SFT-report 1736/2000

Verification of the Norwegian emission inventory

Comparing emission intensity values with similar countries

The report has been made in cooperation with Statistics Norway

Preface

The Norwegian emissions of greenhouse gases are reported annually by the Norwegian Pollution Control Authority (SFT) to the United Nations Framework Convention on Climate Change (UNFCCC).

The Norwegian emission inventory is the result of a co-operation between SFT and Statistics Norway (SN). SN is responsible for the development of the emission models, for the collection and processing of activity data, and for the calculation of national emission levels. SFT is responsible for developing emission factors and providing data reported by industrial plants and specific industries.

By signature of the Kyoto protocol several countries have committed to limit their greenhouse gas emissions. It is mandatory for the success of this protocol and its implementation mechanisms (e.g. emission trading) that the countries report high quality data. In this context routines for quality control and verification are of great importance. As a part of the IPCC report “Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories” different methods of verification of emission estimates are introduced. Countries have been encouraged to verify their national emission data.

This report represents the Norwegian contribution to the work on verification of emission estimates. The aim has been to suggest possible statistical data to use as indicators for comparing emission figures between countries on a general basis, and to test a verification method on the Norwegian national emission estimates.

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1. Summary

In the Kyoto protocol several countries have signed obligations to limit their greenhouse gas emissions. It is mandatory for the success of this protocol and its implementation mechanisms (e.g. emission trading) that the countries report high quality data. In this context routines for quality control and verification are of great importance.

There have been two main goals of this work. The first is to suggest possible statistical data to use as indicators for comparing emission figures between countries on a general basis. The second is to test the method on the Norwegian national emission estimates.

Several approaches to verify emission estimates have been suggested, one is to compare *emission intensity values*[1] (Olivier et. al 1999). The emission intensity values are compiled by normalising the emission rates using various statistical data. In this report we have tested this method to check the quality of the Norwegian emission estimates reported to UNFCCC by comparing them with the estimates from countries that in many respects are similar to Norway. We are also checking the trend estimates by comparing the emission intensities for both 1990 and 1996.

We have selected the countries Sweden, Canada and New Zealand to compare with our national estimates. These countries have common structural features; cold winters, scarcely populated areas, they produce electricity from hydropower and have some common industrial processes.

The method is based on the official emission estimates reported from the countries to UNFCCC and activity data (for example GDP, population, energy statistics or production) from official sources like OECD or UN. For each sector where Norway has reported emissions we have calculated emission intensity values of each pollutant per various type of statistical data, for example emissions per TJ energy. These values are compared, both the level and the trend. Comparisons are made at different levels of aggregation of the IPCC summary tables. Conclusions have first been made on what statistical data is best suited for each emission source. This is based on the analytical soundness of the indicator, data quality and the output values. Finally a comparison is made between emission intensity values of Norway and the other countries for the selected indicator(s).

1.1. Main results of the verification

Conclusions are made both on the suitability of this method for verifying emission data, see 2.1.1, and on the conclusions that may be drawn for the reliability of the Norwegian reported data that this study is based on.

1.1.1. General suitability of method

In general this method seems suitable for detecting errors from gross reporting. It is, however, likely to be better for some source categories than for others (see below). In order to draw the correct conclusions it is also necessary to have certain knowledge of the countries included in the comparison. Furthermore it is important to compare countries that for each source category are expected to give similar results.

For most emission sources we have compared emission intensity values based on more than one type of activity data. In this study we have concluded that one indicator is better than others for the purpose

[1] In this work we use the term emission intensity *value* rather than emission intensity *indicator*. This is to avoid confusion with the term *indicator* that denotes the statistical (activity) data used in the calculation of the emission intensity values. The formal terminology and definition of the emission intensity indicators are still under preparation. In the work of Olivier et al. (1999) the term *emission density indicator* was used.

of verification of emissions from each emission source. However, for a proper check of data it could be an advantage to compare more than one indicator. This will strengthen the conclusions made.

Energy
For combustion related emissions from energy (IPCC Table 1A) we have tested indicators like GDP, population, energy consumption and transport activity (tonne-km or passenger-km). Energy use (from IEA statistics) was, not surprisingly, the best indicator. This was the case for mobile combustion in transport and stationary combustion in energy and manufacturing industries and other sectors (Table 1).

For the fugitive emissions from fuel (IPCC Table 1B) energy use is not relevant. In the sector *coal mining*, production of coal is probably the best (and maybe only) indicator, but our results were poor due to different type of mining (surface or underground mining). Oil and gas production is assumed to be the best indicators to verify fugitive emissions from the oil and gas sector, but differences in production technologies had large impact on the results.

Table 1. Summary of indicator suggestion*. Energy

Sector	Sub-sector	Suggested indicator	Maximum percentage difference[1] 1990	1996	1990 and 1996	Source
Fuel combustion						
Energy industries	All	Energy use	86	27	87	OECD/IEA
	Public electricity and heat production	Energy use[2]	20	83	88	OECD/IEA
	Petroleum refining	Fossil fuels used	24	35	48	OECD/IEA
	Manufacture of solid fuels and other energy	-[4]				
Manufacturing industries and construction[3]	All	Energy use	112	110	144	OECD/IEA
	Iron and steel	-[4]				
	Non-ferrous metals	Energy use	8	15	19	OECD/IEA
	Chemicals	-[4]				
	Pulp, paper and print	Energy use	24	70	70	OECD/IEA
	Food processing, beverages and tobacco	-[5]				
	Other	Energy use	11	121	139	OECD/IEA
Transport	All	Energy use	33	22	33	OECD/IEA
	Aviation	Energy use	87	43	87	OECD/IEA
	Navigation	Energy use	118	239	239	OECD/IEA
	Road	Energy use	38	71	71	OECD/IEA
	Railways	Energy use[6]	29	23	29	OECD/IEA
	Other	-[7]				
Other sectors	All	Energy use	55	94	94	OECD/IEA
	Commercial/ institutional	Energy use	91	61	128	OECD/IEA
	Residential	Energy use	55	73	73	OECD/IEA
	Agriculture/forestry/ fishing	Energy use	538	1919	1919	OECD/IEA
Fugitive emissions from fuels						
Solid fuels	Coal mining	Production of coal[8]	1008	1218	1220	OECD/IEA
Oil and gas	Oil (CH_4)	Production of oil[8]	5999	5972	7746	OECD/IEA
	Oil (CO_2)	Production of oil[8]	1308	1270	1448	OECD/IEA
	Natural gas (CH_4)	Production of gas[8]	25460	44133	51903	OECD/IEA
	Natural gas (CO_2)	Production of gas[8]	20	63	63	OECD/IEA
	Venting and flaring (CO_2)	Production of oil and gas[8]	287	668	668	OECD/IEA
	Venting and flaring (CH_4)	Production of oil and gas[8]	404	207	804	OECD/IEA
CO_2 from biomass		Energy use	203	123	203	OECD/IEA

* The suggestions and values are based on CO_2 emissions if not otherwise indicated.
[1] Maximum percentage difference in emission intensity values is [(greatest value - smallest value)/smallest value]%, see page 19. This is calculated for 1990 and 1996 separately and for both years pooled.
[2] Sweden 1990 is not included.
[3] Detailed emission data for the sub-sectors is not available for New Zealand in 1990 and 1996 and for Sweden in 1990.
[4] Few observations and very high percentage difference between the highest and lowest emission intensity value.
[5] Too few observations to base a suggestion on.
[6] New Zealand is not included
[7] Too few values of emission intensity and too diverse reporting to make a suggestion
[8] Sweden is not included

Industrial processes

For emissions from industrial processes indicators like population and GDP are not relevant. For these emission sources relevant production data is the best indicator to be used for the verification. For emissions from metal production, the use of feedstock is also relevant. Emissions from metal production are in general difficult to compare among countries due to inconsistent reporting of feedstock and emissions between energy sources and industrial processes/feedstock.

The indicators population and GDP were tested for the sector *Consumption of Halocarbons and Sulphur Hexacloride* which also is included in IPCC Table 2 Industry. Potential emission estimates were used in the comparison since few countries report actual emissions. These estimates are very rough and comparisons on actual emission estimates are needed to draw relevant conclusions.

Table 2. Summary of indicator suggestions*. Industrial processes

Sector	**Sub-sector**	**Suggested indicator**	**Maximum percentage difference 1990**	**1996**	**1990-1996**	**Source**
Mineral products	Cement	Production	66	44	122	UN
Metal production	Iron and steel	-[1]	-	-	-	
	Ferroalloys	Production[2]	76	88	88	UN
	Aluminium	Production	58	22	58	UN
Consumption of HFC, PFC and SF_6	All	GDP[3]	410	348	2003	OECD

* The suggestions and values are based on CO_2 emissions if not otherwise indicated.
[1] High percentage difference between the highest and lowest emission intensity value if not special considerations are taken.
[2] Canada and New Zealand are not included.
[3] Canada is not included for 1990 and Sweden is not included for 1996.

Solvent and product use
Based on data from only Norway and Sweden it seems like the indicator population is relevant to check emission data for solvent and product use. This should, however, be tested for more countries.

Table 3. Summary of indicator suggestions. Solvent and other product use. CO_2

Sector	**Sub-sector**	**Suggested indicator**	**Maximum percentage difference 1990**	**1996**	**1990-1996**	**Source**
Solvent and other product use	All	Population[1]	6	16	21	UNFCCC

[1] Canada and New Zealand are not included.

Agriculture
The indicators animal population (cattle number), meat production, agricultural area, crop production, fertiliser consumption and agricultural output have been tested in this work.

For emissions from enteric fermentation the population of cattle seems to be the best indicator. But none of the proposed indicators assessed the emissions very well for the countries included in this study. Also for emissions from manure management the results were poor. An analysis on a more detailed level would make the use of more specific indicators possible.

For agricultural soils meat production at first glance seems to be a good indicator (with relatively small deviations between the countries). But since meat production does not include important sources like fertilisers, crop residues and animals kept for other purposes than production, the results seem coincidental. Possible future reporting of more detailed data will help to identify better indicators for comparison. More countries should be included in the study before any further conclusions can be drawn.

Table 4. Summary of indicator suggestions. Agriculture

Sector	Sub-sector	Gas	Suggested indicator	Maximum percentage difference 1990	1996	1990 and 1996	Source
Agriculture	All	CH_4	Cattle number	139	85	139	FAO
		N_2O	Agricultural output[1]	107	79	107	OECD
	Enteric fermentation	CH_4	Cattle number	195	134	195	FAO
	Manure management	CH_4	Animal output	321	378	417	OECD
	Agricultural soils	N_2O	Agricultural output[1]	106	66	106	OECD

[1] Meat production actually gives better results, but this is considered to be coincidental

Waste

For emissions of CH_4 from waste disposal, number of tonnes municipal waste disposed of in landfills is a possible indicator for verification.

Table 5. Summary of indicator suggestions. Waste. CH_4

Sector	Sub-sector	Suggested indicator	Maximum percentage difference 1990	1996	1990-1996	Source
Solid waste disposal	Managed waste disposal on land	Municipal waste disposed of on landfills[1]	64	102	102	OECD

[1] New Zealand is not included.

1.1.2. Results for Norway

This project has identified several smaller reporting errors, especially emissions reported in another source category than it should according to the IPCC reporting instructions (IPCC 1997). Detailed tables of Norwegian reporting errors are given in Appendix E.

Energy

For most of the sectors listed in IPCC Table 1 Energy the Norwegian emission estimates seem reasonable when comparing the emission intensity values based on energy use. For fugitive emissions from coal mining and oil and gas extraction on the other hand, the emission estimates were not comparable with data reported from the other countries.

Industrial processes

For most of the industrial processes where the indicator production could be tested, we were able to verify the estimates. However, in some sectors we had problems because of differences between the sectors used for the production and emission data. Also, since the other countries do not have the same industrial activities as Norway, the foundation of comparisons were for some processes poor. These problems are also described in Section 1.2.

Solvent and product use

The Norwegian emission estimate for solvent and other product use (IPCC Table 3) seems reasonable. The emission intensity value is based on population (emissions of CO_2 / million capita).

Agriculture

For agriculture there were large deviations from country to country. For enteric fermentation Norway has emission intensity values of the same magnitude as Canada and Sweden. The values for New Zealand are much higher due to the high number of sheep. Taking into account the differences in the distribution of husbandry animals the Norwegian emission estimates seems reasonable. For methane emissions from manure management the percentage difference between the emission intensity values are too large to draw any conclusions.

Waste
The proposed indicator gives higher values for Norway than for Sweden and Canada. Emission estimates for methane from landfills are uncertain, so differences between Norway, Canada and Sweden on 60 - 100 % could be expected.

1.2. Uncertainties/problems during the work

Several issues make this type of verification complicated and will contribute with uncertainties in the final conclusions:

- Different countries report emission data in different ways. Some countries report CO_2 emissions from production of metals as energy emissions, others as non-combustion emissions and others again something in-between.
- The OECD energy statistics first present preliminary figures that later are being revised. The figures for 1996 are only preliminary, but the emission figures from the UNFCCC are often based on revised energy figures. This leads to inconsistency in the data.
- To verify the emission data we need as disaggregated emission data as possible. Several countries (among them Norway) do only report a summary table over emissions in 1990 and detailed data for the latest year. For verification of trends we need detailed data for 1990, too.
- Inconsistencies between the sectors used in the emission reporting and reporting of the activity data, especially the energy data, have been a problem.
- OECD and UN do not list energy and production data for sectors with few companies. This means that for some sectors, data is lacking.
- Not all countries have reported emissions of SF_6 and PFCs.
- More countries would be needed to verify the Norwegian emissions from industrial processes. For instance Norway is the only one of these four countries that produces carbide.
- Norway produces nitric acid as an intermediate product in the production of fertilizers. Norway does not report production of nitric acid to the UN production statistics, since this only is an intermediate and not an end product. We have therefore not found any suitable indicator for production of nitric acid.

1.3. Conclusions

We consider the method described in this report as appropriate for checking data for some sectors, but less promising for others. For energy use the method gives a certain verification of the Norwegian emission estimate for most of the sectors. For some of the industrial processes like iron and steel, on the other hand, the method does not give a satisfactory result because of inconsistency between the sectors used in the international reporting of emission data and activity data.

To achieve better results from verifications like this, it is essential that the emission estimates are reported according to the revised 1996 IPCC guidelines. Emissions from use of coal and coke used as reducing agents and not for energy purposes should for instance not be reported under Table 1: Energy but under Table 2: Industrial processes. Further, it is important that the countries report data on a detailed level, also for the base year according to the Kyoto protocol, 1990. The exercise of comparing the data has, however, been very useful for identifying errors in the Norwegian reporting, that are emissions reported in an erroneous source category.

One lesson from this work is that a comparison is useful, but that it should be performed between more than four countries. For several sectors only one country or no countries at all but Norway had reported emissions. Many of the industrial processes important for Norway are not important for the other countries chosen. This would have been an advantage if some countries were chosen because of their similarity to Norway in for instance transport and climate, while others were chosen because they report emissions from industrial processes relevant for Norway.

In this work no distinction has been made between important and less important sources in the inventory. It is expected that the inventory quality is better for the important sources as frequently more resources are put into these estimates.

The described method may be used by a neutral institution to check the emission estimates. To get a more conclusive verification of emission estimates from certain sectors (for instance the industrial process iron and steel production), it can be necessary to contact the national focal points for supplementary information. It is also necessary to have certain knowledge of national circumstances in order to interpret the results. A deviation from other countries reporting, or inconsistent emission intensity values between years, does not necessarily mean that the reported estimates are wrong, but additional quality control should be directed towards these emission sources.

No large errors in the Norwegian emission inventory have been detected in this work, see Appendix E. This process of verification has, however, revealed several smaller reporting errors, mainly emissions that have been reported in other categories than they should according to the IPCC 1996 Revised Guidelines (IPCC 1997). These errors were corrected before the next reporting to the UNFCCC.

Finally, it is important to realise that this method of verification only considers consistency compared to what other countries report. It is not a verification of the scientific value of the inventory data themselves.

2. Introduction

In the Kyoto protocol several countries have signed obligations to limit their greenhouse gas emissions. It is mandatory for this protocol and its implementation mechanisms (e.g. emission trading) that the countries report high quality data.

High quality emission data are:
- Transparent
- Consistent
- Comparable
- Complete
- Accurate.

According to IPCC/OECD/IEA (1998):

Validation is the establishment of sound approach and foundation. The legal use of validation is to give an official confirmation or approval of an act or product. In the context of emission inventories validation involves checking to ensure that the inventory has been compiled correctly in line with reporting instructions and guidelines. It checks the internal consistency of the inventory.

Verification refers to the collection of activities and procedures that can be followed during the planning and development, or after completion of an inventory that can help to establish its reliability for the intended applications of that inventory. Typically, methods external to the inventory are used to check the truth of the inventory, including comparisons with estimates made by other bodies or with emission and uptake measurements determined from atmospheric concentrations and/or concentration gradients of these gases.

Verification procedures are a part of the good practice procedures for inventory preparations (IPCC/OECD/IEA 1998).

All the aspects of quality cannot be checked by one single method. There have been several suggestions for methodologies for verification at national and international level. This report will consider one method; to compare emission estimates reported to UNFCCC by countries from different source categories by dividing the emission estimates, aggregated or disaggregated, by appropriate statistical data to obtain *emission intensity values*. In similar countries one would expect that these emission intensities are comparable. Furthermore, statistics will also indicate changes in activity level and be used to verify changes in emission data from the base year (1990). Evidently this method has its weaknesses. Countries are always different and this may be reflected in the emission data. Furthermore, changes over time do not only follow the activity level, but also abatement and technological changes. For this reason such comparisons should be performed for rather similar countries.

This work has two main goals:

- to suggest possible statistical data to use as indicators for comparing emission figures between countries
- to test the method on the Norwegian national estimates as reported to the UNFCCC in the national communication.

The goal of the work is not to detect errors in other countries' national inventories, but to check for inconsistencies in the Norwegian national data.

We have selected the countries Sweden, Canada and New Zealand to compare with our national emission estimates. The reason is that these countries have common structural features: cold winters, scarcely populated areas, they produce electricity from waterpower and have some common industrial processes. A comparison of some basic background data is made in Section 2.2.

2.1. Data sources

To find statistical data on indicators we have only used international data sources where data for all four countries are included. The reason for this is that these data are considered *neutral* in the respect that they have been reported independently from the national communications of GHG emissions. They may deviate from those reported in national communications or are actually used in the inventory. They are not necessarily more correct, but are as neutral data considered suited for a verification study. The use of data from international sources only also sets limitations on the indicators to use. More appropriate indicators could be available from national sources.

2.1.1. UNFCCC

The emission data used in this work have been based on national greenhouse gas inventories for the years 1990 and 1996 provided by the UNFCCC. An exception is that we have used more detailed emission data than those reported for Norway[2]. They are, however, consistent with the data reported at a more aggregated level (Norwegian Pollution Control Authority 1999). Summary tables of emissions are given in Appendix A and sectoral tables for *Energy* and *Industrial processes* are found in Appendix B and Appendix C, respectively.

In addition, background information was found in the national communications of Canada (Environment Canada 1994 and 1997), Norway (Ministry of Environment 1994 and 1997), New Zealand (Ministry of the Environment 1994 and 1997) and Sweden (Ministry of the Environment and Natural Resources 1994 and 1997). These sources also give emission inventories as reported to UNFCCC in 1994 and 1997, but these data may deviate from the inventories reported in 1998 and 1999 due to recalculations.

2.1.2. OECD

We have utilised OECD reports to find data on:

- Gross domestic product (GDP)
- Population
- Energy use
- Transport activity (tonne-km and passenger-km)
- Economic output from agriculture
- Municipal waste statistics
- Fertiliser consumption

Different reports were used: "OECD in Figures", "OECD Environmental Data", "Economic Accounts for Agriculture", "Energy Statistics of OECD Countries", "Oil Information", "Coal Information", and "Oil and Gas Information".

[2] In the 1999 report only the 1997 inventory is on a detailed level. Inventories for the years 1990 to 1996 are given in summary tables only. Data on a more detailed level is available at Statistics Norway.

2.1.3. UN

We have used UN reports as data sources on:

- Transport activity (tkm and pkm for aviation)
- Production data
- FAO statistics: number of animals, meat production, agricultural area and crop production.

The following reports were used: "Statistical Yearbook", "FAO Production Yearbook", "National Accounts Statistics" and "Industrial Commodity Statistics".

