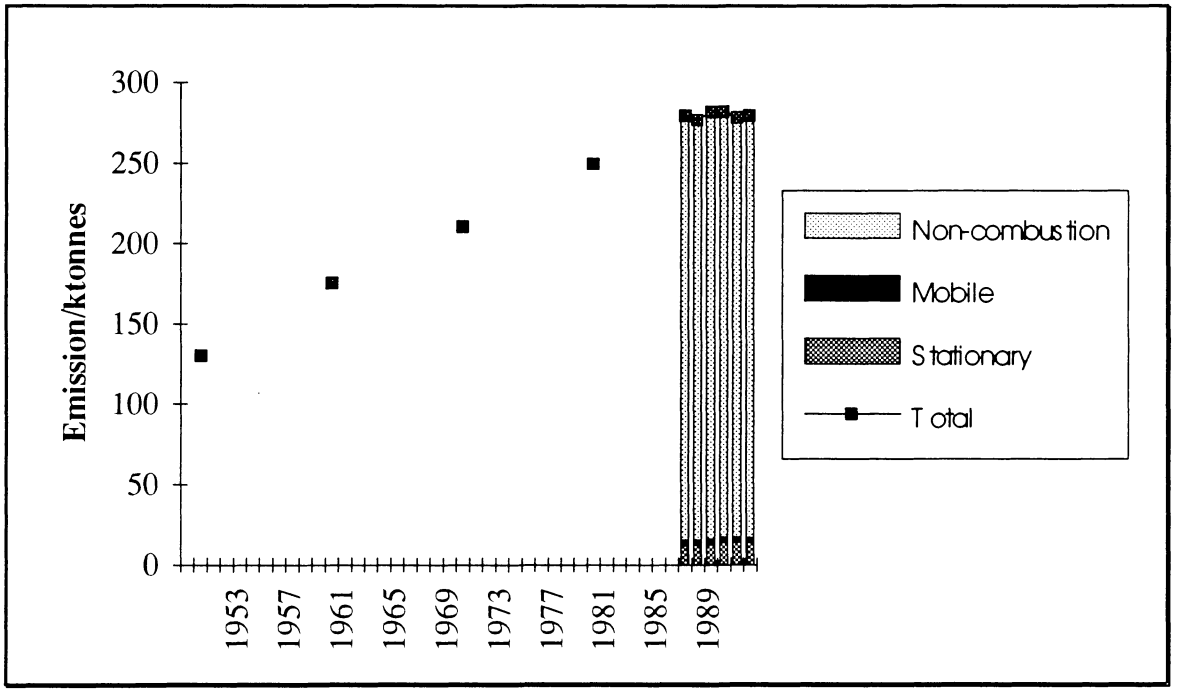
IE = Indirect emissions of CO_2 as CH_4 and NMVOC will be oxidized in the atmosphere. Indirect emissions are not counted from biological, renewable sources.

Figure 3.13. Emissions of CO_2 by source 1973-1992. Million tonnes



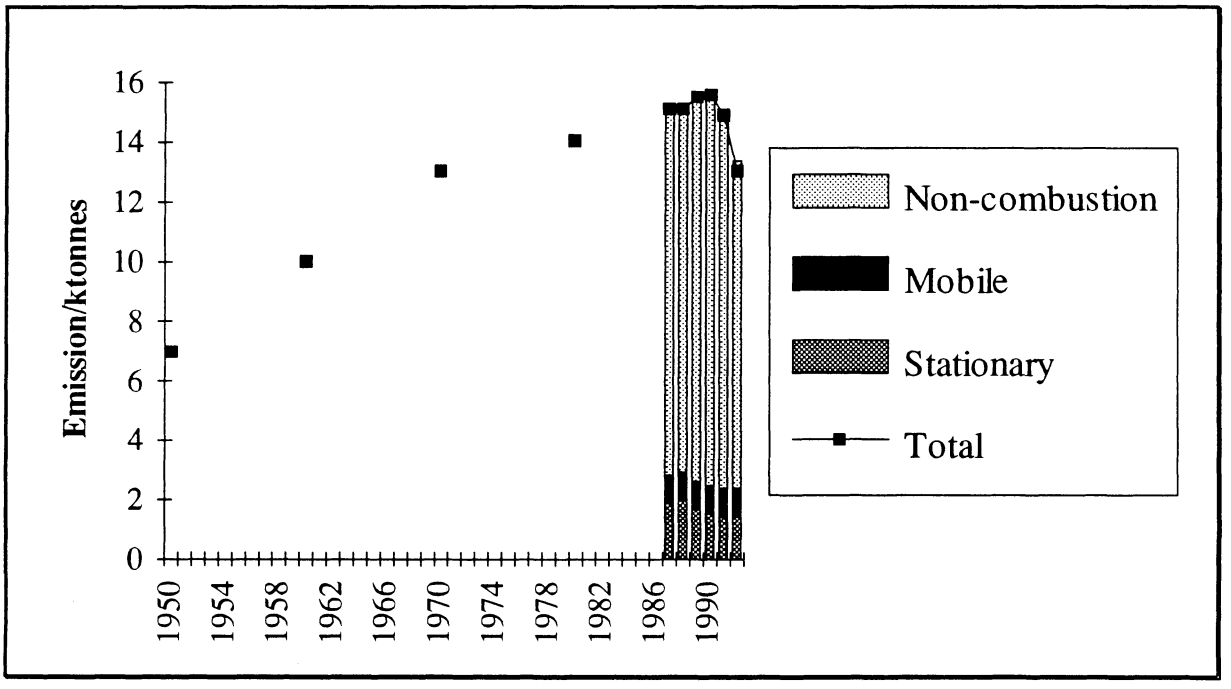
Source: Statistics Norway and the State Pollution Control Authority

Figure 3.14. Emissions of CH_4 by source 1950-1992. ktonnes



Source: Statistics Norway and the State Pollution Control Authority

Figure 3.15. Emissions of N_2O by source 1950-1992. ktonnes.