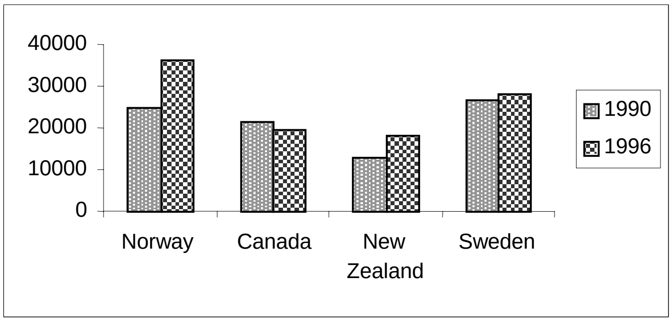
2.2. Background information

Geography, climate, industry structure and level of economic development may explain emissions of pollutants to air. By selecting countries similar in conditions and structure, we would expect to find the same level of emissions relative to specific indicators.

The selected countries all have low population densities compared to other OECD countries. Canada has 3 inhabitants/km^2, Norway and New Zealand 13 inhabitants/km^2 and Sweden 20 inhabitants/km^2 (Statistics Norway 1998). Large distances between inhabitants enhance the needs for transport, which is an important source of CO_2 emissions. Also, all four countries have cool climates with average temperatures below 15 ^oC. Low temperatures during winter make heating requirements high.

Gross domestic product (GDP) per capita in 1990 and 1996 are shown in Figure 1. Compared to other OECD countries, the selected countries have medium to high values of GDP per capita. From 1990 to 1996, GDP per capita increased in all countries except Canada. Norway has had the largest increase in GDP/capita.

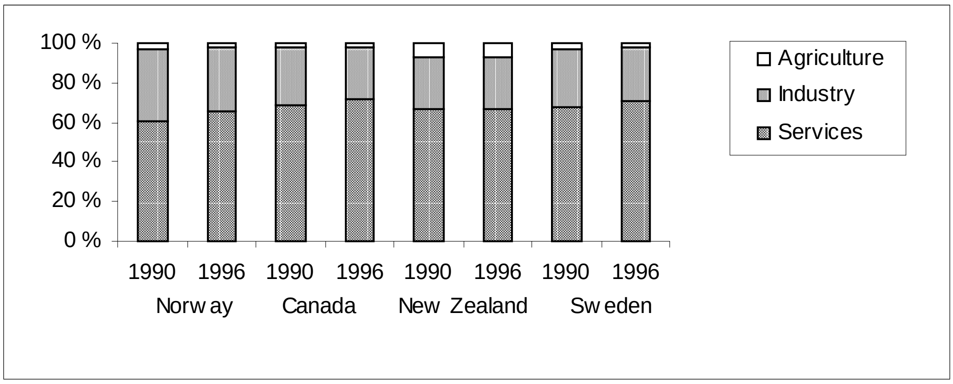
Figure 1. GDP per capita. USD/capita. 1990 and 1996



Sources: OECD (1992a and 1998a)

The relative contributions to GDP from different sectors are quite similar for the four countries (Figure 2). Services contribute to about 60-70 per cent and manufacturing industry to about 25-35 per cent of GDP. Agriculture is most important in New Zealand where it contributes to 7 per cent of GDP, while the similar figures for the other three countries are 2-3 per cent, only. For all countries except New Zealand, the contributions from services have increased from 1990 to 1996.

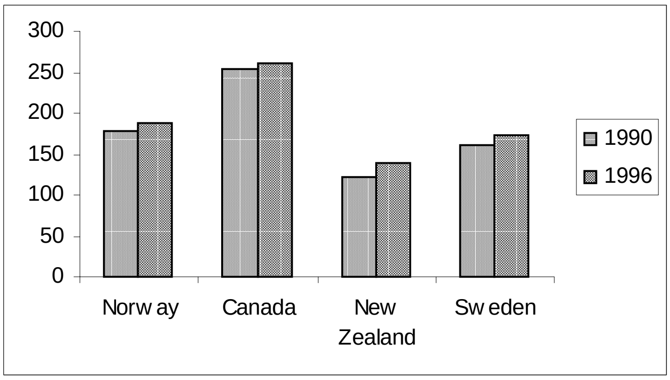
Figure 2. Sectoral contribution to GDP. Percentage. 1990[1] and 1996[2]



[1] Canada: 1989
[2] Sweden and New Zealand: 1994, Canada 1993
Sources: OECD (1992, 1993, 1994, 1998 and 1999)

Total energy consumption per capita is shown in Figure 3. In all countries there has been a small increase in energy consumption per capita since 1990. Out of total energy consumption, electricity accounts for about 20-45 per cent (OECD/IEA 1993b and 1999a). Consumption of other energy sources than electricity is highest in Canada and lowest in Norway.

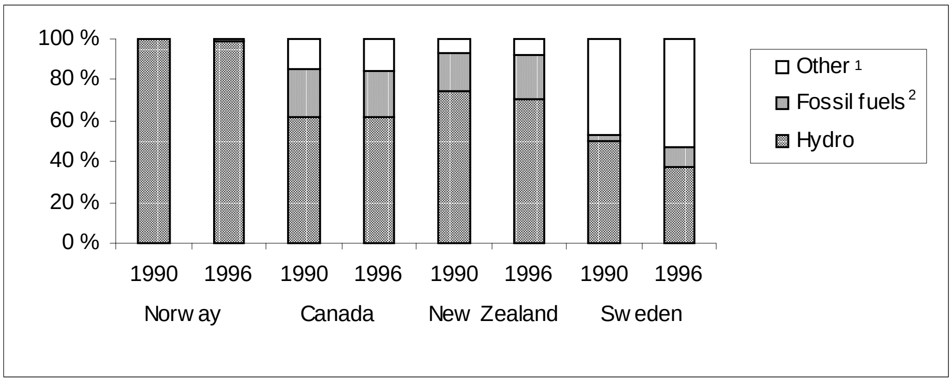
Figure 3. Energy consumption[1] per capita. GJ/capita. 1990 and 1996



[1] Includes consumption of commercial energy only
Sources: OECD/IEA (1993b and 1999a)

Hydropower is the main primary source of electricity in all the countries except Sweden (Figure 4). In 1996 nuclear power was a more important source of electricity in Sweden than hydropower (OECD/IEA 1999a). The use of air polluting energy sources in production of electricity is low in all the four countries.

Figure 4. Primary sources of electricity. Percentage. 1990 and 1996



[1]Nuclear, geothermal, solar energy etc.
[2]Includes solid fuels like waste, wood etc.
Sources: OECD/IEA (1993b and 1999a)

Table 6 and Table 7 show the reported national emissions of different greenhouse gases in CO_2 equivalents. Carbon dioxide contributes most to total GWP weighted emissions in all countries except New Zealand, where CH_4 emissions are more important. Total emissions of greenhouse gases have risen by 4-12 per cent between 1990 and 1996, with the largest increase in Canada

Table 6. Emissions of greenhouse gases. ktonnes CO_2 equivalents. 1990

Country	CO_2	CH_4	N_2O	HFCs [1, 2]	PFCs [1, 2]	SF_6 [1]	Total
Norway	35 203	6 658	5 418	0.02	2 546	2 188	52 012
Canada	470 000	69 300	58 900	0.00	6 000	3 000	607 200
New Zealand	26 115	35 133	11 470	0.03	587	23	73 328
Sweden	55 443	5 964	8 060	0.00	397	478	70 342

[1] Reported values of potential emissions used where actual emissions are not estimated.
[2] Mean GWP values for HFCs and PFCs in Norway 1990 are used to calculate emissions in CO_2 equivalents.
Source: UNFCCC

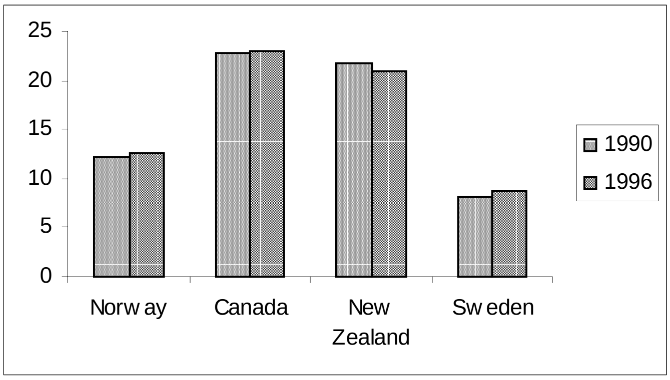
Table 7. Emissions of greenhouse gases. ktonnes CO_2 equivalents. 1996

Country	CO_2	CH_4	N_2O	HFCs [1, 2]	PFCs [1, 2]	SF_6 [1]	Total
Norway	41 140	7 254	5 109	52	1 270	526	55 351
Canada	523 000	84 000	71 300	500	6 000	1 000	685 800
New Zealand	30 498	33 453	11 780	330	176	25	76 262
Sweden	63 352	5 481	8 060	0.00	0.00	0.00	76 893

[1] Reported values of potential emissions are used where actual emissions are not estimated.
[2] Mean GWP values for HFCs and PFCs in Norway 1996 are used to calculate emissions in CO_2 equivalents.
Source: UNFCCC

The total emission of greenhouse gases per capita are rather diverse, ranging from about 8 to 23 tonnes CO_2 equivalents per capita (Figure 5). For all the compared countries except New Zealand the emissions per capita have increased from 1990 to 1996.

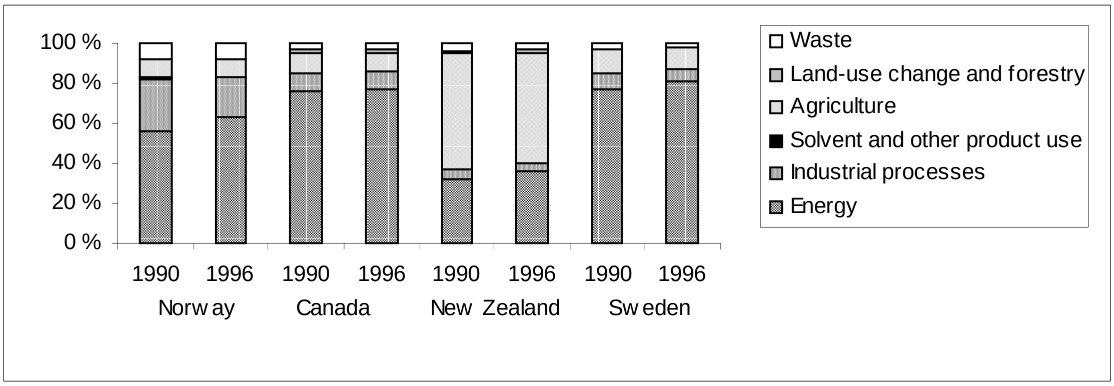
Figure 5. Emissions of greenhouse gases per capita. Tonnes CO_2 equivalents/capita. 1990 and 1996



Sources: UNFCCC, OECD (1992a and 1998a)

Figure 6 shows how emissions of greenhouse gases are distributed between different sectors. In all countries except New Zealand, energy consumption contributes most to total emissions. In New Zealand agriculture is the dominant source of national emissions. Emissions from industrial processes contribute more to total emissions in Norway than in the other countries. In all countries emissions due to energy consumption have increased relative to other sources in the period from 1990 to 1996.

Figure 6. Sectoral emissions of greenhouse gases. Percentage. 1990 and 1996



Source: UNFCCC

According to the Kyoto protocol, Canada has to reduce emissions of greenhouse gases with 6 per cent from 1990 level during the period 2008-2012. Within the same period, New Zealand has to stabilise emissions at 1990 level, while Norway is allowed to rise emissions with 1 per cent. As a member of the European Union (EU), Sweden is obligated to reduce emissions of greenhouse gases with 8 per cent. However, after internal distribution of obligations within EU, Sweden's emissions may actually rise with 4 per cent.

2.3. Methodology

The comparisons are performed for each source category reported by Norway, namely *Energy*, *Industrial processes*, *Solvent and other product use*, *Agriculture* and *Waste* (see Appendix A). The IPCC summary table is for many sources too aggregated for drawing any meaningful conclusions. On the other hand, the reported data at the most disaggregated level may be too inconsistent to compare. An analysis at the most detailed level for all sources will also be extremely time-consuming. Consequently, only for the most important source categories, *Energy* and *Industrial processes* (see Figure 6), are the comparisons performed at the most detailed level given by the IPCC sectoral reporting tables. For the other source categories the analysis was carried out at the most detailed level in the summary table. Table 8 shows the level of aggregation chosen for each source category.

Table 8. Level of analysis for the different source categories.

	Category level[1]			
Main reporting sectors	1	2	3	4
1. Energy			x	x
2. Industrial processes			x	
3. Solvent and other product use	x			
4. Agriculture	x	x		
6. Waste		x		

[1] The first level is the main reporting category, the second level is the first sub-category etc.

Light grey shade denotes the number of source levels given in the IPCC sectoral reporting tables, while darker grey shows the levels presented in the summary tables.

Different possible indicators have been evaluated for each source category based on statistical data available from international literature. A rough initial selection was made based on the nature of the source. For the initial indicators the reliability and validity is discussed. With the indicator's *reliability* we mean to what extent the data source is reliable and gives consistent data. *Validity* expresses how good we expect the indicator to correlate with the specific emissions.

Emission intensity values are estimated for the selected indicators for the years 1990 and 1996, and the reliability of the Norwegian emission estimates are evaluated based on these results. In the assessment of indicators we focus on the deviations in emission intensities both between countries and years. As measure on deviation we use maximum percentage difference:

$$maximum\ percentage\ difference = \frac{maximum\ emission\ intensity\ value - minimum\ emission\ intensity\ value}{minimum\ emission\ intensity\ value}$$

Maximum percentage difference is calculated both for each year separately and for the two years pooled. The pooled value is calculated by the same equation, but here the largest and smallest emission intensity value for both years together are used. In the indicator appraisal we lay particular stress on the pooled value, but our assessment also include individual judgement.

For combustion, the indicator appraisals are only performed for CO_2 emissions. The best indicator found for CO_2 is then applied in the comparisons of N_2O and CH_4 emissions.

2.4. Presentation of the results

The main reporting categories are given specific chapters. The most extensive source category is *Energy*, covering a large number of emission sources. For each sub-category reported in the IPCC summary tables within *Energy* we give a presentation of:

- emissions given by weight and in percentage of total national emissions
- the indicators tested and a pre-assessment of the reliability and the validity of the indicators
- a verification analysis for:
  - total emissions of the sub-category
  - emissions from different sources within the sub-category.

The verification analysis given for each source/sub-category consists of:

- emission intensity values given by different indicators
- assessments on to what extent the results indicate verifications of the Norwegian estimates
- an appraisal of the indicators tested.

The structure of analysis for the other main source categories is similar, but the evaluation is performed at different levels (see Table 8). For *Agriculture*, we have performed the analysis on a more aggregated level, so that only the main sector and its sub-sectors are considered. The chapters on *Solvent and other product use* and *Waste* are analysed at the most detailed level given in the summary tables, while the analysis on *Industrial processes* is performed at the most detailed level in the sectoral reporting tables.

The analysis method is described in more details in the previous sub-section.

3. Energy

This chapter first considers the sectors included in the reporting of emissions from energy use in the IPPC Standard Reporting Table 1 and from biomass combustion reported as memo item (not included in national totals) in IPCC Standard Reporting Table 7:

- Energy industries
  - Public electricity and heat production
  - Petroleum refining
  - Manufacture of solid fuels and other energy industries
- Manufacturing industries and construction
  - Iron and steel
  - Non-ferrous metals
  - Chemicals
  - Pulp, paper and print
  - Food processing, beverages and tobacco
  - Other (oil drilling, construction, all other manufacture)
- Transport
  - Civil aviation
  - Road transportation
  - Railways
  - Navigation
  - Other
- Other sectors
  - Commercial/institutional
  - Residential
  - Agriculture/forestry/fishing
- CO_2 emissions from biomass.

In the end of this chapter fugitive emissions from fuels, also reported in IPCC Table 1, are considered:

- Fugitive emissions from solid fuels
  - Coal mining
- Fugitive emissions from oil and natural gas
  - Oil
  - Natural gas.

Energy use is one possible indicator to assess emissions from combustion. There are however some possible sources of error when using energy use as an indicator. A general source of error may be that the same conversion factors have been used for all countries. Use of gas and liquid and solid fuels are given in different units in the OECD/IEA energy statistics. In this work the energy data are converted to TJ by using Norwegian conversion factors from 1996 for the different energy commodities. This may be a source of error since the conversion factors may vary from one country to another.

3.1. Energy industries

This source-sector includes emissions from public electricity and heat production, petroleum refining and manufacture of solid fuels and other energy industries.

3.1.1. Emissions

Energy industries are an important source of emissions of CO_2 in the four countries, accounting for about 15 to 30 per cent of the total national CO_2-emissions in 1990 and 1996 (Table 9 and Table 10). The sector is a minor emission source of N_2O and CH_4. It contributes from less than 0.1 to about 1 per cent of the national emissions of methane in all four countries, while it accounts for 0.1 to 6 per cent of the total N_2O emissions.

The emissions of CO_2 from energy industries in Norway reported for 1990 are about 67 ktonnes higher than the value used in this work. While the reported emissions of CO_2 from manufacturing industries and construction are 67 ktonnes lower than the figure used here. The sum of the reported CO_2 emissions and the figures used in this work are however the same. The difference at sector level is due to emissions from oil drilling which erroneously are included in energy industries in the reported figures from Norway.

Table 9. Emissions from energy industries and percentage of total national emissions. ktonnes and percentage. 1990

	Emissions from energy industries (ktonnes)			Percentage of total national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	7328	2	0.1	21	0.7	0.3
Canada	133000	2	3	29	0.05	1
New Zealand	6040	0.3	0.03	23	0.02	0.1
Sweden	8849	1	1	16	0.4	4

Source: UNFCCC

Table 10. Emissions from energy industries and percentage of total national emissions. ktonnes and percentage. 1996

	Emissions from energy industries (ktonnes)			Percentage of total national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	9953	3	0.1	24	1	0.5
Canada	140000	2	3	28	0.04	1
New Zealand	6271	0.2	0.03	21	0.01	0.1
Sweden	14295	2	2	23	1	6

Source: UNFCCC

3.1.2. Indicators

The following indicators have been selected to compare the Norwegian emissions from energy industries with the other countries.

GDP measured in current prices and exchange rates.

Reliability The reliability of this indicator is presumed to be very good.

Validity The validity of GDP as an indicator of emissions from energy industries may be good as these industries contribute considerably to the GDP. However, the energy industries' contributions to GDP differ between the countries and the indicator is therefore assessed not to be the first choice for comparing emissions between the four countries. The validity is expected to be better for the whole sector, than for sub-sectors within the energy industries.

Population

Reliability The reliability of this indicator is presumed to be very good.

Validity Population is not expected to be a better indicator than GDP since the energy industries in many cases are more correlated with GDP than population. Figure 2.1 illustrates differences in GDP/capita between the four countries. The lowest GDP/capita are about half of the highest for both years, indicating that the two indicators are not very correlated.

Electricity produced from fossil fuels

Reliability The reliability of this indicator is presumed to be very good.

Validity Electricity produced from fossil fuels may be a good indicator as it is more directly correlated to the emissions than GDP and population. Electricity produced from hard coal, lignite, sub-bituminous coal, peat, coke oven gas, blast furnace gas, liquid fuel, refinery gas, natural gas and gas works gas are reported to OECD. The validity is, however, expected to be better for the sub sector *electricity and steam generation*, than for the whole sector.

Energy use in energy industries, converted into TJ by using Norwegian conversion factors from 1996. Electricity and biomass are not included in the energy data used in this chapter when comparing CO_2 emission estimates. Use of biomass is however included when calculating the indicators for CH_4 and N_2O.

Reliability The energy data given in OECD/IEA (1998a) for Norway in 1996 are preliminary figures, which have been revised since the reporting. The emissions reported are based on the revised figures. Also energy data for 1990 have been revised since the reporting. This will be an important source of uncertainty in the emission intensity values for all the sectors.

The sectors used in the reporting to the OECD/IEA may differ from the sectors used in the reporting to the UNFCCC. This may be a source of inconsistency between the two data sets. For all countries there is a problem with the consistency between the waste and biomass data for 1990 and 1996, as these are reported together in 1990, while they are specified in 1996. Municipal waste combusted will not be included in 1990, but only in 1996.

Also, a general source of error with this indicator is that the same conversion factors have been used for all countries.

Validity Use of fossil fuels and waste in the energy sector is expected to be a better indicator than GDP and population, as it is more directly correlated to the emissions.

Production of oil and gas

Reliability Production of natural gas and crude oil is given in different units in the sources used in this work (OECD/IEA 1993a and 1998a). The same conversion factor for crude oil has been used for all four countries (which may be a source of error since the conversion factor may vary from one country to another).

Validity This is expected to be a better indicator for the sub sector *manufacture of solid fuels* and *other energy industries*, than for the whole energy sector.

In the following chapters we discuss the indicators' ability to explain the emissions from energy industries. We suggest an indicator for the different sub-sectors by comparing the different data, focusing on the gap between the lowest and highest emission intensity values.

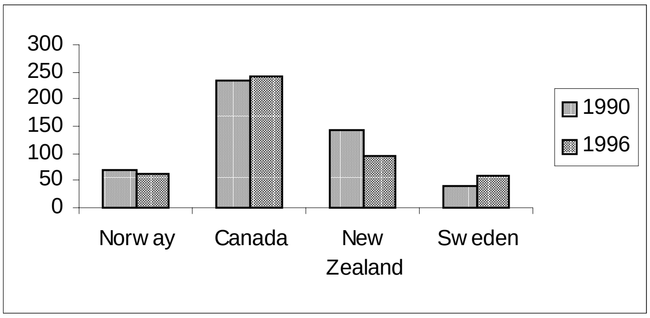
3.1.2.1. Total emissions from energy industries

In order to get an overview of the comparability between the emissions and the different indicators, the total emissions from energy industries are considered first. It is however important to be aware of the fact that an indicator may be valid for one sub sector of energy industries although it is not valid for total emissions.

GDP
Comparing emissions from energy industries with GDP, measured in current exchange rates, is a rough comparison. The emission intensity values vary between the four countries (Figure 7). The value of the indicator for Norway lies within the interval of the other countries, which may indicate that the Norwegian estimated emissions are reasonable compared to the other three countries.

The emission intensity values for the two years are quite even in Norway and Canada.

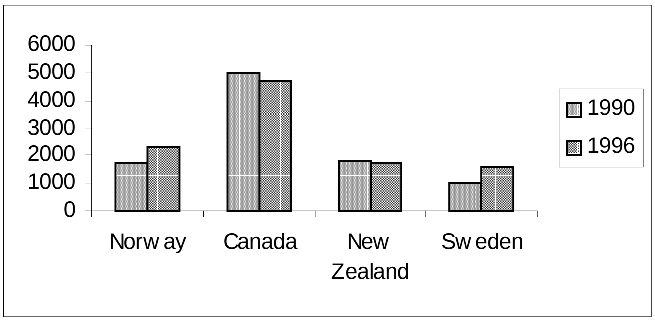
Figure 7. Emissions of CO_2 relative to GDP. Energy industries. ktonnes CO_2/billion USD. 1990 and 1996



Sources: UNFCCC, OECD (1993 and 1998a)

Population
This indicator looks much the same as the GDP, when comparing Figure 7 and Figure 8. The Norwegian value is within the interval of the other countries.

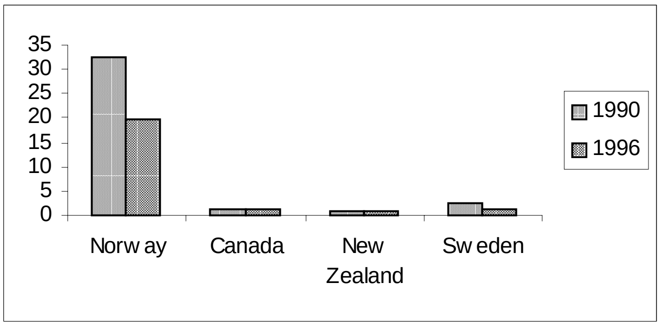
Figure 8. Emissions of CO_2 relative to population. Energy industries. ktonnes CO_2/million capita. 1990 and 1996



Sources: UNFCCC, OECD (1993 and 1998a)

Electricity produced from fossil fuels
Figure 9 shows that the Norwegian value is higher compared to the other countries. This may be due to the fact that most of the electricity in Norway is made from hydropower, and the CO_2-emissions from the energy industries are mainly generated from another source than electricity production (oil and gas production).

Figure 9. Emissions of CO_2 relative to electricity produced from fossil fuels. Energy industries. ktonnes CO_2/GWh. 1990 and 1996

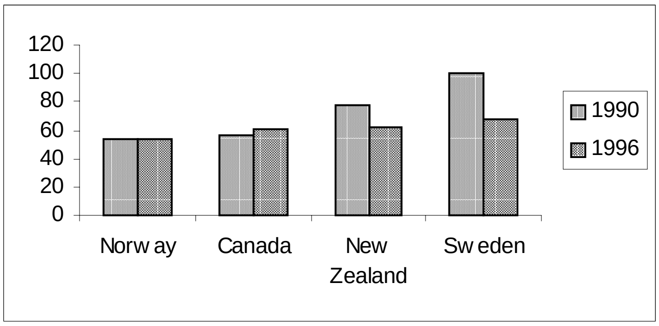


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Energy use
Municipal waste combusted is included in the total amount of energy use in the countries. In the Norwegian reported CO_2 emissions only the fossil part of carbon in the waste is included. If this part differs between the countries it may be a source of inconsistency between the countries' energy data. Another source of error using energy consumed as an indicator is the use of the same conversion factors for all countries.

Figure 10 shows that the Norwegian values are consistent between the years, and they are at the same level compared to those for the other countries. This may indicate that the Norwegian emission estimates are reasonable. We are not able to explain why the emission intensity values in 1990 for New Zealand and Sweden are higher than the values for Norway and Canada.

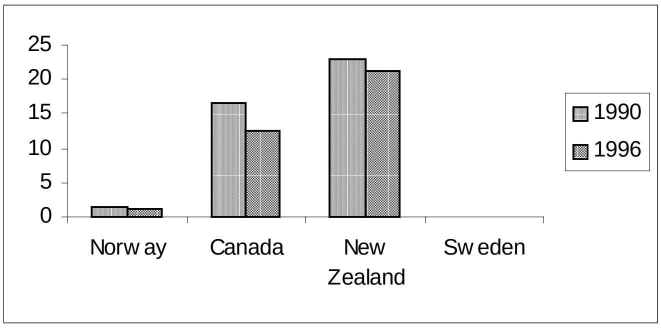
Figure 10. Emissions of CO_2 relative to energy use. Energy industries. ktonnes CO_2/PJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Oil and gas produced
This emission intensity value is lower for Norway than for Canada and New Zealand. One possible reason for the low Norwegian values may be that most of the electricity in Norway is made from hydropower. Sweden has no production of natural gas and only small production of crude oil in 1990, and is not included in the figure.

Figure 11. Emissions of CO_2 relative to production of oil and gas. Energy industries. ktonnes CO_2/PJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Indicator appraisal

From Table 11, energy use seems to be the best overall indicator for CO_2 emissions from energy industries. However, the highest emission intensity value is 86 per cent higher than the lowest in 1990. The same percentage is 27 in 1996.

Table 11. Maximum percentage difference in the emission intensity values for the different indicators. Energy industries

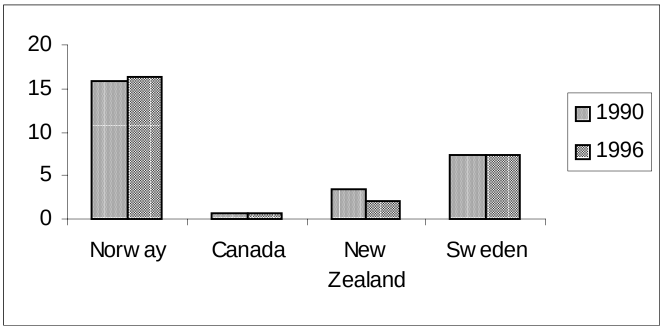
Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
GDP	501	326	523
Population	383	191	383
Electricity produced from fossil fuels	3187	2273	3823
Energy use[1]	86	27	87
Oil and gas produced	1346	1679	1833

[1] Municipal waste combusted is included in 1996 figures.

Emission intensity values of CH_4 and N_2O for the suggested indicator

Biomass burned is included when making emission intensity values for CH_4 and N_2O. The Norwegian values for CH_4 are higher than for the other countries (Figure 12). The differences between the countries may be due to use of different energy commodities, different combustion processes or different emission factors. The values for 1990 and 1996 are similar.

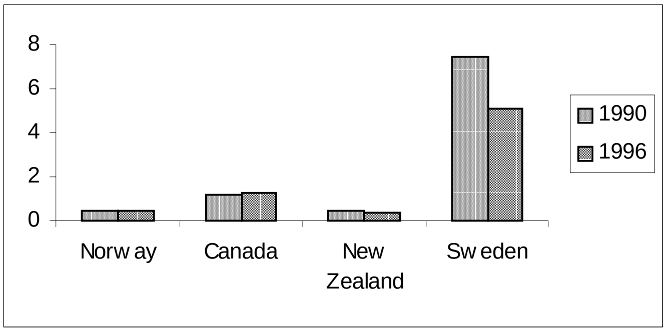
Figure 12. Emissions of CH_4 relative to energy use. Energy industries. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

The Norwegian emission intensity values for N_2O are at the same level as those for New Zealand, but lower than the values for Canada and Sweden (Figure 13). The difference may be due to the use of different energy commodities from one country to another or the use of different emission factors. The Norwegian values are nearly the same in 1990 and 1996.

Figure 13. Emissions of N_2O relative to energy. Energy industries. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

In the next paragraphs we will consider how the same indicators apply to the sub-sectors within the energy production and transformation industries. The emissions used when making the indicators for these sub-sectors are given in Appendix B.

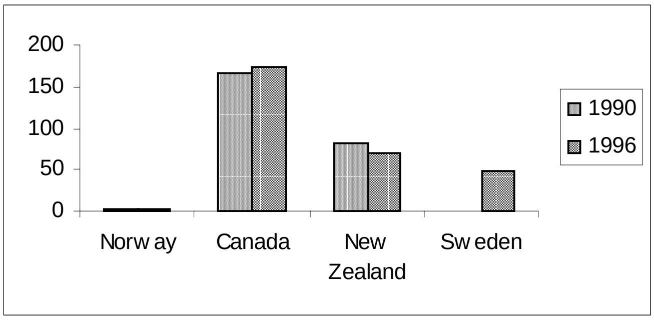
3.1.2.2. Public electricity and heat production

Norway and Sweden have only reported the total emissions from combustion in energy industries to the UNFCCC in 1990. More detailed data for the Norwegian emissions are available from Statistics Norway, but more detailed data for Sweden is lacking. The testing of the indicators have been performed without data for 1990 from Sweden.

GDP

The Norwegian emission intensity values are considerably lower compared to the other countries (Figure 14). This is most likely due to the high portion of electricity made from hydropower in Norway.

Figure 14. Emissions of CO_2 relative to GDP. Public electricity and heat production. ktonnes CO_2/billion USD. 1990 and 1996

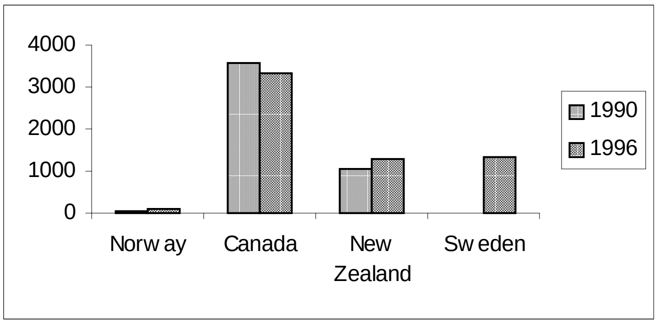


Sources: UNFCCC, OECD (1993 and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

Population

Again, as for GDP, the Norwegian emission intensity value is significantly lower than for the other countries (Figure 15). It seems like neither GDP nor population gives a good indication of the reliability of the Norwegian emissions from this sector, as the emissions are very small compared to the other countries due to the high portion of electricity made from hydropower in Norway.

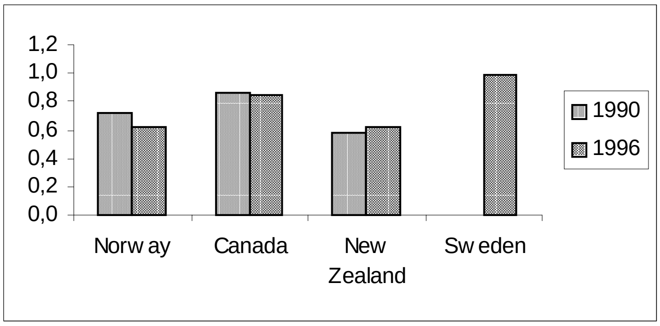
Figure 15. Emissions of CO_2 relative to population. Public electricity and heat production. ktonnes CO_2/million capita. 1990 and 1996



Sources: UNFCCC, OECD (1993 and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

Electricity produced from fossil fuels
The indicator seems to confirm that the Norwegian emissions from this sub sector are reasonable, as the Norwegian value lies in the same interval as the other countries (Figure 16). The Norwegian emissions are however small. The emission intensity values of all the four countries are around the same level.

Figure 16. Emissions of CO_2 relative to electricity. Public electricity and heat production. ktonnes CO_2/GWh. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

Energy use
It seems that the energy sector in OECD's energy statistics does not cover the whole consumption of energy in the energy industry sector used to calculate the emission data reported to the UNFCCC. The consumption of fuels in the energy industries seems to be reported in the transformation and energy sectors in OECD. It is assumed that the fossil fuel used in electricity plants, CHP (combined heat and power) plants and heat plants reported to the OECD correspond to calculated emissions from public electricity and heat production reported to the UNFCCC. Municipal waste is included, while electricity, biomass and fuels used as feedstock are not.

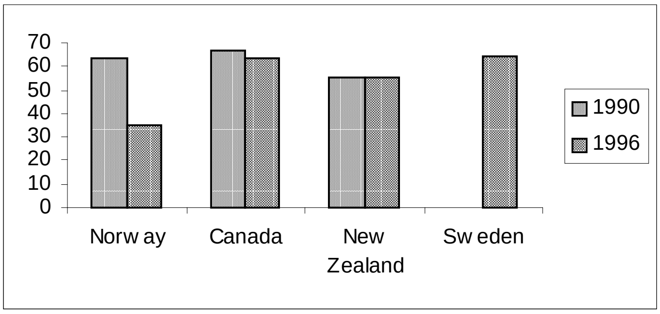
The emissions of CO_2 per unit energy used in 1990 are at about the same level for all the countries (Figure 17). In 1996 the Norwegian value is almost half the value in 1990 while Canada and New Zealand indicators are at the same level in 1996 as in 1990. Municipal waste is not included in 1990 for either of the countries due to reporting together with biomass (see section 3.1.2). A possible explanation for the Norwegian emission intensity value for 1996 being lower compared to the others is that the Norwegian CO_2 emissions reported only include the fossil part of carbon in the waste combusted. If this part differs between the countries it may be a source of inconsistency between the countries' energy data.

Another explanation for the low Norwegian value in 1996 is that emissions from combustion of natural gas at gas terminals are reported under the sub sector *Manufacture of solid fuels and other energy industries*. However, in the OECD/IEA energy statistics the natural gas is given under electricity plants. This leads to inconsistency between the energy and emission data for Norway. It seems that gas terminals not are included in the energy reporting for 1990 for Norway.

Norway reports consumption of blast furnaces within this sector. However, in the Norwegian emission inventory model the emissions are calculated directly from coal and coke figures and not through consumption of blast furnace. This might give different figures on the energy contents.

Blast furnace gas is counted as feedstock in the Norwegian emission inventory model, and in the emission figure reported to the UNFCCC. But in the OECD/IEA energy statistics, it is not specified if it is defined as feedstock or not. This may however be the situation for the other countries as well.

Figure 17. Emissions of CO_2 relative to energy use. Public electricity and heat production. ktonnes CO_2/PJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

Indicator appraisal

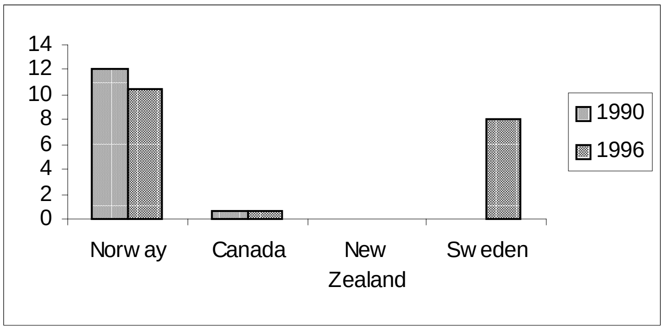
Energy use and electricity produced from fossil fuels seems both to be good indicators to use. There is lower percentage difference between the highest and the lowest emission intensity value for energy use in 1990, than for electricity produced from fossil fuel. The highest emission intensity value for energy used is however 83 per cent higher than the lowest in 1996 (Table 12). This is mainly due to the low Norwegian value in 1996 and due to inconsistency between the energy and emission data. These observations and the fact that most electricity in Norway is made from hydropower may lead to the supposition that energy use probably is a better indicator to use.

Table 12. Maximum percentage difference in the emission intensity values for the different indicators. Public electricity and heat production

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
GDP	10788	8577	11240
Population	9247	4545	9247
Electricity produced from fossil fuels	50	60	72
Energy use	20	83	88

Emission intensity values of CH_4 and N_2O for the suggested indicator
The emission intensity values for Norway for CH_4 are higher than for the other countries[3] (Figure 18). Energy use as an indicator seems to indicate that there is an inconsistency between the Norwegian energy data and the emission data (see discussion for CO_2 above). Detailed data for Sweden in 1990 and New Zealand for both years, which are not available from the sources used in this work, would be needed before we can make a more certain evaluation of the reliability of the indicator for the Norwegian emissions of CH_4. The Norwegian methane emissions are small, however, increasing from 0.09 ktonnes in 1990 to 0.11 ktonnes in 1996.

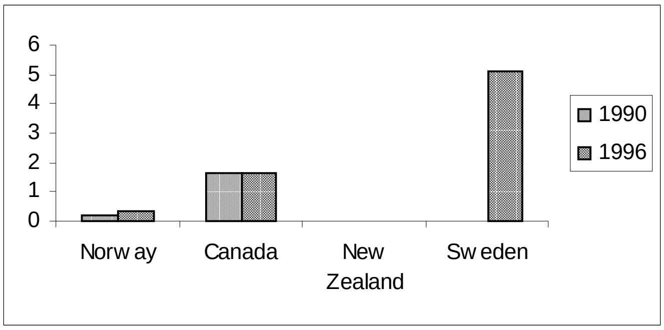
Figure 18. Emissions of CH_4 relative to energy use. Public electricity and heat production. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)
Detailed emission data for New Zealand for both years and Sweden in 1990 are not available from the sources used.

Figure 19 shows that the Swedish emission intensity value for N_2O is considerably higher compared with the values for Norway and Canada. One reason for this may be the high use of biomass as fuel in Sweden and the use of different emission factors. The Norwegian value increases from 1990 to 1996. However, the Norwegian emissions of N_2O are insignificant due to low activity level and differences might be caused by round off.

Figure 19. Emissions of N_2O relative to energy use. Public electricity and heat production. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD (1993a, 1993b and 1998a)
Detailed emission data for New Zealand for both years and Sweden in 1990 are not available from the sources used.

3.1.2.3. Petroleum refining

As mentioned earlier, Norway and Sweden have only reported the total emissions of CO_2, CH_4 and N_2O from energy industries in 1990 to the UNFCCC. More detailed data for the Norwegian emissions

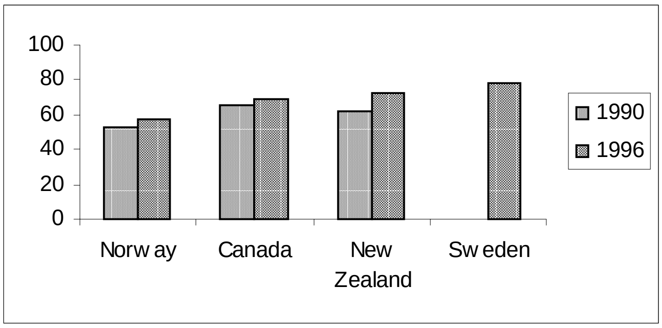
[3] Now including biomass in the energy data.

are available from Statistics Norway, but more detailed data for Sweden is lacking. The testing of the indicators have been performed without data for 1990 from Sweden.