Source: Statistics Norway and the State Pollution Control Authority

Appendix 1. Economic sectors in the Norwegian emission model

Agriculture, hunting, forestry and fishing

23 100 Agriculture, crop production
23 121 Agriculture, livestock production, hunting and trapping
23 131 Own-account capital formation in agriculture, income from transport etc.
23 145 Forestry and logging
23 150 Fishing, sealing and whaling

Oil production and mining

23 158 Coal mining
23 159 Metal ore mining
23 165 Crude petroleum and natural gas production (incl. own-account prospecting and drilling)
23 176 Stone quarrying, gravel and sand pits, other mining and quarrying

Manufacturing

23 201 Slaughtering and other production of meat products, meat canning
23 210 Manufacture of dairy products
23 215 Canning and preserving of fruits and vegetables
23 220 Preserving and processing of fish
23 225 Canning of fish
23 230 Manufacture of fish oils and fishmeal
23 235 Manufacture of vegetable oils
23 240 Refining and hardening of animal oils
23 245 Manufacture of margarine
23 250 Manufacture of grain mill products
23 255 Manufacture of bakery products
23 260 Manufacture of cocoa, chocolate and sugar confectionery
23 265 Manufacture of other food products
23 270 Manufacture of prepared animal feeds
23 275 Manufacture of spirits and wine
23 280 Manufacture of malt liquors
23 285 Manufacture of soft drinks and carbonated water
23 290 Manufacture of tobacco products
23 295 Manufacture of yarn
23 300 Manufacture of fabrics, narrow fabrics and elastic fabrics
23 305 Manufacture of made-up textile goods, except wearing apparel
23 310 Manufacture of knitted goods
23 321 Manufacture of carpets, mats and rugs, cordage, ropes, nets, other textiles
23 333 Manufacture of outer garments of textiles and plastic, other wearing apparel
23 346 Manufacture of hats, caps, leatherclothing, fur clothing, other leather products
23 350 Manufacture of footwear
23 355 Sawing and planing of wood
23 360 Manufacture of particle board
23 365 Prefabrication of wooden houses
23 370 Manufacture of doors, windows, stairs, building materials, wood products
23 375 Manufacture of furniture and fixtures of wood
23 380 Manufacture of mechanical pulp
23 385 Manufacture of sulphate and sulphite pulp
23 390 Manufacture of paper and paperboard
23 395 Manufacture of fibre board
23 400 Manufacture of packing materials and other paper and paperboard articles
23 405 Printing and bookbinding
23 410 Publishing of newspapers
23 415 Other publishing
23 420 Manufacture of basic industrial chemicals, except fertilizers
23 425 Manufacture of fertilizers and pesticides
23 430 Manufacture of basic plastic materials and man-made fibres
23 435 Manufacture of paints, varnishes and lacquers
23 446 Manufacture of drugs and medicines, soap, cleaning preparations and toilet preparations
23 450 Manufacture of explosives and ammunition
23 455 Manufacture of other chemical products
23 460 Petroleum refining
23 461 Gas terminal
23 465 Manufacture of products of petroleum and coal
23 470 Manufacture and repair of rubber

products
23 475 Manufacture of plastic products

23 486 Manufacture of ceramics, glass and glass products
23 495 Manufacture of cement and lime
23 501 Manufacture of structural clay products, concrete and concrete products
23 505 Stone cutting, polishing and grinding, manufacture of other stoneware and earthenware
23 510 Manufacture of iron and steel
23 515 Manufacture of ferroalloys
23 520 Iron and steel founding
23 525 Manufacture of aluminium
23 530 Manufacture of other non-ferrous metals
23 535 Rolling of non-ferrous metals and non-ferrous metal founding
23 546 Manufacture of cutlery, tools and general hardware, manufacture of furniture and fixtures of metal
23 555 Manufacture of structural metal products
23 566 Manufacture of metal containers, metal netting, wire, nails and screws
23 570 Manufacture of other metal products
23 575 Manufacture of turbines and engines and agricultural machinery
23 580 Manufacture of machinery for manufacturing, mining, quarrying and construction
23 582 Manufacture and repair of oil drilling rigs and ships, oil production platforms etc. and specialized spare parts
23 591 Manufacture of office machinery and household machinery
23 595 Repair of machinery
23 600 Manufacture of other machinery
23 605 Manufacture of electric motors and equipment for electricity production
23 610 Manufacture of radio, television and communication apparatus
23 615 Manufacture of electrical household appliances
23 620 Manufacture of insulated cabels and wires
23 625 Manufacture of other electrical apparatus and equipment
23 630 Building of ships
23 635 Building of boats
23 640 Manufacture of ship and boat engines and components and fixtures for ships and boats