Energy use

Fossil fuels consumed appear, as expected, to be a good indicator for verifying the Norwegian emissions from petroleum refining. The Norwegian emissions seem to agree very well with the emissions from the other countries (Figure 20). The trend is the same for three of the four countries, but ideally the emissions of CO_2 per unit of fossil fuel should have been the same, the columns should have had similar heights. The Norwegian use of refinery gas given in OECD/IEA (1993a) is about 60 ktonnes higher than the figure used in the calculation of the Norwegian emissions reported to the UNFCCC due to revised statistics. When today's figure is used, the Norwegian emission intensity values are similar in 1990 and 1996. There are not given any figures for the use of gas/diesel oil and residual fuel oil in Norway for 1996 in OECD/IEA (1998a) for this sector even if there was a small consumption. In 1990 it was about 6 ktonnes, it is somewhat lower in 1996.

Figure 20. Emissions of CO_2 relative to fossil fuel use. Petroleum refining. ktonnes CO_2/PJ. 1990 and 1996

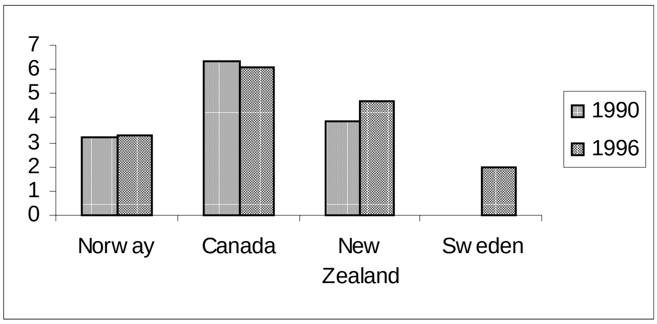


Sources: UNFCCC, OECD/IEA (1993a and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

Input to petroleum refineries

Emissions of CO_2 per input of crude oil and NGL to petroleum refineries are almost the same for Norway in 1990 and 1996 (Figure 21). The Norwegian emission intensity values lie in the interval of the values from the other countries. These observations may indicate that the Norwegian emissions are reliable. According to the OECD/IEA Energy Statistics only Canada has input of NGL in addition to crude oil.

Figure 21. Emissions of CO_2 relative to input of crude oil to petroleum refineries. Petroleum refining. ktonnes CO_2/PJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Oil and gas produced
Oil and gas produced is assumed not to be a relevant indicator for verifying the Norwegian emissions for petroleum refining since most of the oil produced is exported and is not refined in Norway. Sweden has only minor production of crude oil in 1990.

Indicator appraisal

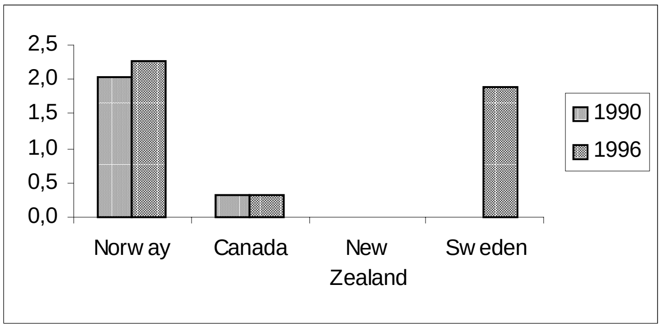
Not surprisingly, energy use seems to be the best indicator to use for verifying the Norwegian emissions from petroleum refining. The highest value is 24-35 per cent higher than the lowest value (Table 13).

Table 13. Maximum percentage difference in the emission intensity values for the different indicators. Petroleum refining

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Input to petroleum refineries	98	210	221
Fossil fuel use	24	35	48

Emission intensity values of CH_4 and N_2O for the suggested indicator
Emissions of CH_4 per unit fossil fuels used based on data reported to the OECD/IEA and the UNFCCC are higher in 1996 than in 1990 for Norway (Figure 22). If today's figure of refinery gas is used for 1990 (see discussion for CO_2 above) the Norwegian values become similar in 1990 and 1996. This new figure for fossil fuel used is not given in Figure 22 since only figures reported to OECD/IEA is used in this work. This and a comparison with the Swedish value, which is at the same level as the Norwegian values, indicate that the Norwegian emissions are reliable. The Canadian values are, however, lower for both years.

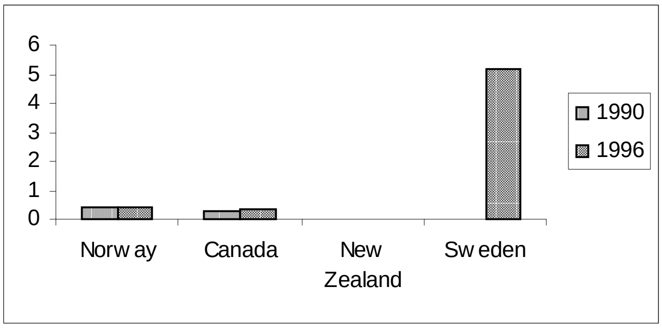
Figure 22. Emissions of CH_4 relative to fossil fuel use. Petroleum refining. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Norway and Canada have almost the same emissions of N_2O per unit fossil fuels used, both in 1990 and 1996 (reported energy data is used). Compared to Canada, the Norwegian emission estimates seem reliable. The Swedish emission intensity value is considerably higher compared to the other two countries.

Figure 23. Emissions of N_2O relative to fossil fuel use. Petroleum refining. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.1.2.4. Manufacture of solid fuels and other energy industries

As mentioned above, Norway and Sweden have only reported the total emissions from energy industries in 1990 to the UNFCCC. More detailed emission data for Norway are available from Statistics Norway, but more detailed data for Sweden are unfortunately lacking in the sources used in this work.

The following sub-sectors are included in this sector when Norway reports to the UNFCCC:

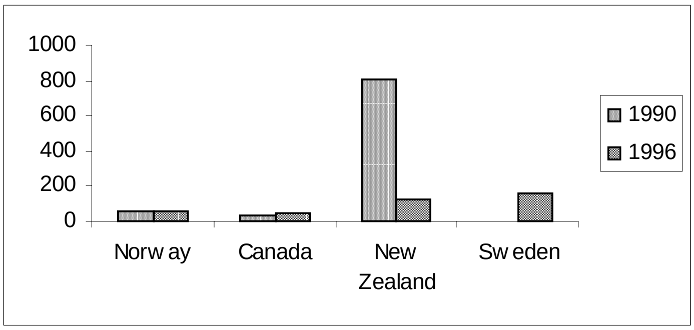
- Coal mining
- Extraction of oil and gas (including NGL)
- Gas terminals
- Transport of oil and gas by pipelines.

According to the revised 1996 IPCC Guidelines emissions from the last source should have been reported under *Transport* (Chapter 3.3). However, this is a minor source of emission within this sector[4], and the influence on the following results is negligible.

Energy use

The Norwegian emission intensity values for CO_2 (Figure 24) are in the interval of the other three countries and there is consistency between the two years, indicating that the Norwegian emissions may be reasonable. It is not known why New Zealand has such a high value in 1990.

Figure 24. Emissions of CO_2 relative to energy use. Manufacture of solid fuels and other energy industries. ktonnes CO_2/PJ. 1990 and 1996



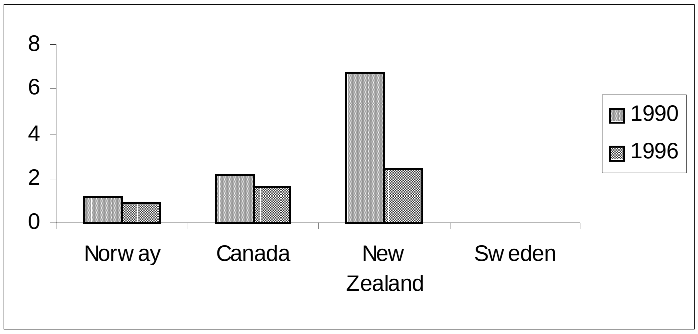
Sources: UNFCCC, OECD/IEA (1993a and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

[4] In 1996 CO_2 emissions from pipeline transport represented 0.2 per cent of the total CO_2 emissions reported for this sector.

Oil and gas produced

The Norwegian emission intensity value is decreasing from 1990 to 1996 (Figure 25). In Norway, the amount of combustion per unit oil and gas produced has decreased during the years, due to better energy efficiency. The drop in the emission intensity value may, however, also be due to the fact that three other sectors in addition to extraction of oil and gas are included in the sector *Manufacture of solid fuels and other energy sectors*. Another reason may be that the Norwegian production data given in OECD/IEA (1993a and 1998a) have been revised. When using the revised data, the differences between the Norwegian values become somewhat smaller. It is unknown why New Zealand has such a high value in 1990. Due to the large variance in technologies for oil and gas production, more countries should be included in the comparison before further conclusions are drawn. Sweden has only reported minor production of crude oil in 1990 and is not considered in the comparison.

Figure 25. Emissions of CO_2 relative to oil and gas produced. Manufacture of solid fuels and other energy industries. ktonnes CO_2/PJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)
Detailed emission data for Sweden in 1990 is not available from the sources used.

Indicator appraisal

The indicator oil and gas produced has the least difference between the highest and lowest emission intensity values (Table 14). But this indicator does not include Sweden, as they have no production of oil and gas. Due to the high differences between the highest and lowest values for the other indicators it is difficult to make any conclusions. Production of oil and gas and energy use, are probably both suitable indicators, but are expected to vary due to different technologies in use.

Table 14. Maximum percentage difference in the emission intensity values for the different indicators. Manufacture of solid fuels and other energy industries

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Energy used	2587	290	2587
Oil and gas produced	471	167	632

3.2. Manufacturing and construction

Manufacture and construction include the following sub-sectors:

- Iron and steel
- Non-ferrous metals
- Chemicals
- Pulp, paper and print
- Food, beverages and tobacco
- Other (construction, all other manufacturing).

3.2.1. Emissions

Manufacturing industries and construction account for from 10 to 25 per cent of the total CO_2 emissions in the four countries (Table 15 and Table 16). The emissions of CH_4 and N_2O contribute with respectively 0.02-2 per cent and 0.3-11 per cent of the national emissions. Sweden has the highest percentage of both CH_4 and N_2O, while the other three countries are more similar.

Table 15. Total emissions from manufacturing industries and construction and percentage of total national emissions. ktonnes and percentage. 1990

	Total emissions from manufacturing industries and construction (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	3110	0.4	0.1	9	0.1	0.5
Canada	62300	2	2	14	0.05	1
New Zealand	4710	0.4	0.1	18	0.02	0.3
Sweden	13050	5	2	24	2	8

Source: UNFCCC

Table 16. Total emissions and emissions from manufacturing industries and construction. ktonnes. 1996

	Total emissions from manufacturing industries and construction (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	3816	0.4	0.1	9	0.1	0.6
Canada	66900	2	2	13	0.05	1
New Zealand	5646	0.5	0.1	19	0.03	0.3
Sweden	14400	5	3	23	2	11

Source: UNFCCC

3.2.2. Indicators

Norway and Sweden have reported detailed emissions for these sectors, but only in 1996. In 1990 they have reported emissions for manufacturing industries and construction as a total, as New Zealand has done it both years. Detailed emission data for Norway in 1990 are however available from national sources. Due to the data availability from the sources we have used in this work, indicators for New Zealand can only be made for this sector as a total. Detailed emission data are given in Appendix B.

The following indicators have been used to compare the Norwegian emissions with the other countries.

Energy use in manufacturing industries and construction calculated into TJ by using Norwegian conversion factors from 1996. Biomass is included in the energy data only when considering CH_4 and N_2O, while electricity and energy commodities used as raw material are excluded.

Reliability A source of error may be inconsistency between the energy data and emission data between the countries. Coal and coke used as feedstock in Norway are not specified in the OECD/IEA energy statistics, everything is given as energy use. This may also be the situation for the other countries. Another problem is that special waste like waste oils, paint and solvents are not included in the OECD/IEA energy statistics, but emissions from combustion of these are included in the reported figures for Norway.

Another source of error is the use of the same conversion factor for all countries to obtain total energy use. The point that energy data given in OECD/IEA (1998a) for Norway in 1996 are preliminary figures, while the reporting of emissions are based on revised figures of energy use also cause uncertainty (see chapter 3.1 Energy Industries).

The sectors used in the reporting to the OECD/IEA may differ from the sectors used in the reporting to the UNFCCC. This may be a source of inconsistency between the two data sets.

Validity The indicator is expected to reflect the emission data very well, based on the fact that the four countries are fairly similar and it is the fuel combustion that causes the emissions.

Value added

Reliability Data for all four countries are only available until 1994 from the United Nations. In this work 1990 and 1996 are the years considered, but this indicator will only be regarded for 1990. The indicator will only be used for the main sectors, as detailed data for New Zealand and Sweden in 1990 not are available from the sources used.

Validity It is expected to be a better indicator for the sub-sectors than for the whole sector. But as mentioned above this indicator will only be used for the main sectors due to lack of data.

Production volume

Reliability A problem when using this as an indicator is that for many products data is not given due to confidentiality reasons. This will lead to inconsistency between the emissions and the amount of products. Another factor that will give inconsistency between the two data sets is that in some cases it is not quite clear which products that should be summed up to correspond to a certain sub-sector. Due to these reasons the indicator is not assumed to be very reliable. Using production data as an indicator would most likely give a better result if more detailed emission data, emissions for each type of product, were available.

Validity It is considered as an indicator for some of the sub-sectors only. It is presumed to be a good indicator for the sub-sectors where the production volume is easily added. Detailed emission data from Sweden in 1990 and from New Zealand are not available from the sources used in this work. Therefore the Norwegian emissions can only be compared to Canadian emissions and Swedish emissions in 1996.

Energy expenditure is not possible to use as an indicator due to lack of data at a sufficiently detailed level.

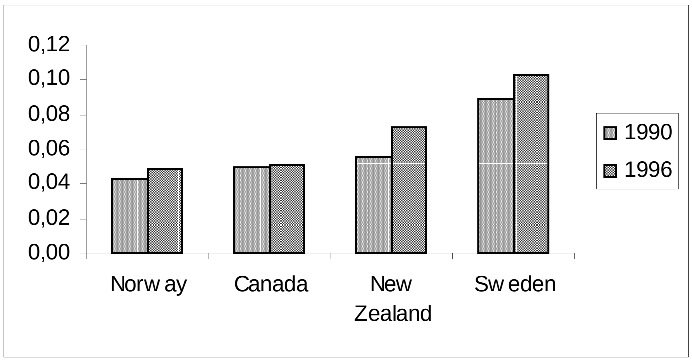
3.2.2.1. *Total emissions from manufacturing and construction*

Energy use
Comparing total emissions from manufacturing and construction with total energy use, excluding electricity and biomass, gives an indicator on the comparability of the two data sets. The correlation between the two data sets is assumed to be high, especially for CO_2 that depends only on the amount of energy used.

The energy data cover energy used for manufacturing and construction only, and the difference between the four countries are therefore presumed to reflect inconsistency between what the countries report to OECD/IEA and the emissions reported to UNFCCC. Such an inconsistency may arise because different institutions or departments report data on energy use and emissions, e.g. emissions from processes may be reported under emissions from energy use. Another reason may be differences between the two frameworks under which the data are reported. This weakness is also valid for other indicators.

The indicator of CO_2 emissions per unit energy used varies between the countries and by years (Figure 26). It is not known why the Swedish emission intensity value is so high compared to the other countries. The Norwegian values lie in the lower interval of the other countries and are nearly the same as those for Canada. The reason for the low emission intensity values might be that coal and coke used as feedstock are included in the consumption figures in the OECD/IEA statistics. This is particularly serious for Norway, as the amount of coal and coke used as feedstock in metal production is considerable.

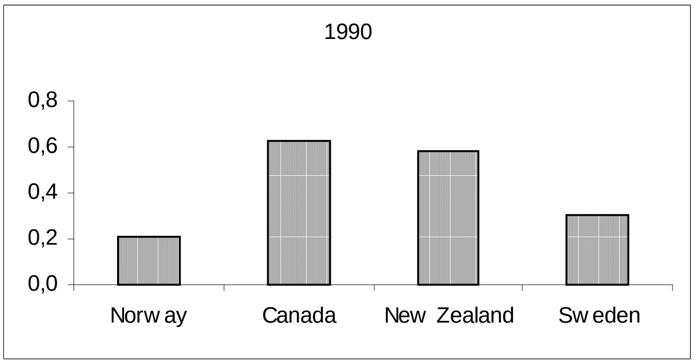
Figure 26. Emissions of CO_2 relative to energy use. Manufacturing and construction. ktonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added
When using value added as an indicator, the Norwegian emission intensity value is the lowest (Figure 27). This might be due to a high fraction of energy being electricity. It is difficult to say anything about the reliability of the Norwegian emission estimates from this indicator, and nothing can be said about the reliability over years.

Figure 27. Emissions of CO_2 relative to value added. Manufacturing and construction. ktonnes CO_2/million USD. 1990



Sources: UNFCCC, UN (1997b)

Indicator appraisal

Energy use seems to be the best indicator to use when comparing the Norwegian emissions with the other countries. The difference between the highest and lowest emission intensity value is about the same in 1990 and 1996 (Table 17).

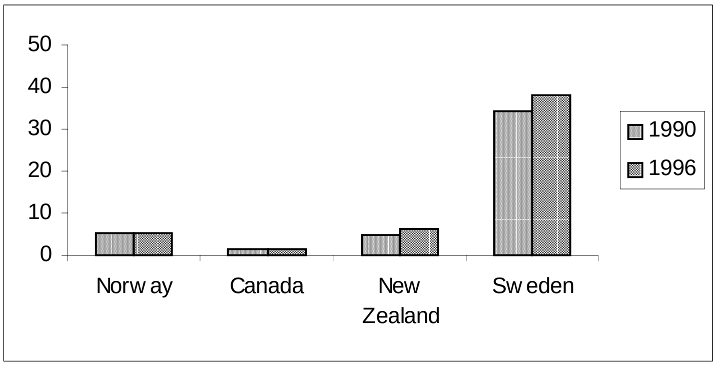
Table 17. Maximum percentage difference in the emission intensity values for the different indicators. Manufacturing and construction

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Energy use	112	110	144
Value added	203	-	-

Emission intensity values of CH_4 and N_2O for the suggested indicator

The Norwegian emission intensity values of methane are nearly the same for both years and they lie in the interval of the other countries (Figure 28). This may indicate that the Norwegian emissions are reasonable, regarding level. The Swedish values are significantly higher compared to the other countries. One reason may be use of different energy commodities or emission factors.

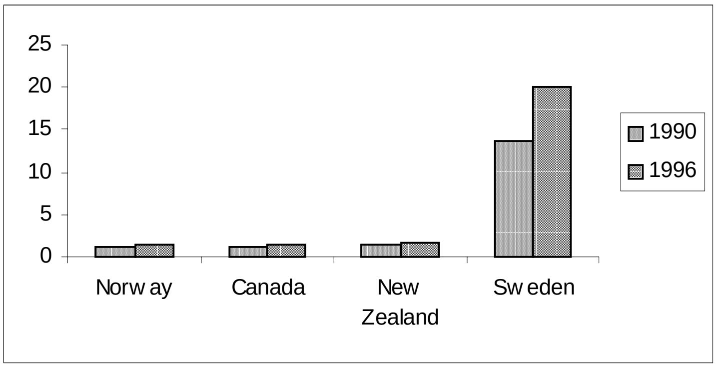
Figure 28. Emissions of CH_4 relative to energy use. Manufacturing and construction. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Using energy use as an indicator, the Norwegian emission intensity values of N_2O seems reliable both at level and by years as the Norwegian values are nearly the same for both years and lie in the interval of the other countries (Figure 29). Again the Swedish values are considerably higher compared to the others.

Figure 29. Emissions of N_2O relative to energy use. Manufacturing and construction. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.2.2.2. Iron and steel

Since detailed emission data from both years for New Zealand and from 1990 for Sweden not are available from the sources used, the Norwegian emissions can only be compared with emissions from Canada and from Sweden in 1996. This will make the comparison of the Norwegian emissions with the other countries, in order to test the reliability of the Norwegian emissions, more uncertain, as it will be based on fewer data.

Energy use

Figure 30 shows that it is difficult to say anything about the reliability of the Norwegian emissions from a comparison with the other countries. The Swedish value is much higher compared to the others. Different emissions factors and definitions may be the explanation. In the OECD/IEA energy statistics *Iron and steel* includes:

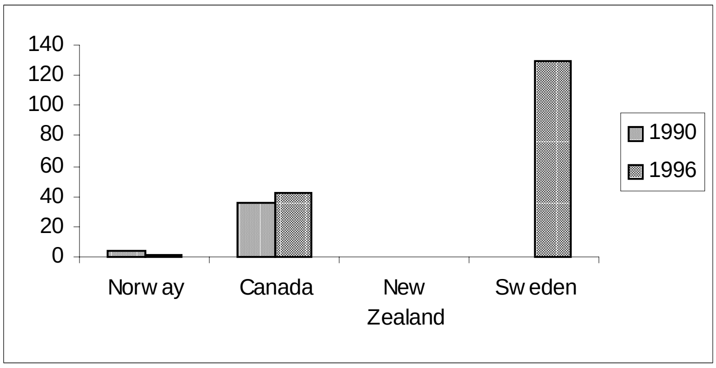
- ISIC 271 Basic iron and steel
- ISIC 2731 Casting of iron and steel.