23 645 Manufacture and repair of railway and tramway equipment
23 651 Manufacture of motor vehicles, motor cycles and bicycles and other transport equipment, manufacture of aircraft
23 681 Manufacture of professional and scientific instruments, photographic and optical goods, jewellery and related goods, musical instruments, sporting and athletic goods, other manufacturing industries

Electricity, gas and water supply

23 689 Electricity, gas and water supply, district heating supply

Construction

23 700 Construction
23 717 Oil and gas exploration and drilling (separate activity on a contract basis)

Wholesale and retail trade etc., hotels and restaurants

23 721 Wholesale and retail trade etc.
23 760 Hotels and restaurants

Transport, storage and communication

23 801 Railway, tramway and subway transport
23 805 Scheduled motor bus transport
23 815 Taxi and other unscheduled passenger transport by road
23 821 Unscheduled freight transport by road, supporting services to land transport
23 824 Pipeline transport for oil and gas
23 830 Ocean transport
23 835 Coastal and inland water transport
23 840 Supporting services to water transport
23 845 Air transport, domestic
23 846 Air transport, international
23 850 Services allied to transport and storage

23 855 Postal services
23 860 Telecommunication services

Financing, insurance, real estate and business services

23 865 Banking
23 869 Imputed service charges of banks
23 872 Operation of other financial institutions, financial services
23 876 Insurance
23 885 Dwellings
23 891 Commercial buildings, other real estate services
23 901 Business services, machinery and equipment rental and leasing

Community, social and personal services

23 920 Sanitary and similar services
23 925 Education and research and scientific institutes
23 930 Health and veterinary services
23 935 Welfare services
23 941 Business, professional and labour associations, other social and related community services
23 950 Recreational and cultural services
23 955 Repair of vehicles, household appliances and goods for personal use
23 961 Laundries, laundry services and cleaning and dyeing plants, miscellaneous personal services
23 965 Domestic services

Production accounts for general government

Production accounts for central government and social insurance administration

21 825 Supporting services to land transport (roads and streets)
21 840 Supporting services to water transport
21 845 Air transport
21 910 Public administration
21 915 Defence
21 925 Education and research and scientific institutes
21 930 Health and veterinary services
21 941 Other social and related community services, recreational and cultural services
21 991 Other services, central government

Production accounts for local government

22 825 Supporting services to land transport (roads and streets)
22 910 Public administration
22 920 Sanitary and similar services
22 925 Education and research and scientific institutes
22 930 Health and veterinary services
22 935 Welfare services
22 941 Other social and related community services, recreational and cultural services
22950 Recreational and cultural services

33 000 Private households

66 000 Foreign activity in Norway

Appendix 2. Background data for estimating emissions from road traffic

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

	1991	1990	1989	1987	1980	1973
Passenger cars, gasoline	1,612,508	1,613,992	1,618,593	1,604,769	1,210,384	831,225
Light duty, gasoline	94,571	95,902	95,951	90,813	56,182	70,416
Heavy light duty, gasoline	6,511	6,063	5,712	4,876	2,015	681
Heavy duty, gasoline	4,273	4,605	4,919	5,456	6,041	12,429
Heavy buses, gasoline	271	277	278	300	33	114
Passenger cars, diesel	66,769	61,774	58,203	55,289	23,426	5,630
Light duty, diesel	60,983	58,309	55,726	47,508	6,706	1,206
Heavy light duty, diesel	12,224	9,385	7,180	5,451	1,781	443
Light heavy duty, diesel	33,451	32,545	31,762	30,064	22,430	14,124
Medium heavy duty, diesel	20,983	21,961	22,632	24,506	27,374	23,341
Heavy heavy duty, diesel	21,843	22,131	22,350	21,149	10,815	2,910
Heavy buses, diesel	11,011	10,507	10,193	10,119	7,961	6,599
Sum	1,945,396	1,937,448	1,933,499	1,900,297	1,375,148	969,116

Source: Directorate of Public Roads

Average annual mileage (km per vehicle)

	1991	1990	1989	1987	1980	1973
Passenger cars, gasoline	13,775	13,775	13,796	13,616	13,100	13,200
Light duty, gasoline	13,775	13,775	13,796	13,616	13,100	13,200
Heavy light duty, gasoline	13,775	13,775	13,796	13,616	13,100	13,200
Heavy duty, gasoline	15,493	15,842	15,842	16,057	23,819	23,819
Heavy buses, gasoline	41,940	41,940	43,099	41,134	42,591	36,099
Passenger cars, diesel	19,240	20,105	19,596	19,810	18,704	27,220
Light duty, diesel	16,189	17,123	17,123	17,196	13,526	13,526
Heavy light duty, diesel	16,189	17,123	17,123	17,196	13,526	13,526
Light heavy duty, diesel	15,493	15,842	15,842	16,057	23,819	23,819
Medium heavy duty, diesel	15,956	16,125	16,125	16,108	18,723	18,723
Heavy heavy duty, diesel	31,771	32,007	32,007	33,777	40,164	40,164
Heavy buses, diesel	41,940	41,940	43,099	41,134	42,591	36,099

Source: Institute of Transport Economics, Statistics Norway

Distribution of vehicle-kilometers on driving pattern 1980-1991

	Urban	Rural	Rural	Highway
	≤ 50 km/h	60-70 km/h	80 km/h	90 km/h
Light	23.64%	22.87%	44.82%	8.66%
Heavy	19.51%	21.38%	48.64%	10.47%

Source: Norwegian Institute for Air Research, Directrate of Public Roads and Statistics Norway

Distribution of vehicle-kilometers. Percentage of each fuel.