Energy data reported by Norway include:

- Production of iron and steel
- Production of ferroalloys
- Casting of metals.

A problem is that all coke and coal are shown under energy use in the OECD/IEA energy statistics, but in Norway this is mostly used as feedstock. Emissions from the use of feedstock are reported to the UNFCCC under the main sector *Industrial processes* according to the IPCC Guidelines (IPCC 1997). There is consequently inconsistency between the Norwegian energy data and emission data. This may also be the situation for the other countries. In the chapter for industrial processes (Chapter 4) the emissions from both combustion and non-combustion of fuels are used when assessing an indicator for this sector.

Figure 30. Emissions of CO_2 relative to energy use. Iron and steel. ktonnes CO_2/PJ. 1990 and 1996



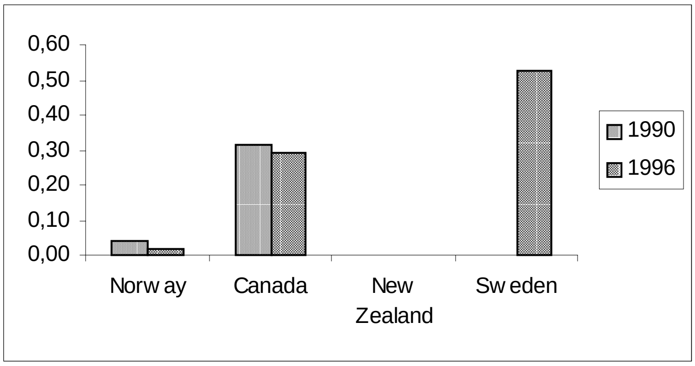
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added
Detailed data for value added is not available from the sources used. In UN (1997b), value added is given for basic metal industries, which include more than the sub-sector iron and steel, which is used when reporting emissions to UNFCCC.

Emission per produced volume
It does not seem useful to make use of production volume as an indicator for comparison of the Norwegian emissions with the other countries. The values vary considerably between the countries, both at level and years (Figure 31). As mentioned above, a problem when using production volume as an indicator is that for many products data is not given due to confidentiality reasons. This will lead to inconsistency between the emissions and the amount of products.

Another problem is as mentioned above that there is inconsistency regarding reporting of emissions, if they are to be reported as process or energy. The Norwegian emissions from use of coal and coke in this sector are (according to the IPCC reporting guidelines) reported as process emissions. The reporting routine may however differ from one country to another.

Figure 31. Emissions of CO_2 relative to production volume. Iron and steel. ktonnes CO_2/ktonnes products. 1990 and 1996



Sources: UNFCCC, UN (1998)

Indicator appraisal
As shown in Table 18, there are great differences between the highest and the lowest emission intensity values. We therefore conclude that it is difficult to use either of the indicators for testing the Norwegian emissions reported. More detailed and consistent data is needed before any of these indicators could be used.

Table 18. Maximum percentage difference in the emission intensity values for the different indicators. Iron and steel

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Energy use	913	7153	7153
Production volume	659	2574	2574

3.2.2.3. Non-ferrous metals

Energy use

Using energy use as an indicator indicates that the Norwegian emissions are reasonable compared to Canada and Sweden (Figure 32). However, the Norwegian emission intensity value is higher in 1996 than in 1990. Different emissions factors and definitions may be the explanation. In the OECD energy statistics *Non-ferrous metals* includes:

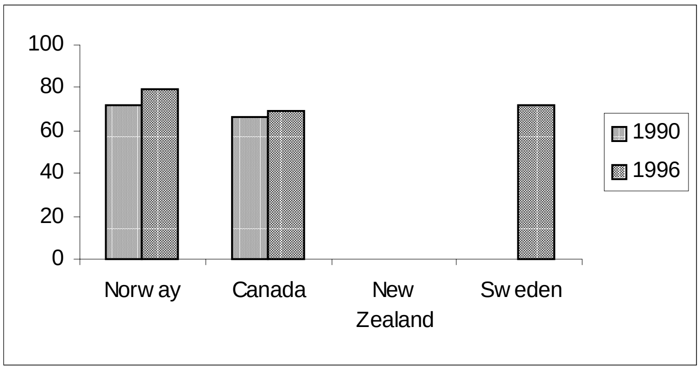
- ISIC 272 Basic precious and non-ferrous metals
- ISIC 2732 Casting non-ferrous metals.

Energy data reported by Norway include:

- Production of aluminium
- Production of other non-ferrous metals.

As mentioned earlier, a problem is that coke and coal are shown under energy use in the OECD energy statistics, but in Norway they are used as feedstock and the emissions from the use are reported to the UNFCCC under industrial processes. There is consequently inconsistency between the Norwegian energy data and emission data. This may also be the situation for the other countries. In the section for industrial processes the emissions from combustion and non-combustion of fuels are used when making an indicator for this sector.

Figure 32. Emissions of CO_2 relative to energy use. Non-ferrous metals. ktonnes CO_2/PJ. 1990 and 1996



Sources: UNFCCC, OECD (1993a and 1998a)

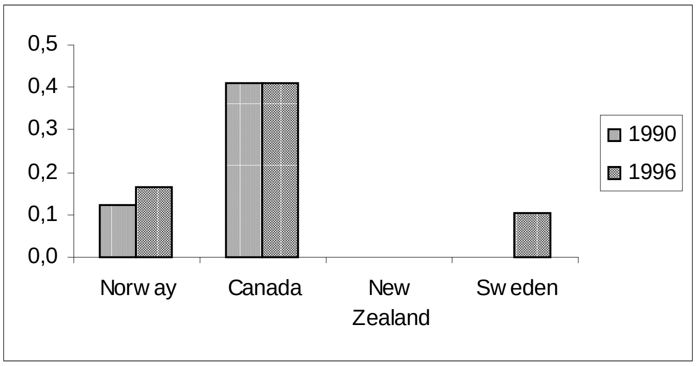
Value added

Detailed data on value added is not available from the sources used. In UN (1997b), value added is given for basic metal industries, which include more than the sub-sector *Non-ferrous metals*, used when reporting emissions to UNFCCC.

Emission per produced volume

As expected, production volume is not a good indicator for testing the emissions of non-ferrous metals reported by Norway (Figure 33). Due to confidentiality reasons, there will be inconsistency between the emissions and the amount of products. There may also be differences in the mix of metals produced.

Figure 33. Emissions of CO_2 relative to production volume. Non-ferrous metals. ktonnes CO_2/ktonnes products. 1990 and 1996



Sources: UNFCCC, UN (1998)

Indicator appraisal

The best indicator for CO_2 emissions from non-ferrous metals is, in spite of the problems described, found to be energy use. The highest emission intensity value is only 8-15 per cent higher than the lowest (Table 19).

Table 19. Maximum percentage difference in the emission intensity values for the different indicators. Non-ferrous metals.

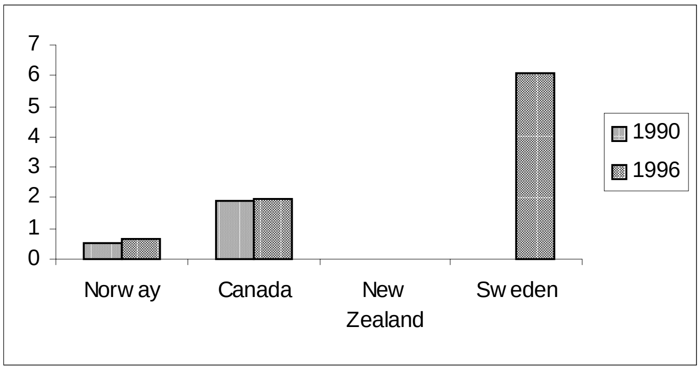
Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Energy use	8	15	19
Production volume	237	303	303

Emission intensity values of CH_4 and N_2O for the suggested indicator

No emission data for methane from non-ferrous metals for Canada and Sweden is available (too few digits) from the sources used in this work, so there are no emission intensity values to compare the Norwegian data to.

The Norwegian emission intensity values of N_2O (Figure 34) are much lower than the values for Canada and Sweden. Different emission factors may be the explanation, together with inconsistency between energy and emission data between the countries.

Figure 34. Emissions of N_2O relative to energy use. Non-ferrous metals. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.2.2.4. Chemicals

The Norwegian emissions reported include the following important production processes:

- Manufacture of dyes and pigments and other inorganic basic chemicals
- Manufacture of fertilisers, nitrogen compounds and pesticides
- Manufacture of plastics and synthetic rubber in primary forms and other organic basic chemicals.

In the OECD/IEA energy statistics *Chemical industry* includes:

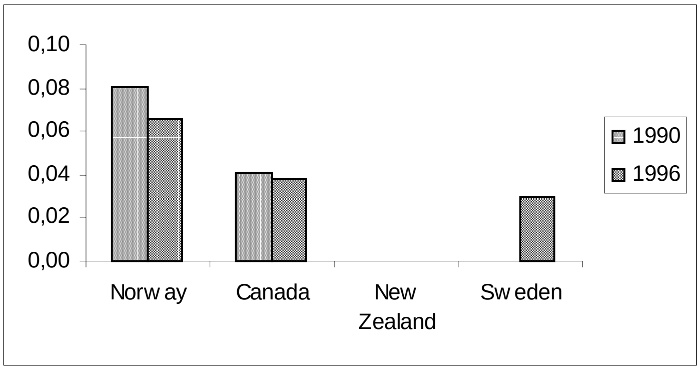
- ISIC Division 24: Chemical and chemical products.

Energy use

Fuel used as feedstock should not be included in the data reported. Regarding coal and coke, the use of these for non-energy purposes is not specified in the OECD/IEA energy statistics. The use of LPG and ethane as feedstock is however specified, and the amounts are not included.

The Norwegian emissions of CO_2 per unit energy used are high compared to the others (Figure 35), but the level seems reasonable. In this sector coal, coke and petrol coke are used as feedstock in Norway, but this is not specified in the OECD/IEA energy statistics. If this is considered and revised figures for energy consumption are used, the Norwegian emission intensity values become lower and nearly the same in both years.

Figure 35. Emissions of CO_2 relative to energy use. Chemicals. ktonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added

This indicator is not used due to difficulties in finding detailed data. Value added is given for manufacture of chemicals and chemical petroleum, coal, rubber and plastic products. Coal is not included in the sector *Chemicals* which is used when reporting to the UNFCCC.

Emission per produced volume

This indicator is not used, because of lack of data due to confidentiality reasons.

Indicator appraisal

Energy use is the only indicator available. Table 20 below shows that the highest emission intensity value is 97-124 per cent higher than the lowest emission intensity values. The high percentage makes it too uncertain to evaluate the emissions reported by Norway by using this indicator. Besides emissions from New Zealand and Sweden in 1990, are not included due to lack of data.

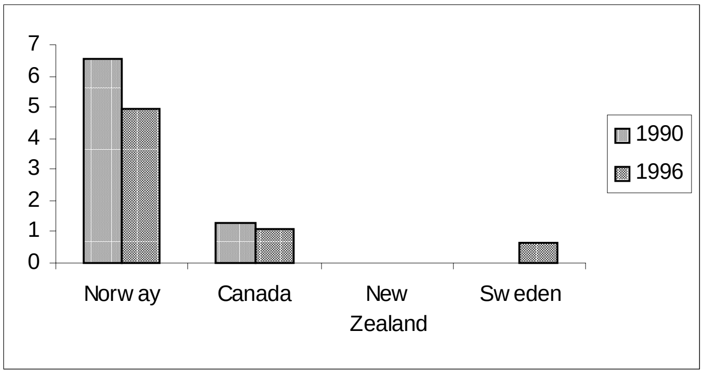
Table 20. Maximum percentage difference in the emission intensity values for the different indicators. Chemicals

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Energy use	97	124	176

Emission intensity values of CH_4 and N_2O

Estimated emissions of methane per unit energy use in Norway differ a lot between the two years (Figure 36). The main reason is, as discussed above, that the energy data have been revised since the reporting. If the revised energy data is used for both years, the difference seen for Norway is considerably reduced, but the emission intensity values are still higher compared to the other countries. This might be caused by the use of different fuels.

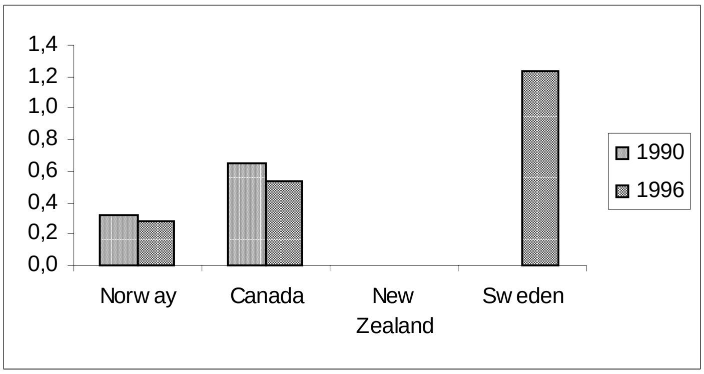
Figure 36. Emissions of CH_4 relative to energy use. Chemicals. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

The Norwegian trend for emissions of N_2O per unit energy used is the same as for CO_2 and CH_4, with higher value in 1990 compared to 1996 (Figure 37). If revised figures for energy consumption are used, the Norwegian values will be nearly the same in both years. The Norwegian values are still lower compared to the other countries, but this might be related to the use of different fuels.

Figure 37. Emissions of N_2O relative to energy use. Chemicals. kg N_2O/TJ. 1990 and 1996



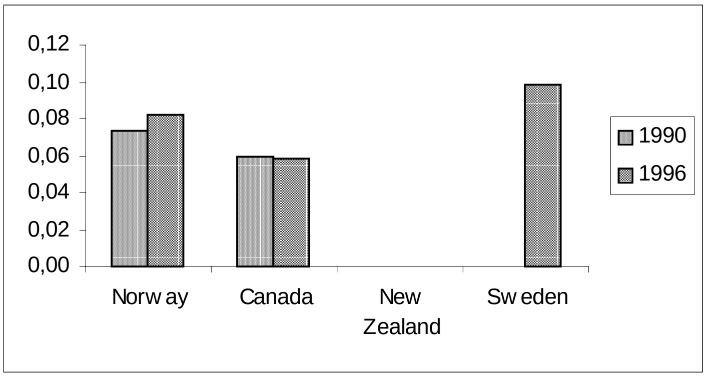
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.2.2.5. Pulp, paper and print

Energy use

The Norwegian emission intensity value for CO_2 is higher in 1996 than in 1990 (Figure 38). This is because the reported emissions are based on revised figures on energy data. If using revised energy data, the Norwegian emission intensity values become 0.077 ktonnes CO_2 per TJ in both years. Canada has nearly similar values as Norway.

Figure 38. Emissions of CO_2 relative to energy use. Pulp, paper and print. ktonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added
Data for 1996 is not available. Detailed emission figures are not available for Sweden in 1990 and New Zealand in both years from the sources used in this work.

Emission per produced volume
This indicator is not used as a complete set of relevant production data is lacking due to confidentiality reasons.

Indicator appraisal

The only indicator available is energy use, and as seen in the table below, the highest emission intensity value is 24 per cent higher than the lowest in 1990 and 70 per cent higher in 1996. Energy use seems to be a good indicator for this source sector.

Table 21. Maximum percentage difference in the emission intensity values for the different indicators. Pulp, paper and print

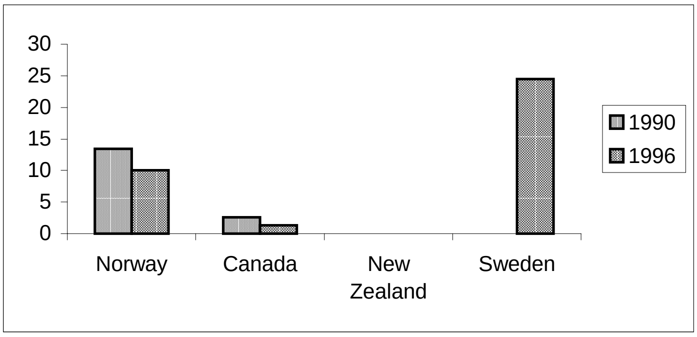
	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
Energy use	24	70	70

Emission intensity values of CH_4 and N_2O for the suggested indicator
The reported emissions of CO_2 from this sector do not include emissions from combustion of wood and wood waste. Emissions from these energy commodities are however included in the reported emissions of CH_4 and N_2O. These energy commodities consequently need to be included when using energy use as an indicator for the emissions of CH_4 and N_2O.

Wood and wood waste is not given in the Energy Statistics of OECD countries (OECD/IEA 1993a). However, other solid fuels, including peat, wood, wood waste, municipal waste, industrial waste and black liquor are given in the Energy Balances of OECD countries (OECD/IEA 1993b).

Using energy as an indicator for CH_4 gives emission intensity values for Norway that lie within the interval of the other countries (Figure 39). If revised figures on the Norwegian energy consumption are used, the emission intensity value will still be higher in 1990 than in 1996. This relates to the use of different mix of fuels in the two years, e.g. with higher consumption of heavy fuel oils in 1996.

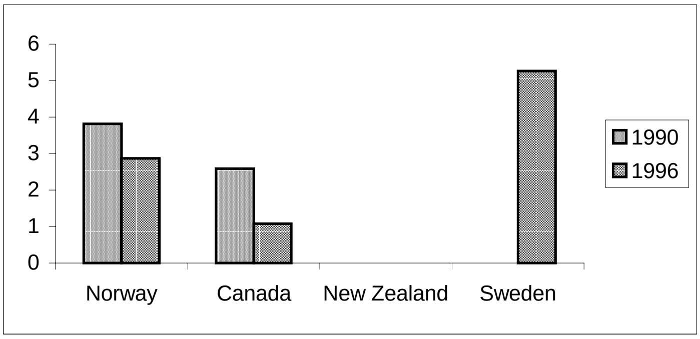
Figure 39. Emissions of CH_4 relative to energy use. Pulp, paper and print. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)
No data for use of biomass is given for Canada in 1990

Energy use as an indicator gives emissions intensity values of N_2O for Norway that lie in the interval of Canada and Sweden (Figure 40). This indicates that the Norwegian emission estimates are reasonable. The reliability of the indicator is however difficult to assess since only three of the four countries are considered and only two of the countries have emission intensity values for both 1990 and 1996. The Norwegian values are decreasing from 1990 to 1996, also if revised energy figures are used. This is mainly due to more use of heavy fuel oils in 1996.

Figure 40. Emissions of N_2O relative to energy use. Pulp, paper and print. kg N_2O/TJ. 1990 and 1996



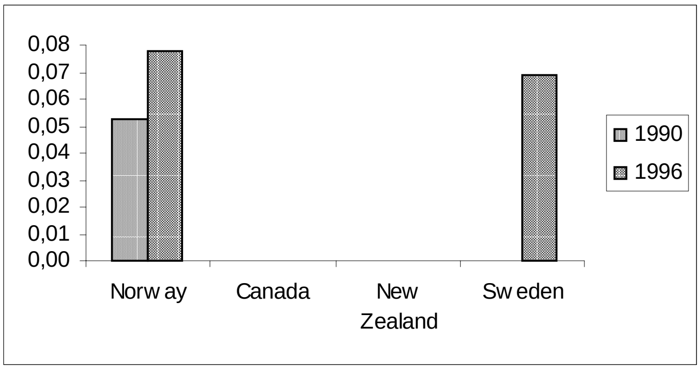
Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)
No data for use of biomass is given for Canada in 1990

3.2.2.6. Food processing, beverages and tobacco

Energy use

Consumption of fuel in this sub-sector is not reported by Canada, and no emissions are reported either. The Norwegian values can only be compared to the 1996 value for Sweden. This makes it difficult to test the reliability of the emissions reported by Norway. The energy data given in the OECD/IEA energy statistics for Norway for 1990 and 1996 have been revised since the reporting. The energy data reported for 1996 by Norway is preliminary, and they have been revised since the reporting. The emissions reported are based on the revised figures. Also energy data for 1990 has been revised since the reporting, a difference is especially seen for residual fuel oil. This explains most of the differences in the Norwegian emission intensity values (Figure 41).

Figure 41. Emissions of CO_2 relative to energy use. Food processing, beverages and tobacco. ktonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added
Data for 1996 is not available. Detailed emission figures are not available for Sweden for 1990 and both years for New Zealand.

Emission per produced volume
This indicator is not used, as several production data are lacking due to confidentiality reasons.

Indicator appraisal
The only indicator available is energy use, and as seen in the table below, the highest emission intensity value is 13 per cent higher than the lowest in 1996. Since there is only one emission intensity value besides those for Norway, it makes it difficult to use the indicator to test the reliability of the emissions reported by Norway. However, it is likely to be a good indicator in general.

Table 22. Maximum percentage difference in the emission intensity values for the different indicators. Food processing, beverages and tobacco

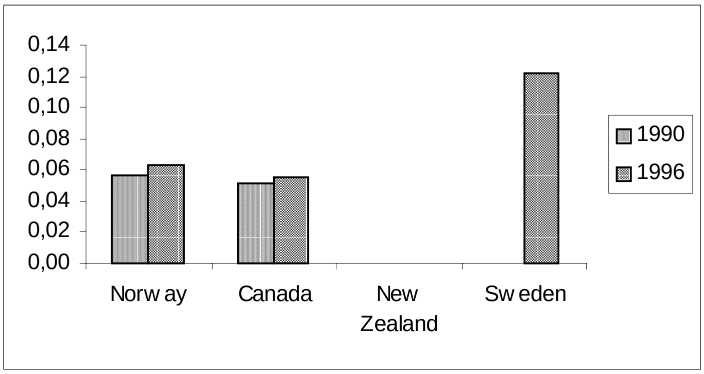
Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Energy use	-	13	-

Emission intensity values of CH_4 and N_2O for the suggested indicator
No indicator suggested due to too few reported data.

3.2.2.7. Other (oil drilling, construction, all other manufacture)

Energy use
As seen in Figure 42, the Norwegian emission intensity values are very similar to the Canadian ones, both at level and in years. This may indicate that the Norwegian emissions are reliable. Why the Swedish value is so high might be due to different definitions of energy and emissions.

Figure 42. Emissions of CO_2 relative to energy use. Other (oil drilling, construction, all other manufacture). ktonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added
Data for 1996 is not available. Detailed emissions are not available for Sweden for 1990 and both years for New Zealand.

Emission per produced volume
This indicator is not used as several production data are lacking due to confidentiality reasons. Besides, this sub-sector includes several different industries, which would make it difficult to make a sum of total physical production.

Indicator appraisal

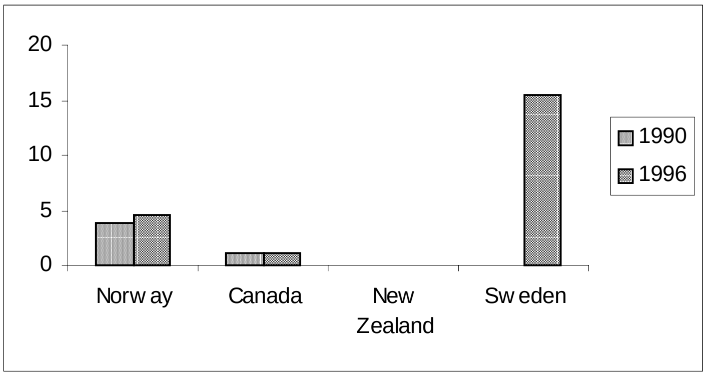
Energy use is the only indicator available. The difference between the highest and lowest emission intensity values is much higher in 1996 (Table 23Table 23), because of the high Swedish value. Energy use is likely to be a good indicator.

Table 23. Maximum percentage difference in the emission intensity values for the different indicators. Other (oil drilling, construction, all other manufacture)

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Energy use	11	121	139

Emission intensity values of CH_4 and N_2O for the suggested indicator
Using energy use as an indicator for the emissions of methane indicates that Norway has higher emissions per unit energy used than Canada, but much lower than Sweden (Figure 43). Why the Swedish emission intensity value is so high is not known. Energy use is likely a good indicator to assess emissions from this sub-sector.

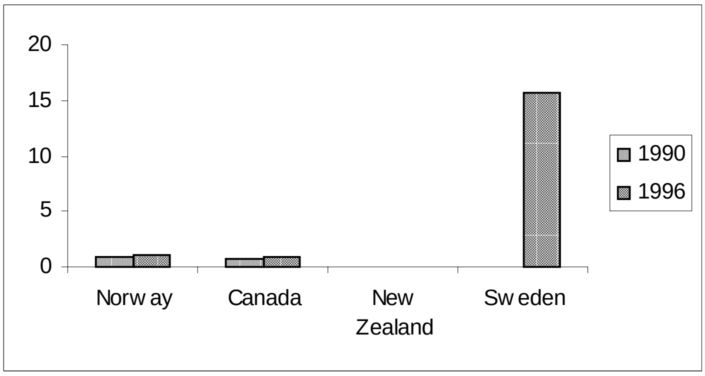
Figure 43. Emissions of CH_4 relative to energy use. Other (oil drilling, construction, all other manufacture). kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

The emissions of N_2O per unit energy used are about the same for Norway and Canada, while Sweden has a very high value compared to the other two countries (Figure 44). Different methodology and emission factors may explain the difference. Energy use is likely a good indicator for N_2O emissions from this sub-sector.

Figure 44. Emissions of N_2O relative to energy use. Other (oil drilling, construction, all other manufacture). kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

3.3. Transport

This is a relatively heterogeneous group of emission sources. Different indicators may be relevant for the different sources. Emission data and activity data are consequently split into aviation, navigation, road, railways and other, according to the IPCC standard reporting tables[5]. We are considering domestic activity and emissions only, as international shipping and aviation are excluded from the Kyoto protocol and are not included in the national totals.

3.3.1. Emissions

Transport is an important source of CO_2 emissions in all four countries, counting for about 30-50 per cent of national emissions for this pollutant. The emissions of CH_4 and N_2O are contributing with

[5] Sweden and Canada have listed a distinct category for pipeline transport (though only Canada reports emissions). However, according to the IPCC guidelines (see chapter 1 in the reporting instructions), pipeline transport should be included in the category *Other*. Norway has reported emissions from pipeline transport elsewhere (see Section 3.3.2.6)

about 1-8 per cent and 1-16 per cent respectively. The four countries seem to be quite similar regarding emissions from mobile combustion, relative to total national emissions.

Energy use for transport covers several different types of energy carriers due to the variety of means of transportation. While the emissions of CO_2 depend on the amount of fuel used only, CH_4 and N_2O emissions are determined by the conditions of combustion. The CH_4 and N_2O emissions are quite uncertain and differences between countries may occur due to this. Although CO_2 emissions depend on fuel consumption only, the methodologies upon which the emissions are calculated may vary from country to country and therefore also the emissions of this pollutant. In principle, however, technologies in use are about the same in these countries and estimates of all three pollutants should be comparable.

Table 24. Total emissions from transport and percentage of total national emissions. ktonnes and percentage. 1990

	Total emissions from transport (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	13533	4	1	38	1	4
Canada	147200	23	29	31	1	15
New Zealand	8645	7	0.4	33	0.4	1
Sweden	18650	23	3	34	8	10

Source: UNFCCC

Table 25. Total emissions from transport and percentage of total national emissions. ktonnes and percentage. 1996

	Total emissions from transport (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	14964	3	1	36	1	8
Canada	166590	21	51	32	0.5	22
New Zealand	10972	7	0.5	36	0.4	1
Sweden	19573	19	2	31	6	16

Source: UNFCCC

3.3.2. Indicators

We have used the following four indicators to compare the emission data for Norway with corresponding data for Canada, New Zealand and Sweden, for 1990 and 1996.

GDP measured in current prices and exchange rates.

Reliability The reliability of this indicator is presumed to be very good.

Validity The validity of GDP as an indicator of emissions from transport is highly questionable. Transport's contribution to GDP differs between the countries and the indicator is therefore assessed as an overall last resort for comparing emissions between the four countries. The validity is assumed to be better for the whole sector, than for sub-sectors like aviation.

Population

Reliability The reliability of this indicator is presumed to be very good.

Validity Population is assumed to be a better indicator than GDP since the transport in many cases are more correlated with population than GDP. Figure 2.1 illustrates differences in GDP/capita between the four countries. The lowest GDP/capita are about half of the highest for both years, indicating that the two indicators are not very correlated.

Energy used for transport. The energy used is converted to TJ in order to sum up total energy use by different means of transportation. Electricity is excluded.

Reliability — The biggest problem with the indicator is the level of comparability. The sectors by which the countries report their emissions to UNFCCC and energy use to OECD/IEA, seem to match the corresponding sectors at first glance. There are, however, reasons to believe that each country might classify its mobile emission sources differently, regarding whether they report energy used or emissions.

Validity — We assess the indicator to reflect the emission data very well. This is based on the fact that the four countries are fairly similar and that it is the energy use that causes the emissions.

Transport activity measured in tonne-km (tkm) and passenger-km (pkm). Passenger-km is converted into tonne-km before comparing the transport activity with emissions. 1 tkm is set to equal 0.0864 pkm (Holtskog and Rypdal 1997).

Validity — We assess the indicator to reflect the emission data fairly well. This is based on the fact that the four countries are fairly similar and the capacity of the different means of transportation is about the same in each country. The biggest drawback concerning this indicator is the inclusion of activity data of electrified railways.

In the following chapters we discuss the indicators' ability to explain a country's emissions from transport. We suggest an indicator for each mean of transportation by comparing the different data, focusing on the gap between the lowest and highest emission intensity values.

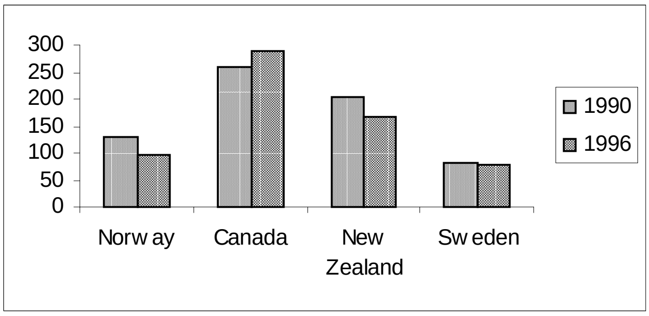
3.3.2.1. Total emissions from transport

In order to get an overall view of the comparability between the emissions and the different indicators, we first consider total emissions from transport. It is, however, important to be aware of the fact that an indicator may be valid for one mean of transportation although it is not a valid indicator for total emissions. Differences may also well be due to different mix in transport modes.

GDP

Comparing emissions from transport with GDP, measured in current prices and exchange rates, is obviously a very rough comparison. The result is therefore surprisingly good since the value of the indicator for CO_2 is about the same magnitude for all countries. The value of the indicator for Norway lies in the interval between the other countries, indicating that the Norwegian emissions are reliable.

Figure 45. Emissions of CO_2 relative to GDP. Transport. ktonnes CO_2/billion USD. 1990 and 1996

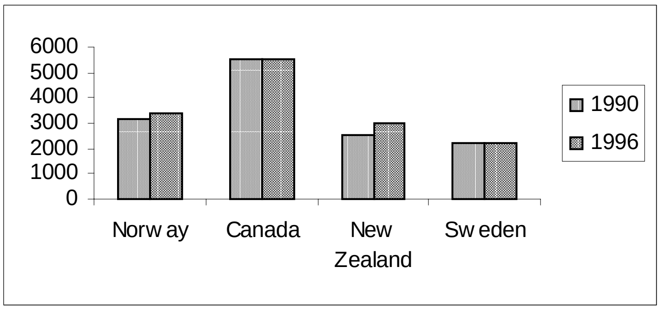


Sources: UNFCCC, OECD (1992a and 1998a)

Population

Using population data to verify emissions is, as for GDP, also a very rough approach. Figure 46 shows that the interval of the emission intensity values are about the same as for GDP. The Norwegian values are within the interval of the other countries, showing that Norwegian emissions are reasonable compared to the other three countries when using population as indicator of emissions. Emissions relative to the population have increased in all countries from 1990 to 1996.

Figure 46. Emissions of CO_2 relative to population. Transport. ktonnes CO_2/million capita. 1990 and 1996



Sources: UNFCCC, OECD (1992a and 1998a)

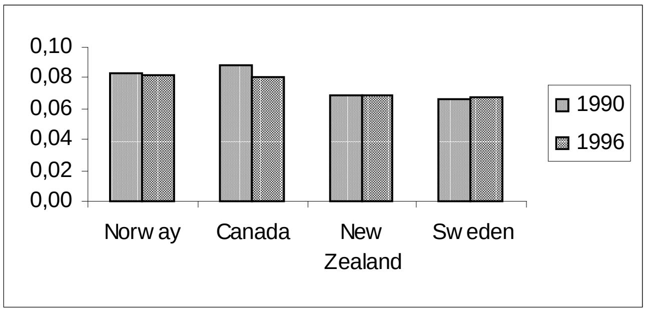
Energy
Comparing total emissions from transport with total energy use, excluding electricity, gives an indicator on the comparability of the two data sets. The correlation between the emission and energy use is assumed to be very high, especially for CO_2 that depends solely on the amount of energy used.

The energy data are covering energy used for transport only, and the differences between the four countries are therefore presumed to reflect inconsistency between what the countries report to OECD/IEA as the energy used for transport, and the emissions reported to UNFCCC from this sector. This may e.g. be due to the fact that it is not the same institution or department which report both energy and emission data. Another reason may be blurry categorisation of the energy use and emissions, or simply smaller differences between the two frameworks under which the data are reported. This point will be further elaborated under the different sub-sectors of transportation. The weakness is also valid for several other indicators.

As shown in Figure 47, the indicator of CO_2 emissions per unit of energy used is relatively constant both between the countries and by time. The difference in emission intensity values in Canada from 1990 to 1996 is due to a change in the sector classification of the energy used for pipeline transport in the OECD reporting framework. Canada reports emissions from pipeline transport in both years, but in the OECD statistics the energy used is only available for 1996.
The Norwegian emission intensity values are at the same level as the Canadian values, especially when assuming that the 1996 emission intensity value for Canada is too low. The evenness between years indicates consistent reporting rules within countries.

We may conclude that, since the estimations of CO_2 emissions seem reliable, the two sources of information, UNFCCC and OECD/IEA, are comparable. It is apparent that the sector classification regarding both emissions of CO_2 and energy used are fairly consistent at this level of comparison.

Figure 47. Emissions of CO_2 relative to energy use. Transport. ktonnes CO_2/TJ. 1990 and 1996



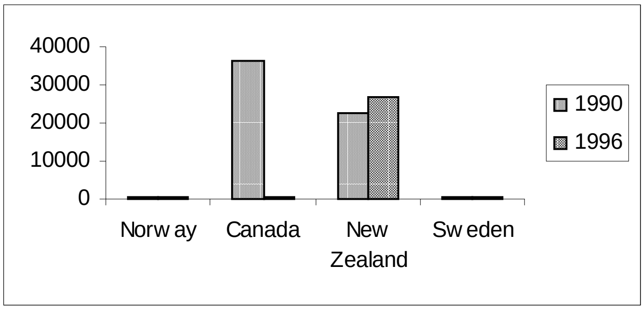
Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Transport activity

Using transport activity, measured in passenger-km (pkm) and tonne-km (tkm), as an indicator of CO_2 emissions has two major weaknesses. One is that electrified railways are included in the activity data, but not in the emission data since they have no direct emissions. The other is that the factor used for converting pkm to tkm in order to produce one activity indicator introduce inaccuracies.

The emission intensity values for CO_2 vary a lot and it is difficult to draw any conclusions, see Figure 48. The variation is mostly due to lack of complete activity data for New Zealand and Canada (1990). Norway and Sweden have about the same emissions per tkm, indicating a verification of Norway's emissions since these two countries are fairly similar.

Figure 48. Emissions of CO_2 relative to transport activity. Transport. ktonnes CO_2/billion tkm (including pkm). 1990 and 1996



The 1996 aviation data are from 1995. The activity data for New Zealand (1990 and 1996) and Canada (1990) cover aviation only.
Sources: UNFCCC, UN (1994 and 1997a), OECD (1992a and 1998a).

Indicator appraisal

The best overall indicator for CO_2 emissions from transport is found to be energy. The highest emission intensity value is only about 20-30 per cent higher than the lowest.

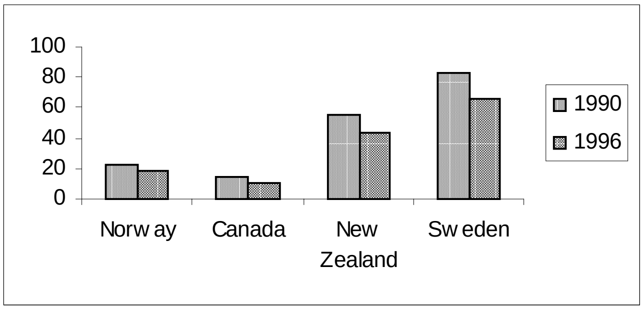
Table 26. Maximum percentage difference in the emission intensity values for the different indicators. Transport

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
GDP	216	270	270
Population	154	153	155
Energy	34	22	34
Transport activity	12201	9667	13185

Since the emission intensity values based on energy use are about the same for all the countries, the Norwegian emission data from transport are assessed to be reasonable.

Emission intensity values of CH_4 and N_2O for the suggested indicator
Figure 49 shows that CH_4 emissions per unit energy consumed vary a lot between the four countries. This may be due to (1) different emission factors used, and/or (2) different composition of energy carriers used and combustion conditions and/or (3) different mix of transport modes. Figure 49 also illustrates that there has been a reduction in emissions of CH_4 from 1990 to 1996, probably due to the increasing amount of vehicles equipped with catalytic converter. The differences between 1990 and 1996 for each of the countries may also express differences in (1) the composition of the stock of vehicles, and (2) road traffic's share of emissions from mobile combustion.

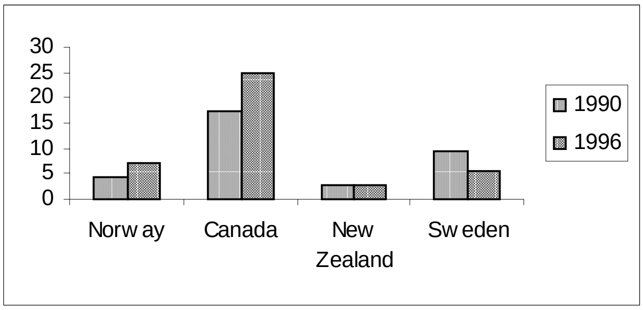
Figure 49. Emissions of CH_4 relative to energy use. Transport. kg CH_4/TJ. 1990 and 1996



The 1996 emission data for Canada and New Zealand is from 1995. Emission data does not include emissions from railways.
Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Figure 50 illustrates that the N_2O emissions per unit energy consumption within transport have increased from 1990 to 1996 for all countries, except for Sweden. Catalytic converters on passenger cars increase the emissions of N_2O and the pattern in Figure 49 and Figure 50 are therefore reasonable. The reduction in Sweden's emissions of N_2O is due to a decrease in the emissions from the sub-sector *Other*[6]. The Norwegian emission intensity values are within the interval, for both CH_4 and N_2O, of the other countries and it is therefore reason to believe that the emission data reflect current knowledge and are credible.

Figure 50. Emissions of N_2O relative to energy use. Transport. kg N_2O/TJ. 1990 and 1996



The 1996 emission data for Canada and New Zealand is from 1995. Emission data for Sweden does only include emissions from the sectors *Road* and *Other*.
Sources: UNFCCC and OECD/IEA (1993a and 1998a)

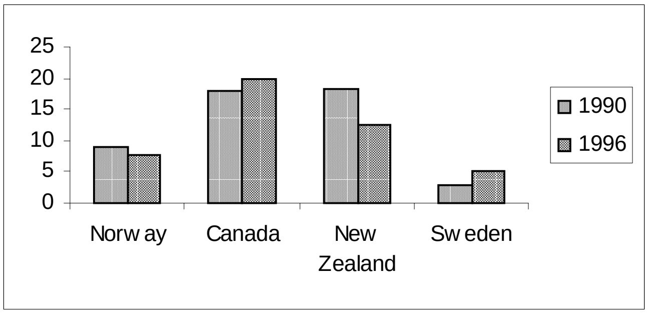
In the following we will consider the sub-sectors of transport.

[6] The sub-sector *Other* covers off-road vehicles, pipeline transportation and other mobile emission sources which are not included under *Road, Aviation, Navigation* or *Railways.*

3.3.2.2. Aviation
These emissions cover domestic aviation both below and above 1000 metres.

GDP
Although this indicator was assumed to be most suitable for comparing total emissions from transport, we see from Figure 51 that GDP is also partly correlated with CO_2 emissions from aviation.