	1991	1990	1989	1987	1980	1973
Passenger cars, gasoline	93.793	93.723	93.735	93.967	94.585	89.856
Light duty, gasoline	5.501	5.569	5.557	5.318	4.390	7.612
Heavy light duty, gasoline	0.379	0.352	0.331	0.285	0.157	0.074
Heavy duty, gasoline	0.280	0.308	0.327	0.377	0.858	2.424
Heavy buses, gasoline	0.048	0.049	0.050	0.053	0.008	0.034
Passenger cars, diesel	28.684	28.101	26.896	27.287	18.463	11.753
Light duty, diesel	22.043	22.590	22.502	20.352	3.822	1.251
Heavy light duty, diesel	4.419	3.636	2.899	2.335	1.015	0.459
Light heavy duty, diesel	11.572	11.665	11.866	12.027	22.512	25.797
Medium heavy duty, diesel	7.475	8.012	8.606	9.834	21.596	33.512
Heavy heavy duty, diesel	15.495	16.027	16.870	17.796	18.304	8.961
Heavy buses, diesel	10.311	9.970	10.360	10.369	14.287	18.267
Sum gasoline	100	100	100	100	100	100
Sum diesel	100	100	100	100	100	100

Source: Statistics Norway

Annual number of cold starts

	1991	1990	1989	1987	1980	1973
Number of cold starts	701	701	686	692	567	571

Source: Statistics Norway

Fuel for road traffic (tonnes)

	1991	1990	1989	1987	1980	1973
Gasoline						
Sale	1,736,257	1,789,172	1,782,519	1,758,066	1,391,143	1,088,484
Non-road traffic consumption	39,455	39,490	39,353	40,524	39,070	38,989
Road traffic consumption	1,696,802	1,749,682	1,743,174	1,717,542	1,352,073	1,049,495
Diesel						
Sale	1,079,676	1,064,912	1,051,969	1,102,472	740,279	574,871
Non-road traffic consumption	249,562	253,344	226,313	240,303	184,644	137,969
Road traffic consumption	830,114	811,568	825,656	862,169	555,635	436,902

Source: Statistics Norway

Appendix 3. Balance sheets of energy for Norway. 1990

a) Physical units

	Coal	Coke	Fuel-wood, black liquor, garbage	Crude oil	Gaso-line	Kero-sene	Medi-um distil-lates	Heavy fuel	Lique-fied gas	Natu-ral gas	Other gases [1]	Elec-tri-ty	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	303	161	987	80659	4200	1083	5949	1320	1104	27642	790	121848	1413
1.1. Prod. of primary energy sources	303	.	987	80659	[3] 201	.	.	.	[3] 885	27642	.	[2] .	.
1.2. Prod. of secondary energy sources	.	161	.	.	3999	1083	5949	1320	219	.	790	121848	1413
2. Imports	713	901	0	1623	642	102	827	593	1031	-	-	334	-
3. Exports	254	119	0	68493	2564	412	3610	973	1043	25380	-	16241	-
4. Bunkering [4]	-	-	-	-	-	-	227	232	-	-	-	.	-
5. Changes in stocks (+ net decrease, - net increase)	-13	-18	..	-1473	0	-12	-4	39	-33	.	-	.	.
6. Gross inland availabilities (1+2-3-4+5)	749	926	988	12316	2278	761	2936	747	1059	2262	790	105941	1413
8. Energy converted	21	17	98	12742	211	2	116	525	3	-	0	304	-
8.1. In blast furnaces	-	17	-	-	-	-	-	-	-	-	-	-	-
8.2. In crude petroleum refineries	-	-	-	12742	211	2	113	525	3	-	-	-	-
8.3. In thermal power plants	-	-	-	-	-	-	2	0	-	-	-	-	-
8.4. In power plants for combined generation of electric energy and heat	21	-	47	-	-	-	0	-	-	-	-	-	-
8.5. In district heating plants	-	-	51	-	-	-	2	0	-	-	0	304	-
9. Consumption by energy producing industries	-	-	-	-	1	1	72	4	-	2037	699	1954	-
9.1. Crude petroleum and natural gas production	-	-	-	-	0	0	61	-	-	2037	-	95	-
9.2. Coal mines	-	-	-	-	0	0	4	-	-	-	-	22	-
9.3. Petroleum refineries	-	-	-	-	0	-	2	4	-	-	699	448	-
9.4. Pumping storage power plants	-	-	-	-	-	-	-	-	-	-	-	339	-
9.5. Hydro electric power plants	-	-	-	-	-	0	5	0	-	-	-	992	-
9.6. Thermal power plants	-	-	-	-	-	-	-	-	-	-	-	27	-
9.7. Power plants for combined generation of electric energy and heat	-	-	-	-	-	-	-	-	-	-	-	15	-
9.8. District heating plants	-	-	-	-	-	-	0	-	-	-	-	17	-
10. Consumption for non-energy purposes	.	.	.	.	-	-	-	-	1022	-	-	-	-
10.1. In chemical industry	.	.	.	.	-	-	-	-	1022	-	-	-	-
10.2. In other industry	.	.	.	.	-	-	-	-	-	-	-	-	-
11. Losses in transport and distribution	..	..	..	..	..	..	..	..	..	..	-	7237	547
12. Statistical differences (6-8-9-10-11-13)	-26	10	-	-426	277	98	-145	-241	4	225	-	-362	-
13. Net inland consumption	754	899	889	-	1789	661	2892	459	29	-	91	96808	866
14. Industry, mining and quarrying	743	897	406	-	13	1	148	343	26	-	91	45280	188
14.1. Mining and quarrying	-	-	-	-	0	0	36	20	0	-	-	708	-
14.2. Manuf. of paper and paper prod.	6	-	298	-	0	0	6	65	0	-	-	6805	-
14.3. Manuf. of industrial chemicals	-	178	4	-	0	-	7	49	2	-	64	5169	85
14.4. Manuf. of iron, steel and ferro-alloys	483	418	0	-	0	-	9	19	0	-	10	8108	7
14.5. Manuf. of aluminium and other non-ferrous metals	-	165	-	-	0	0	48	25	1	-	17	16641	-
14.6. Other manufacturing industries	253	136	105	-	12	1	43	165	23	-	-	7849	96
15. Transport	-	-	-	-	1765	493	1135	76	-	-	-	639	-
15.1. Railways and subways	-	-	-	-	-	-	30	-	-	-	-	639	-
15.2. Air transport	-	-	-	-	4	493	-	-	-	-	-	-	-
15.3. Road transport	-	-	-	-	1761	-	839	-	-	-	-	-	-
15.4. Coastal shipping	-	-	-	-	-	-	266	76	-	-	-	-	-
16. Fishing	-	-	-	-	11	5	427	14	-	-	-	-	-
17. Agriculture	5	-	-	-	-	1	64	3	-	-	-	680	6
18. Households	7	2	483	-	-				3	-	-	30299	286
19. Other consumers	-	-	-	-	-	160	1117	24	-	-	-	19910	386

1) Includes blast furnace gas, refinery fuel and fuel gas. 2) Of which electricity produced in thermal power plants, 466 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.

Overall energy balance sheet[1] for Norway. 1990. Petajoule (PJ) = 10^{15} Joule

	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	Sum
1.1. Production of primary energy sources	9	.	42	3412	50	1120	514	-	.	5146
2. Imports	20	28	0	69	140	-	-	1	-	258
3. Exports	7	4	0	2897	372	1028	-	58	-	4367
4. Bunkering	-	-	-	-	19	-	-	-	-	19
5. Changes in stocks (+ net decrease, - net increase)	0	-1	..	-62	-1	.	-	.	.	-64
7. Net inland availabilities (1.1+2-3-4+5)	21	23	42	521	-202	92	514	-57	-	953
8. Energy converted	1	0	4	539	36	0	514	1	-	1096
1.2. Production of derived energy sources	.	6	-	.	539	33	-	439	5	1022
9. Consumption by energy producing industries	-	-	-	-	3	112	-	7	-	122
10. Consumption for non-energy purposes	.	.	.	-	47	-	-	-	-	47
11. Losses in transport and distribution	..	..	..	..	..	-	-	26	2	28
12. Statistical differences (7-8+1.2-9-10-11-13)	-1	0	-	-18	0	9	-	-1	-	-11
13. Net inland consumption	21	28	38	-	250	4	-	349	3	693
13.1. Industry, mining and quarrying	21	28	17	-	22	4	-	163	1	256
13.2. Transport	-	-	-	-	150	-	-	2	-	152
13.3. Other consumers	0	0	20	-	77	-	-	183	2	284
14. Calculated energy consumption [3]	17	23	24	-	111	4	-	349	3	530
14.1. Industry, mining and quarrying	17	23	11	-	19	4	-	163	1	237
14.2. Transport	-	-	-	-	37	-	-	2	-	40
14.3. Other consumers	0	0	13	-	54	-	-	183	2	254
15. Energy losses in final consumption (13-14)	4	6	13	-	139	0	-	-	-	162
15.1. Industry, mining and quarrying	4	6	6	-	3	0	-	-	-	19
15.2. Transport	-	-	-	-	113	-	-	-	-	113
15.3. Other consumers	0	0	7	-	23	-	-	-	-	30

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[1]. 1990

a) Energy sectors, physical units

	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	1000 t	1000 t	1000 t	1000 t	GWh	GWh
Extraction of energy sources	303	-	-	80659	27642	962[3]	201[4]	-	-	-	121382	-
Energy use in extraction sectors	-	-	-	-	-2037[5]	-	-3	0	-206	-14	-1448	-
Imports and Norwegian purchases abroad	713	901	0	1623	-	1121	672	184	1953	6468	334	-
Exports and foreign purchases in Norway	-254	-119	0	-68493	-25380	-1134	-2594	-492	-3654	-1035	-16241	-
Stocks (+ Decrease, - Increase)	-13	-18	.	-1473	.	-36	0	-12	-4	39	.	.
Primary supply	749	764	0	12316	225	913	-1725	-321	-1910	5459	104027	-
Petroleum refineries	-	161	-	-12742	-	234	3733	1066	5834	791	-448	-
Other energy sectors, other supply	-21	-	891	-	-	80	54	14	-4	0	103	1413
Registered losses, statistical errors	26	-10	-	426	-225	-4	-274	-110	213	254	-6875	-547
Registered use outside energy sectors	754	916	891	-	-	1224	1788	650	4133	6504	96809	866