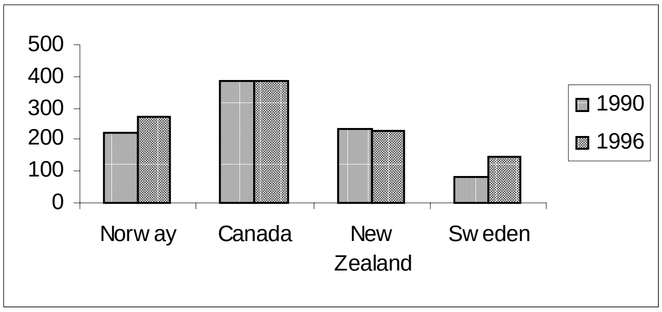
Figure 51. Emissions of CO_2 relative to GDP. Domestic aviation. ktonnes CO_2/billion USD. 1990 and 1996



Sources: UNFCCC, OECD (1992a and 1998a)

Population
Emissions per capita are an acceptable indicator since the countries that we compare Norway to are similar. The emissions per capita are similar for Norway and New Zealand. The increasing trend in emissions per capita in Norway is probably due to increased travelling activity, competition and capacity relative to the growth in population. Norwegian emissions appear to be quite credible, since the emission intensity value is within the interval of the other countries. The high values of emissions per capita in Canada might possibly be because of a higher demand due to a larger domestic geographical area.

Figure 52. Emissions of CO_2 relative to population. Domestic aviation. ktonnes CO_2/million capita. 1990 and 1996

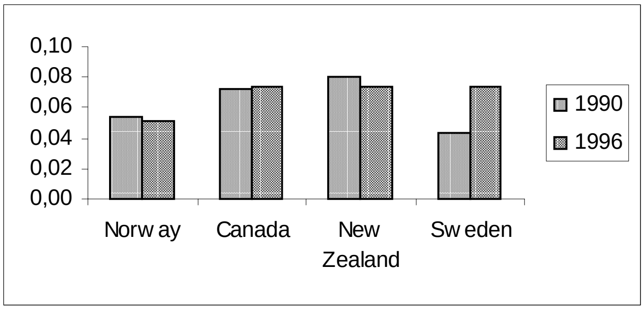


Sources: UNFCCC, OECD (1992a and 1998a)

Energy
The emissions of CO_2 are fairly well correlated with the amount of energy in fuel sold to aviation. The energy reported for aviation to the OECD/IEA, however, most likely includes both domestic and international, while the emission figures should only be based on the domestic fraction. There is a considerable variation between the countries, from which we conclude that there are some differences in the energy reported used and the calculated emissions, maybe due to different methodologies and definitions within each country or due to larger fraction of fuel sold for international aviation. The

variation in time is, however, (except for Sweden) quite small, this indicates that the methodologies and definitions, by which the energy and emission data are calculated in each country, are consistent.

Figure 53. Emissions of CO_2 relative to energy use. Domestic aviation. ktonnes CO_2/TJ. 1990 and 1996

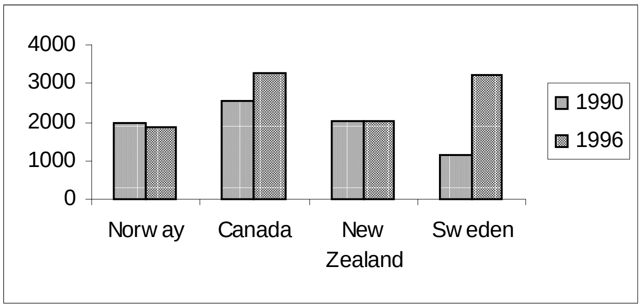


Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Transport activity

Transport activity is supposed to be a better indicator for specific transportation sub-sectors than for the transport sector as a whole. This assumption is verified in Figure 54. The emissions of CO_2 per converted tkm from aviation are about the same for all four countries. Although the Norwegian emissions per tkm in 1996 were the lowest this year, it seems that the Norwegian emissions are reasonable since the difference to the second lowest, New Zealand, is marginal.

Figure 54. Emissions of CO_2 relative to transport activity. Domestic aviation. ktonnes CO_2/billion tkm (including pkm). 1990 and 1996



The 1996 aviation data are from 1995.
Sources: UNFCCC, UN (1994 and 1997a), OECD (1992a and 1998a).

Indicator appraisal

Using energy consumption as an indicator gives the smallest difference between the highest and the lowest emission intensity values for aviation. We therefore conclude that energy use is the best indicator for comparing the emission data for the four countries.

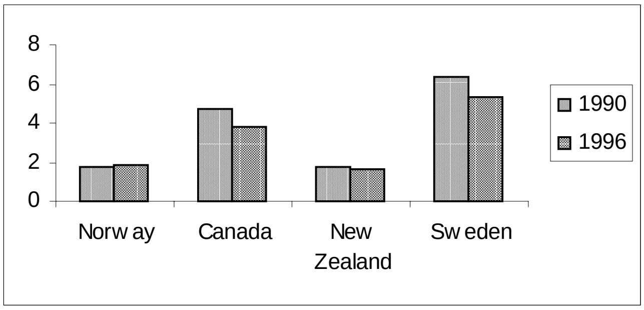
Table 27. Maximum percentage difference in the emission intensity values for the different indicators. Aviation

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
GDP	511	287	570
Population	386	165	386
Energy	87	43	87
Transport activity	123	74	190

The Norwegian emissions per TJ are 30-40 per cent lower, regarding energy use, than the other countries (except for Sweden in 1990). The gap may be due to the mismatching reporting of emissions and energy.

Emission intensity values of CH_4 and N_2O for the suggested indicator
The emission intensity value for CH_4 is somewhat more variable than for CO_2. Figure 55 indicates that there have been smaller changes in composition of national aviation fleet from 1990 to 1996, the change has however been marginal. The indicators for New Zealand and Norway are about the same.

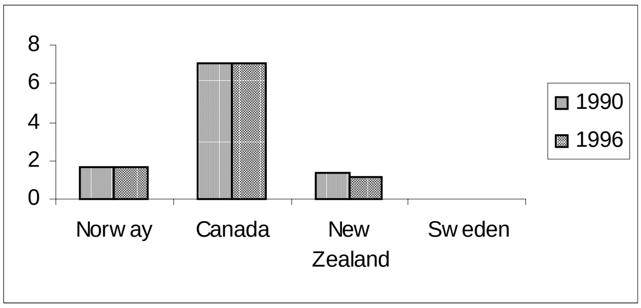
Figure 55. Emissions of CH_4 relative to energy use. Domestic aviation. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

The value of the indicator for N_2O emissions is almost the same for New Zealand and Norway, while Canada has very high N_2O emissions per unit energy used compared to the other countries. These differences may be due to both different methodologies and emission factors. The trend is stable and indicates that no significant changes have taken place from 1990 to 1996.

Figure 56. Emissions of N_2O relative to energy use. Domestic aviation. kg N_2O/TJ. 1990 and 1996

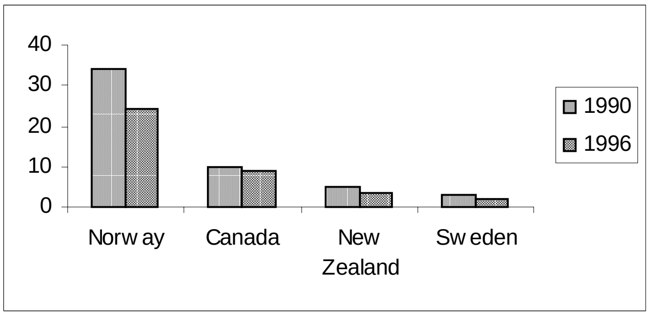


No emission data for Sweden.
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.3.2.3. Navigation
This sector covers domestic shipping only. In the Norwegian inventory emissions from fishing have erroneously been included here, but should have been reported under *Other Sectors* (Appendix E).

GDP
The very high emissions of CO_2 in Norway compared to GDP are partly due to the error in the Norwegian reporting. Norway has, however, much coastal traffic due to the long coastline.

Figure 57. Emissions of CO_2 relative to GDP. Domestic navigation. ktonnes CO_2/billion USD. 1990 and 1996

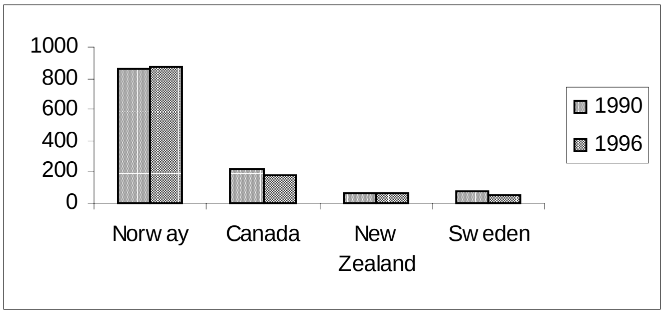


Sources: UNFCCC, OECD (1992a and 1998a)

Population

The pattern is similar as for GDP. The Norwegian emissions per capita are very high compared to the other countries.

Figure 58. Emissions of CO_2 relative to population. Domestic navigation. ktonnes CO_2/million capita. 1990 and 1996

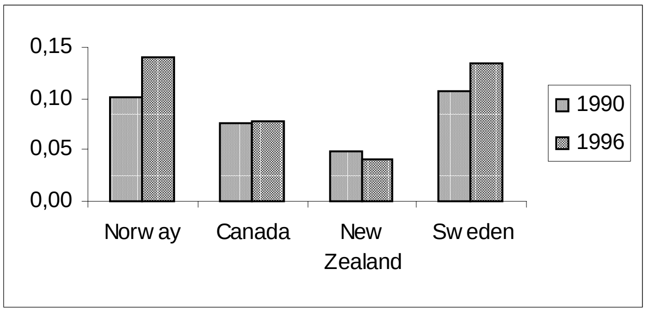


Sources: UNFCCC, OECD (1992a and 1998a)

Energy

The comparison between the four countries is complicated by the error in the Norwegian reporting. Emissions from fishing boats are included in transport when reporting to the UNFCCC, while the energy used for this purpose is included in agriculture when reporting to OECD. Emissions from fishing account for about 40 to 50 per cent of the totals reported from this sector. Excluding emissions from fishing the level of the Norwegian emission intensity values becomes more reasonable, but the difference between 1990 and 1996 is about the same. This is because the energy consumption reported to OECD from this sector for 1990 is considerably higher than the consumption figures that the emission estimates are based on. We consider the consumption figures used in the Norwegian emission inventory to be of higher quality.

Figure 59. Emissions of CO_2 relative to energy use. Domestic navigation. ktonnes CO_2/TJ. 1990 and 1996

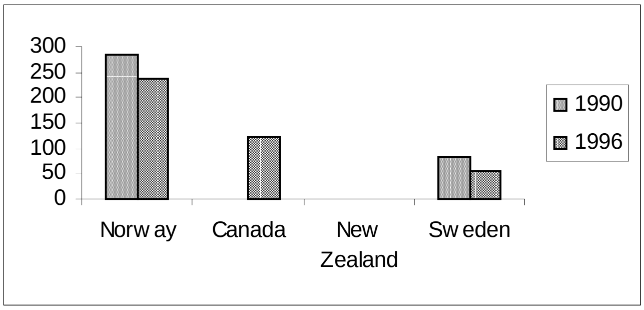


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Transport activity

There are only complete emission intensity values for Norway and Sweden. It is difficult to assess the Norwegian emissions due to the lack of data and erroneous reporting. The size of the gap between Norwegian and Swedish emissions could indicate that transport activity is not suitable due to differences in the composition of the countries' shipping fleet. This indicator is initially assumed to have strong validity.

Figure 60. Emissions of CO_2 relative to transport activity. Domestic navigation. ktonnes CO_2/billion tkm (including pkm). 1990 and 1996



No activity data for Canada (1990) and New Zealand (1990 and 1996)
Sources: UNFCCC, UN (1994 and 1997a), OECD (1992a and 1998a).

Indicator appraisal

The best indicator is found to be energy use. Note that New Zealand and Canada are only partly included in the comparison.

Table 28. Maximum percentage difference in the emission intensity values for the different indicators. Navigation

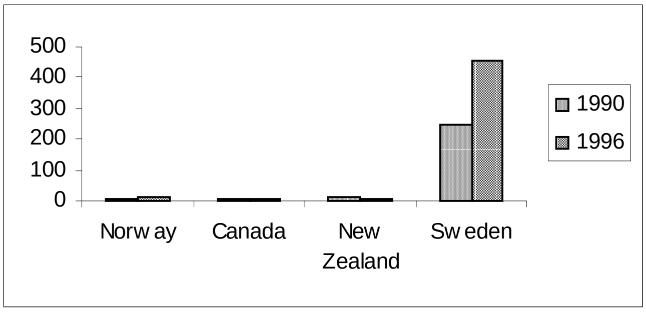
Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
GDP	1098	1272	1835
Population	1204	1652	1652
Energy	118	238	238
Transport activity	246 [1,2]	339 [1,2]	430

[1] Not included Canada (1990)
[2] Not included New Zealand

The emissions of CO_2 per TJ used is considered to be the best indicator although the emissions pr. TJ in New Zealand is less than half the values for Norway and Sweden.

Emission intensity values of CH_4 and N_2O for the suggested indicator
Emissions of CH_4 from domestic shipping in Norway, Canada and New Zealand are about the same for all three countries. The corresponding values for Sweden, however, were very different. If we consider the three countries with similar emission intensity values, the Norwegian emissions seem credible.

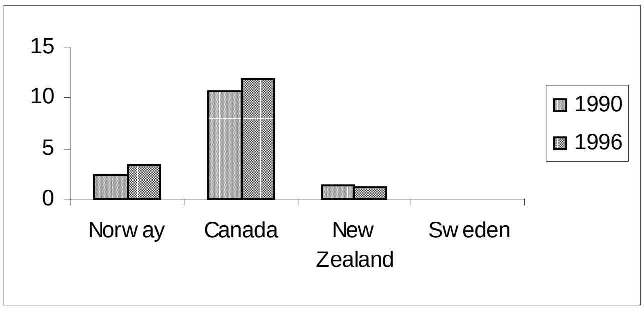
Figure 61. Emissions of CH_4 relative to energy use. Domestic navigation. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

The difference between Norwegian and Canadian emissions of N_2O per TJ is striking. The Norwegian emissions appear to be reasonable compared to New Zealand. It is difficult to draw any conclusions on whether the Norwegian emission estimates are reasonable or not.

Figure 62. Emissions of N_2O relative to energy use. Domestic navigation. kg N_2O/TJ. 1990 and 1996

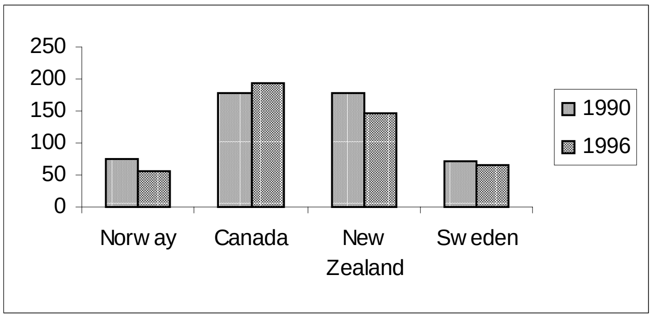


No emission data for Sweden.
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.3.2.4. Road
Calculating the emissions from this sub-sector is complicated. Both diesel and gasoline are used for machinery and off-road vehicles as well as for road transport. Calculating emissions from diesel used for road traffic represents the main problem. Differences between countries may therefore be due to different approaches to this problem.

GDP
Emission estimates for Norway and Sweden are similar, but the gap between these two countries and Canada and New Zealand is big.

Figure 63. Emissions of CO_2 relative to GDP. Road traffic. ktonnes CO_2/billion USD. 1990 and 1996



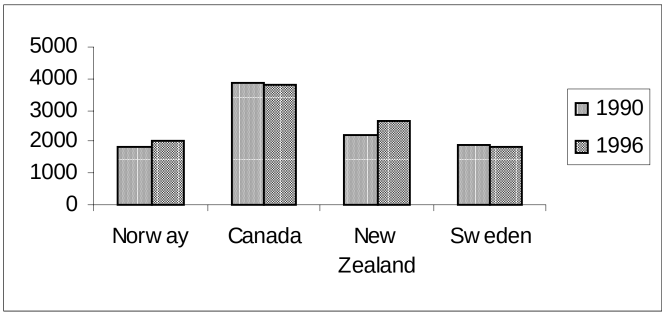
Sources: UNFCCC, OECD (1992a and 1998a)

Population

Emissions of CO_2 per capita for Norway, New Zealand and Sweden are similar, but there is a gap between these three countries and Canada. The values are more homogenous than for GDP, but the difference between the highest and lowest value is still considerable.

The emission intensity values show an increasing trend in all countries.

Figure 64. Emissions of CO_2 relative to population. Road traffic. ktonnes CO_2/million capita. 1990 and 1996



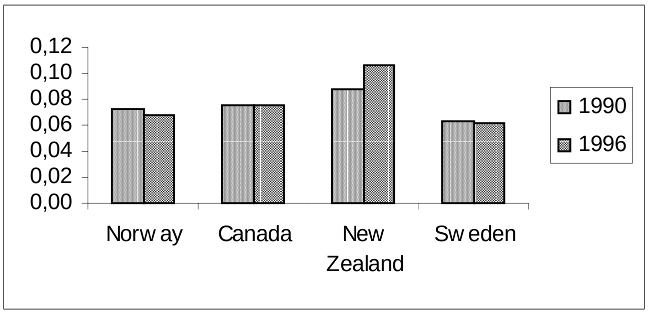
Sources: UNFCCC, OECD (1992a and 1998a)

Energy

There is a mismatch in the sources included when Norway reports emissions and energy consumption from road traffic. Emissions from diesel used in industry machinery and gasoline used in household machinery are reported under *Other Transportation*, according to the IPCC guidelines, while energy consumption from these sources are included in road traffic in the OECD reports. For diesel this mismatch is significant, but for gasoline it is of little importance.

The difference in source definitions causes the apparently decreasing trend in CO_2 emissions per TJ from road traffic in Norway (Figure 65). Some of the differences between the countries might also be due to this mismatch. Still, the emission intensity values of CO_2 are at about the same level for all countries, indicating that the Norwegian emission estimates are reasonable.

Figure 65. Emissions of CO_2 relative to energy use. Road traffic. ktonnes CO_2/TJ. 1990 and 1996

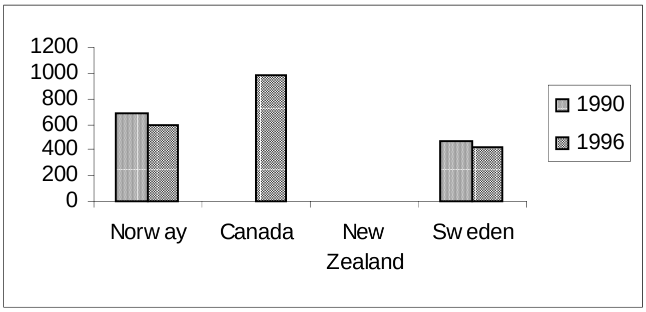


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Transport activity

We were only able to calculate emissions per tkm for Norway, Sweden and Canada. Emissions per tkm for Norway and Sweden are fairly similar. Norwegian emission data do therefore seem reliable compared to Swedish data.

Figure 66. Emissions of CO_2 relative to transport activity. Road traffic. ktonnes CO_2/billion tkm (including pkm). 1990 and 1996



There are no activity for Canada (1990) and New Zealand (1990 and 1996)
Sources: UNFCCC, UN (1994 and 1997a), OECD (1992a and 1998a)

Indicator appraisal

Energy is undoubtedly the best indicator, see Table 29Table 29.

Table 29. Maximum percentage difference in the emission intensity values for the different indicators. Road transport

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
GDP	151	247	247
Population	106	102	106
Energy	38	71	71
Transport activity	46 [1,2]	137 [1,2]	137

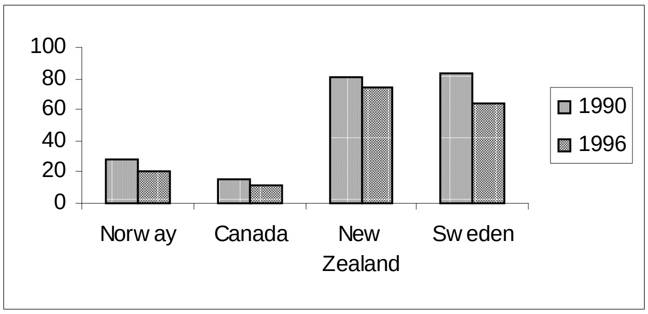
[1] Not included Canada (1990)
[2] Not included New Zealand

Emissions of CO_2 per TJ are about the same for Norway, Canada and Sweden. The Norwegian emissions are therefore assessed as credible.