[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

	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	754	916	891	1224	1788	650	4133	6504	96809
PRODUCTION SECTORS, ESTABLISHMENTS									
Agriculture and fishery	5	-	-	-	17	1	640	19	680
Agriculture	5	-	-	-	12	1	164	5	680
Forestry	-	-	-	-	1	-	18	-	-
Fishery	-	-	-	-	3	0	458	14	-
Mining	-	-	-	0	0	0	36	20	708
Metal ore mining	-	-	-	0	0	0	12	19	499
Other mining	-	-	-	0	0	0	24	1	209
Manufacturing	743	914	409	1221	13	1	322	323	44572
Manufacturing of food, beverages etc.	3	1	1	3	4	0	109	87	2285
Manufacturing of textiles, leather etc.	-	-	0	0	0	0	7	5	158
Manufacturing of wood and wood products	-	-	103	0	1	0	20	9	730
Manufacturing of paper and paper products	6	-	301	0	0	0	6	65	6805
Printing, publishing etc.	-	-	0	2	2	0	3	0	403
Manufacture of industrial chemicals	-	178	4	1177	0	-	7	49	5169
Manufacture of other chemical products, petroleum, coal, rubber and plastic products	112	114	-	3	1	0	31	25	923
Manufacture of cement and lime	120	10	-	-	0	-	4	4	197
Manufacture of other mineral products	17	10	-	5	0	0	26	28	563
Manufacture of iron and steel	70	2	-	-	-	-	5	18	655
Manufacture of ferro-alloys	413	433	0	0	0	-	4	1	7453
Founding of iron and steel	1	0	-	0	0	0	1	-	148
Manufacture of aluminium	-	151	-	1	0	0	47	6	14431
Manufacture of other metals	-	14	-	17	0	-	2	20	2210
Rolling and founding of non-ferrous metals	-	-	-	3	0	-	3	0	192
Manufacture of fabricated metal products, machinery and equipment, other manufac-turing industries	-	0	0	7	4	0	49	7	2250
Construction	-	-	-	-	8	0	207	-	530
Wholesale and retail sale, hotels and restaurants	-	-	-	-	190	2	178	1	5995
Wholesale and retail sale	-	-	-	-	187	2	164	1	4740
Hotels and restaurants	-	-	-	-	2	-	14	-	1255
Transport, storage and communication	-	-	-	-	72	405	2201	6132	1449
Railway, tramway and subway	-	-	-	-	-	-	32	-	640
Scheduled motor bus	-	-	-	-	1	-	106	-	-
Taxi and other unscheduled passenger transport by road	-	-	-	-	19	-	12	-	-
Other land transport	-	-	-	-	12	-	434	-	12
Ocean transport	-	-	-	-	-	-	1314	6045	-
Coastal and inland water transport	-	-	-	-	-	-	276	87	-
Air transport	-	-	-	-	3	405	-	-	-
Supporting transport activities	-	-	-	-	4	-	19	-	294
Post and telecommunications	-	-	-	-	33	-	8	-	503
Financial institutions, insurance, real estate and business services	-	-	-	-	54	0	18	-	1504
Other private service industries	-	-	-	-	43	1	59	4	2244
PRODUCTION SECTORS, GENERAL GOVERNMENT	-	-	-	-	5	86	144	4	8827
Public administration except defence	-	-	-	-	3	-	13	-	1077
Education and research	-	-	-	-	-	-	26	-	2630
Health, social work, veterinary services	-	-	-	-	-	0	36	4	2874
Other public services	-	-	-	-	3	86	69	-	2246
PRIVATE HOUSEHOLDS	7	2	482	3	1387	152	327	1	30299

[1] Including energy goods used as raw materials. District heating not included. [2] Including petrol coke.

Source: Statistics Norway

c) Energy units (PJ)

	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	9	-	-	3412	1120	41[3]	9[4]	-	-	-	437	-	5027
Energy use in extraction sectors	-	-	-	-	-83[5]	-	0	0	-9	-1	-5	-	-97
Imports and Norwegian purchases abroad	20	28	0	69	-	47	30	8	83	271	1	-	556
Exports and foreign purchases in Norway	-7	-4	0	-2897	-1028	-48	-114	-21	-155	-43	-58	-	-4377
Stocks (+ Decrease, - Increase)	0	-1	.	-62	.	-2	0	0	0	2	.	.	-64
Primary supply	21	23	0	521	9	39	-76	-14	-81	229	374	. -	1046
Petroleum refineries	-	6	-	-539	-	10	164	46	247	33	-2	-	-35
Other energy sectors, other supply	-1	-	38	-	-	3	2	1	0	0	0	5	49
Registered losses, statistical errors	1	0	-	18	-9	0	-12	-5	9	11	-25	-2	-14
Registered use outside energy sectors	21	29	38	-	-	52	79	28	175	273	349	3	1045
Ocean transport	-	-	-	-	-	-	-	-	56	253	-	-	309
Domestic use	21	29	38	-	-	52	79	28	119	19	349	3	736
Agriculture and fishery	0	-	-	-	-	-	1	0	27	1	2	0	31
Energy intensive manufacturing	14	24	0	-	-	51	0	-	3	4	108	0	203
Other manufacturing and mining	7	5	17	-	-	1	1	0	12	10	55	0	109
Other industries	-	-	-	-	-	-	16	21	63	4	74	1	180
Private households	0	0	20	-	-	0	61	6	14	0	109	1	212

[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 "Utslipp fra veitrafikken i Norge- Dokumentasjon av beregningsmetode, data og resultater" SFT 93:12.

Light vehicles

Cold start emissions

Technology	Model year	Methane g/start	N_2O g/start	Consumption l/start
Passenger cars, gasoline				
Pre ECE	-74	0,165	-	0,12
ECE 15.00	74-77	0,129	-	0,11
ECE 15.02	78-79	0,129	-	0,10
ECE 15.03	80-84	0,129	-	0,10
ECE 15.03/04	85-88	0,117	-	0,09
US-83	89-92	0,060	-	0,07
Passenger cars, LPG	92-	0,057	-	0,10
Passenger cars, diesel				
No control	-91	0,009	-	0,06
US-87	91-	0,005	-	0,06
Light duty, gasoline				
L2				
Pre ECE	-74	0,189	-	0,14
ECE 15.00	74-77	0,150	-	0,13
ECE 15.02	78-79	0,150	-	0,12
ECE 15.03	80-84	0,150	-	0,12
ECE 15.03/04	85-92	0,135	-	0,10
US-90	93-	0,120	-	0,08
L3				
Pre ECE	-74	0,219	-	0,16
ECE 15.00	74-77	0,171	-	0,15
ECE 15.02	78-79	0,171	-	0,13
ECE 15.03	80-84	0,171	-	0,13
ECE 15.03/04	85-92	0,156	-	0,12
US-90	93-	0,120	-	0,09
Light duty, LPG	93-	0,120	-	0,10
L2	93-	0,120	-	0,11
L3				
Light duty, diesel				
L2				
No control	-93	0,014	-	0,08
US-87	93-	0,010	-	0,08
L3				
No control	-93	0,014	-	0,09
US-87	93-	0,010	-	0,09

Urban emissions

Technology	Model year	Methane g/km	N_2O mg/km	Consumption l/10 km
Passenger cars, gasoline				
Pre ECE	-74	0,096	5	1,35
ECE 15.00	74-77	0,075	5	1,25
ECE 15.02	78-79	0,075	5	1,15
ECE 15.03	80-84	0,075	5	1,15
ECE 15.03/04	85-88	0,069	5	1,05
US-83	89-92	0,014	50	1,0
Passenger cars, LPG	92-	0,014	50	1,3
Passenger cars, diesel				
No control	-91	0,006	5	0,7
US-87	91-	0,003	5	0,7
Light duty, gasoline				
L2				
Pre ECE	-74	0,111	6	1,55
ECE 15.00	74-77	0,087	6	1,44
ECE 15.02	78-79	0,087	6	1,32
ECE 15.03	80-84	0,087	6	1,32
ECE 15.03/04	85-92	0,081	6	1,21
US-90	93-	0,027	60	1,15
	93-	0,027	60	1,50
L3				
Pre ECE	-74	0,129	7	1,80
ECE 15.00	74-77	0,099	7	1,66
ECE 15.02	78-79	0,099	7	1,53
ECE 15.03	80-84	0,099	7	1,53
ECE 15.03/04	85-92	0,093	7	1,40
US-90	93-	0,027	60	1,33
	93-	0,027	60	1,73
Light duty, diesel				
L2				
No control	-93	0,009	8	0,91
US-87	93-	0,007	8	0,91
L3				
No control	-93	0,009	9	1,05
US-87	93-	0,007	9	1,05

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

Technology	Model year	Methane g/km	N_2O mg/km	Consumption l/10 km
Passenger cars, gasoline				
Pre ECE	-74	0,054	9	0,90
ECE 15.00	74-77	0,042	9	0,70
ECE 15.02	78-79	0,042	9	0,68
ECE 15.03	80-84	0,042	9	0,68
ECE 15.03/04	85-88	0,036	9	0,61
US-83	89-92	0,007	20	0,60
LPG	92	0,007	20	0,78
Passenger cars, diesel				
No control	-91	0,008	9	0,50
US-87	91-	0,004	9	0,50
Light duty, gasoline				
L2				
Pre ECE	-74	0,063	10	1,04
ECE 15.00	74-77	0,048	10	0,81
ECE 15.02	78-79	0,048	10	0,78
ECE 15.03	80-84	0,048	10	0,78
ECE 15.03/04	85-92	0,042	10	0,70
US-90	93-	0,014	23	0,69
LPG	93-	0,014	23	0,90
L3				
Pre ECE	-74	0,072	12	1,2
ECE 15.00	74-77	0,057	12	0,93
ECE 15.02	78-79	0,057	12	0,90
ECE 15.03	80-84	0,057	12	0,90
ECE 15.03/04	85-92	0,048	12	0,81
US-90	93-	0,014	23	0,80
LPG	93-	0,014	23	1,04
Light duty, diesel				
L2				
No control	-93	0,011	12	0,65
US-87	93-	0,008	12	0,65
L3				
No control	-93	0,012	14	0,75
US-87	93-	0,008	14	0,75

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

Tecnology	Model year	Methane g/km	N_2O mg/km	Consumption l/10 km
Passenger cars, gasoline				
Pre ECE	-74	0,045	9	0,90
ECE 15.00	74-77	0,036	9	0,70
ECE 15.02	78-79	0,030	9	0,68
ECE 15.03	80-84	0,027	9	0,68
ECE 15.03/04	85-88	0,026	9	0,61
US-83	89-92	0,005	20	0,60
LPG	92	0,004	20	0,78
Passenger cars, diesel				
No control	-91	0,006	9	0,5
US-87	91-	0,002	9	0,5
Light duty, gasoline				
L2				
Pre ECE	-74	0,051	10	1,04
ECE 15.00	74-77	0,042	10	0,81
ECE 15.02	78-79	0,036	10	0,78
ECE 15.03	80-84	0,030	10	0,78
ECE 15.03/04	85-92	0,030	10	0,70
US-90	93-	0,011	23	0,69
LPG	93-	0,011	23	0,90
L3				
Pre ECE	-74	0,060	12	1,2
ECE 15.00	74-77	0,048	12	0,93
ECE 15.02	78-79	0,039	12	0,90
ECE 15.03	80-84	0,036	12	0,90
ECE 15.03/04	85-92	0,033	12	0,81
US-90	93-	0,011	23	0,80
LPG	93-	0,011	23	1,04
Light duty, diesel				
L2				
No control	-93	0,007	12	0,65
US-87	93-	0,004	12	0,65
L3				
No control	-93	0,008	14	0,75
US-87	93-	0,004	14	0,75

Factors for correcting ageing.

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

	Model year	Methane	N_2O	Consumption
Passenger cars, gasoline				
Pre ECE	-74	0,02	-	0,003
ECE 15.00	74-77	0,02	-	0,003
ECE 15.02	78-79	0,02	-	0,003
ECE 15.03	80-84	0,02	-	0,003
ECE 15.03/04	85-88	0,02	-	0,003
US-83	89-92	0,12	-	0,002
LPG	92	0,12	-	0,002
Passenger cars, diesel				
No control	-91	0	-	0,001
US-87	91-	0	-	0,001
Light duty, gasoline				
L2				
Pre ECE	-74	0,02	-	0,003
ECE 15.00	74-77	0,02	-	0,003
ECE 15.02	78-79	0,02	-	0,003
ECE 15.03	80-84	0,02	-	0,003
ECE 15.03/04	85-92	0,02	-	0,003
US-90	93-	0,035	-	0,001
	93-	0,035	-	0,001
L3				
Pre ECE	-74	0,02	-	0,003
ECE 15.00	74-77	0,02	-	0,003
ECE 15.02	78-79	0,02	-	0,003
ECE 15.03	80-84	0,02	-	0,003
ECE 15.03/04	85-92	0,02	-	0,003
US-90	93-	0,035	-	0,001
	93-	0,035	-	0,001
Light duty, diesel				
L2				
No control	-93	0	-	0,001
US-87	93-	0	-	0,001
L3				
No control	-93	0	-	0,001
US-87	93-	0	-	0,001

Heavy vehicles

	Speed	Fuel consumption	Fuel consumption	CH_4	N_2O
	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	0,4	0,4
Rural	60	320	0,18	0,0	0,4
Highway	75	250	0,17	0,1	0,5
After 93					
Urban	32	302	0,21	0,4	0,4
Rural	60	314	0,17	0,0	0,4
Highway	75	245	0,17	0,1	0,5
Total weight 10-20 t					
Before 93					
Urban	32	300	0,33	0,3	0,4
Rural	60	310	0,28	0,0	0,4
Highway	75	245	0,25	0,0	0,5
After 93					
Urban	32	294	0,32	0,3	0,4
Rural	60	304	0,27	0,0	0,4
Highway	75	240	0,25	0,0	0,5
Total weight > 20 t					
Before 93					
Urban	32	295	0,34	0,2	0,4
Rural	60	305	0,33	0,0	0,4
Highway	75	240	0,26	0,0	0,5
After 93-					
Urban	32	289	0,34	0,3	0,4
Rural	60	299	0,32	0,0	0,4
Highway	75	235	0,25	0,0	0,5
Heavy duty, gasoline					
Total weight> 3,5 t					
Urban	32	417	0,225	0,6	0,03
Rural	60	368	0,15	0,7	0,04
Bus, diesel					
Total weight >3,5 t					
Before 93					
Urban	23	280	0,40	0,2	0,4
Rural	60	229	0,25	0,0	0,5
After 93					
Urban	23	274	0,39	0,2	0,4
Rural	60	224	0,25	0,0	0,5
CNG/LNG/ Methane/ Waste gas, city bus		270	0,40	10	0,03
LPG city bus, with TWC*		292	0,42	0,7	0,03

*Three way catalyst

Ageing factors for heavy duty vehicles (HDV)

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

	Fuel consumption	Fuel consumption	Methane	N_2O
All HDV diesel	0,001	0,001	-0,005	0,000
All HDV gasoline	0,002	0,002	0,002	-0,007
from 93 with TWC*	0,002	0,002	0,035	0,010
All HDV gas	0,002	0,002	0,002	-0,007

* Three way catalyst

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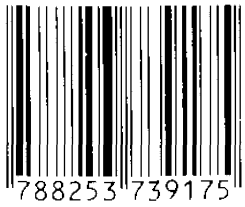

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