Emission intensity values of CH_4 and N_2O for the suggested indicator

The CH_4 emissions per TJ are very different for Norway/Canada and New Zealand/Sweden (Figure 67). This is probably due to different methodologies and different emission factors. The decreasing trend is likely to be caused by a growing stock of vehicles with catalytic converter, which reduces the emission of CH_4. The change in composition of energy consumed is also affecting the trend.

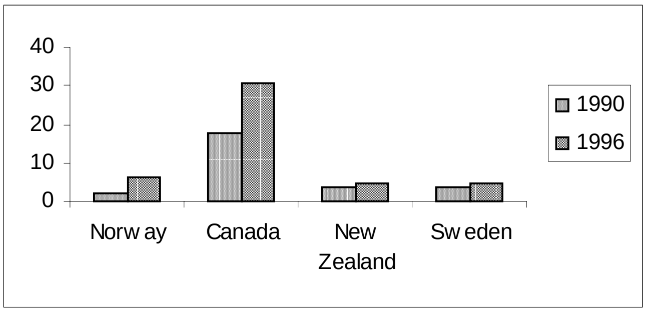
Figure 67. Emissions of CH_4 relative to energy use. Road traffic. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

The indicator for N_2O gives, except for Canada, very similar values (Figure 68). The increasing trend is due to the increasing stock of vehicles with catalytic converters, which increases the emissions of N_2O. Differences between countries are probably caused by different approaches of calculating the emissions, different emission factors, differences in the composition of the stock of vehicles and differences in the composition of energy carriers consumed.

Figure 68. Emissions of N_2O relative to energy use. Road traffic. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

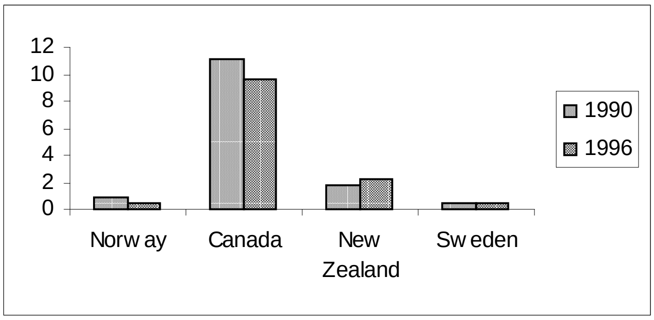
3.3.2.5. Railways

The big differences between Canada and the other countries are assumed to be due to Canada's high share of diesel powered locomotives. One of the reasons for the difference between Sweden and Norway concerning emission intensity values from railways is also that Swedish railways use a higher share of electricity (80-90%) than the Norwegian railways (60-70%).

GDP

The emissions of CO_2 per GDP for Norway lies in the interval between New Zealand and Sweden. The gap between Sweden and Canada is however too big for the indicator to be assessed as good.

Figure 69. Emissions of CO_2 relative to GDP. Railways. ktonnes CO_2/billion USD. 1990 and 1996

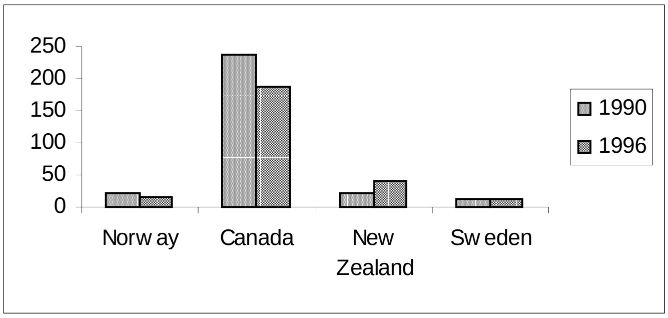


Sources: UNFCCC, OECD (1992a and 1998a)

Population

This indicator seems to be a better choice than the GDP, but that could be coincidental. The CO_2 emissions per capita for Norway and Sweden are closer than emissions per GDP. The difference between the two countries is probably due to Norway's slightly higher consumption of diesel relative to electricity compared to Sweden.

Figure 70. Emissions of CO_2 relative to population. Railways. ktonnes CO_2/million capita. 1990 and 1996

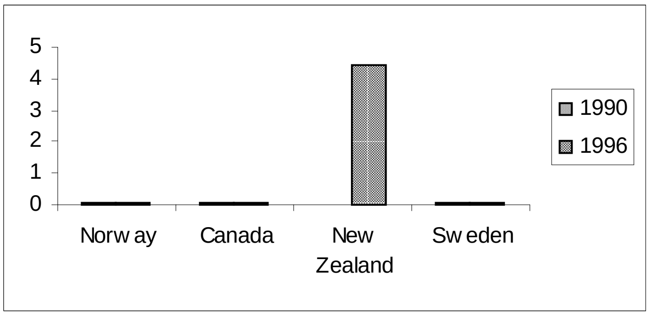


Sources: UNFCCC, OECD (1992a and 1998a)

Energy

The value of the indicator for CO_2 for railways varies little, when we exclude New Zealand which has reported emissions from this mode both in 1990 and 1996, but no energy use in 1990 and very little in 1996. The indicator is assumed to be reliable. There is little difference within each country from 1990 to 1996. The differences between the countries are likely to be caused by different methodologies. The advantage of using the energy as an indicator of emissions from railways is that use of electricity may be excluded. The Norwegian emissions are credible according to Figure 71. There is a decreasing trend in emissions of CO_2 per TJ due to a small discrepancy: fuel oil (probably used for heating) is included in the energy data, but not in emission data.

Figure 71. Emissions of CO_2 relative to energy use. Railways. ktonnes CO_2/TJ. 1990 and 1996

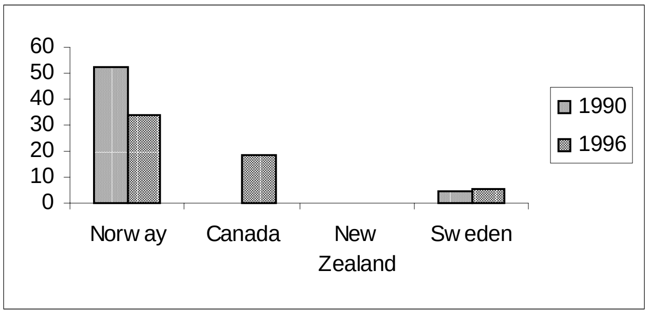


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Transport activity

Only emission intensity values for Norway, Sweden and Canada (1996) are possible to calculate. There is a gap between emissions per converted tkm for Norway and Sweden, while the difference between Norway and Canada is modest. The differences are due to two factors: Composition of energy carriers used and composition of load. Sweden and Canada has a greater share of freight than Norway, the comparison is therefore very dependent on a fair conversion factor for pkm to tkm. The conversion factor is probably too small for railways, and we therefore get this gap. The higher share of electricity in Sweden compared to Norway is probably another reason for Sweden's very low emission intensity values.

Figure 72. Emissions of CO_2 relative to transport activity. Railways. ktonnes CO_2/billion tkm (including pkm). 1990 and 1996



No activity data for Canada (1990) and New Zealand (1990 and 1996).
Sources: UNFCCC, UN (1994 and 1997a), OECD (1992a and 1998a)

Indicator appraisal

The best indicator is found to be energy use. This is reasonable since the other indicators include electrified railways. The comparison illustrated in Table 30Table 30 is performed partly without data from New Zealand and partly without data from Canada (1990).

Table 30. Maximum percentage difference in the emission intensity values for the different indicators. Railways

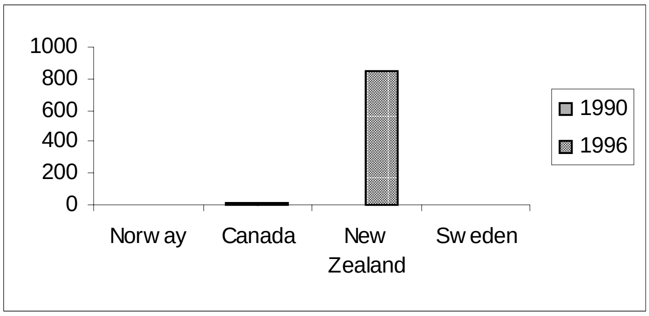
Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
GDP	2530	2303	2661
Population	2013	1542	2013
Energy	29 [2]	23 [2]	29
Transport activity	995 [1,2]	535 [2]	995

[1] Not included Canada
[2] Not included New Zealand

The small difference between Norway, Canada and Sweden gives us reason to believe that the estimates of Norwegian emissions are reliable.

Emission intensity values of CH_4 and N_2O for the suggested indicator
Emissions of CH_4 per TJ are somewhat lower for Norway than for Canada. The emission intensity value for New Zealand (for 1996) is probably incomparable, due to incomplete reporting of energy consumption.

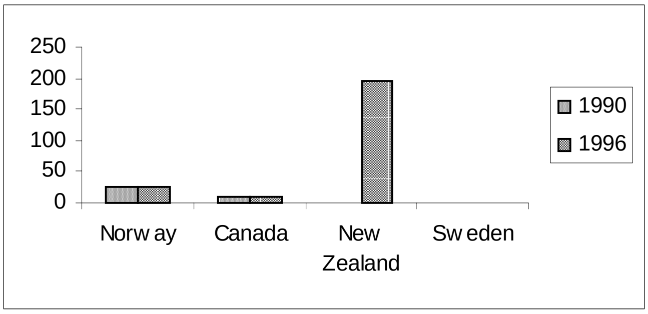
Figure 73. Emissions of CH_4 relative to energy use. Railways. kg CH_4/TJ. 1990 and 1996



No emission data for Sweden (1990 and 1996). No activity data for New Zealand (1990).
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Emissions of N_2O per TJ from railways in Norway are over double the values of Canada. The emission intensity values of N_2O in New Zealand (1996) are not comparable since the reported energy data are likely to be incomplete.

Figure 74. Emissions of N_2O relative to energy use. Railways. kg N_2O/TJ. 1990 and 1996



No emission data for Sweden (1990 and 1996). No activity data for New Zealand (1990).
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

3.3.2.6. Other

This sub-section should include combustion emissions from all remaining transport activities, like pipeline transport and off-road activities (IPCC 1997). However, in the Norwegian inventories, emissions from pipeline transport are reported elsewhere[7]. Also, Canada reports emissions from pipeline transport as a distinct sub-category of transport, and are therefore neither included here.

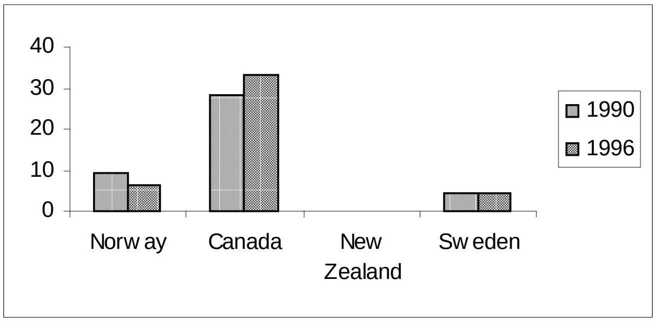
There is likely to be many differences between the countries' reporting practice for this sub-sector. It is in any case likely that the energy data reported are not comparable with the emissions for this source category. It is therefore difficult to compare the different countries' emission intensity values for this sub-sector of transport.

[7] Emissions from pipeline transport are reported under 1A1c *Manufacture of Solid Fuels and Other Energy*.

GDP

The emissions per GDP for Norway and Sweden are at about the same scale, but differ considerably from the Canadian values.

Figure 75. Emissions of CO_2 relative to GDP. Other domestic transport. ktonnes CO_2/billion USD. 1990 and 1996

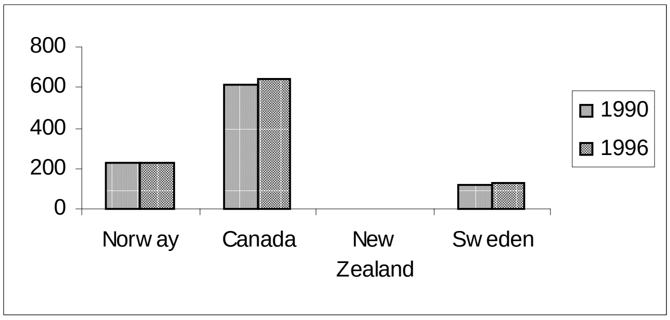


No emission data for New Zealand (1990 and 1996).
Sources: UNFCCC, OECD (1992a and 1998a)

Population

This indicator seems to fit fairly well for Norway and Sweden, and the values are very similar.

Figure 76. Emissions of CO_2 relative to population. Other domestic transport. ktonnes CO_2/million capita. 1990 and 1996

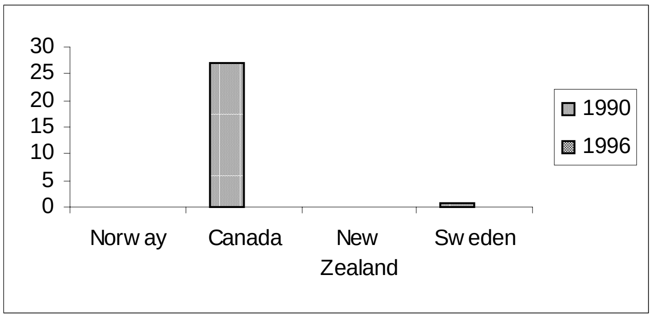


No emission data for New Zealand (1990 and 1996).
Sources: UNFCCC, OECD (1992a and 1998a)

Energy

Norway has not reported any energy used for this sub-sector in the OECD/IEA statistics, no assessments of the Norwegian emissions have therefore been performed.

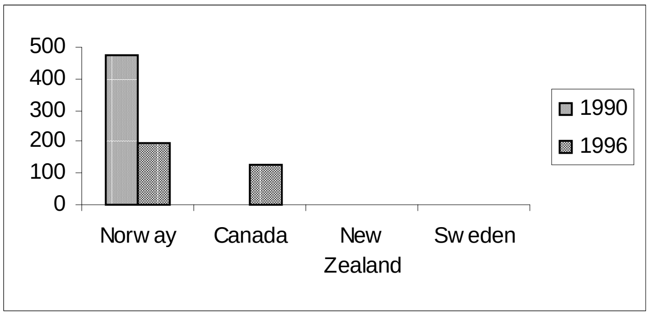
Figure 77. Emissions of CO_2 relative to energy use. Other domestic transport. ktonnes CO_2/TJ. 1990 and 1996



No emission data for New Zealand (1990 and 1996). No activity data for Norway (1990 and 1996) and Sweden (1996).
Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Transport activity
Norway and Canada (1996) are the only countries that have reported both emission data and activity data for this indicator. The sub-sector *Other* covers off-road vehicles, and other mobile emission sources which are not included under *Road*, *Aviation*, *Navigation*, *Railways* or *Pipeline transport*. No assessment of the Norwegian emission estimates is done.

Figure 78. Emissions of CO_2 relative to transport activity. Other domestic transport. ktonnes CO_2/billion tkm (including pkm). 1990 and 1996



No emission data for New Zealand (1990 and 1996). No activity data for Canada (1990), New Zealand (1990 and 1996) and Sweden (1990 and 1996). 1996 activity data for Canada are from 1995
Sources: UNFCCC, UN (1994 and 1997a), OECD (1992a and 1998a)

Indicator appraisal
This sub-sector of transport is too diverse, regarding all the data sources we used, to make any recommendations on what indicator to use. The data reported are also too scarce.

Table 31. Maximum percentage difference in the emission intensity values for the different indicators. Other

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
GDP	553 [2]	663 [2]	657
Population	425 [2]	401 [2]	449
Energy	3279 [2,3]	- [2,3,4]	34141
Transport activity	- [1,2,4]	52 [2,4]	270

[1] Not included Canada
[2] Not included New Zealand
[3] Not included Norway
[4] Not included Sweden

It is not possible to use the data on emissions from the sub-sector *Other* to accept or reject the Norwegian emissions from these sources.

Emission intensity values of CH_4 and N_2O for the suggested indicator
There are no activity data for Norway concerning emissions of CH_4 and N_2O and no comparison of the Norwegian emission data has therefore been made.

3.4. Other sectors

Other sectors include the following sub-sectors:

- Commercial/Institutional
- Residential
- Agriculture/Forestry/Fishing.

In the Norwegian reporting emissions from military fuel use are included in the sub-sector *Commercial/Institutional*, but should have been reported in the sector *Other* (see Appendix E). Norway and Canada do not use this specific sector in the reporting. New Zealand specifies emissions in the sector *Other* as other coal use, while it is specified as military in the Swedish report. In the following analysis, emissions from *Other* are included in *Commercial/Institutional*.

Norway has reported emissions from fishing under *Navigation*. This should be reported in the sub-sector *Agriculture/Forestry/Fishing* (see Appendix E). Both will be corrected in the next UNFCCC reporting.

3.4.1. Emissions

Other sectors account for from 6 to 20 per cent of the total CO_2 emissions in the four countries, see Table 32Table 32 and Table 33. The emissions of CH_4 and N_2O contribute with respectively 0.2-7 per cent and 0.3-4 per cent of the national emissions.

Table 32. Total emissions from other sectors[1] and percentage of total national emissions. ktonnes and percentage. 1990

	Total emissions from other sectors (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	2431	7	0.1	7	2	1
Canada	69900	230	3	14	7	2
New Zealand	2846	3	0.1	11	0.2	0.3
Sweden	10779	10	1	19	4	2

[1] Emissions from *1A5 Other*, reported by New Zealand and Sweden, are included in the emission estimates
Source: UNFCCC

Table 33. Total emissions from other sectors[1] and percentage of total national emissions. ktonnes. 1996

	Total emissions from other sectors (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	2512	7	0.1	6	2	1
Canada	79900	260	4	16	7	2
New Zealand	2705	3	0.1	9	0.2	0.3
Sweden	11123	11	1	18	4	4

[1] Emissions from *1A5 Other*, reported by New Zealand and Sweden, are included in the emission estimates
Source: UNFCCC

3.4.2. Indicators

The following indicators have been used to compare the Norwegian emissions with the other countries.

Energy use in other sectors. Electricity and biomass are excluded. Biomass is, however, included in the indicator for emissions of CH_4 and N_2O.

Reliability Inconsistency between the reporting of emissions to the UNFCCC and energy use to the OECD might be a problem for this sector. For Norway there is inconsistency between the energy data reported in 1990 and 1996, as mobile fishing is included in *Internal Navigation* in 1990 but in *Agriculture* in 1996 in the OECD/IEA energy statistics.

The use of the same conversion factors for all the countries may also be a possible source of error.

Validity The indicator is expected to reflect the emission data very well, based on the fact that the four countries are fairly similar and it is the fuel combustion that causes the emissions. The indicator is assumed to be better for the sub-sector than the main sector.

Population

Reliability The reliability of this indicator is presumed to be very good.

Validity It is considered to be a better indicator for the emissions from the sub-sector residential than for the whole sector.

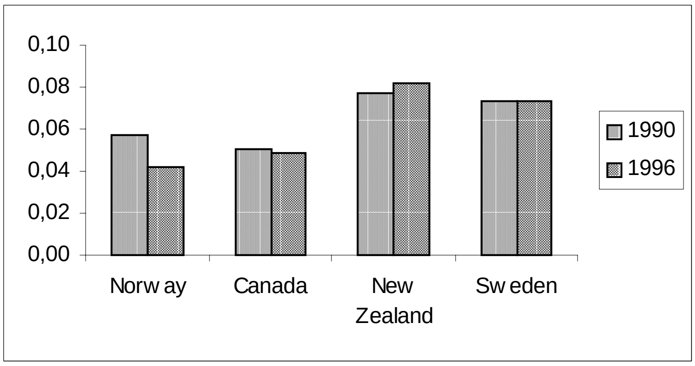
Value added can not be used as an indicator for the sector as a whole due to the residential sector (households). It may however be used for the sub-sectors *Commercial/Institutional* and *Agriculture/Forestry/Fishing*.

3.4.2.1. Total emissions from other sectors

Energy use

Emission intensity values for Canada and Norway are similar, and the values for Sweden and New Zealand are about the same level, but higher compared to the other two countries (Figure 79). The difference seen between the Norwegian values is due to inconsistency between the energy data and the emission data. The energy data includes fuels used for ocean, coastal and inland fishing, while emissions from fishing erroneously are reported under transport in the UNFCCC. If fishing is excluded from the energy data, the Norwegian values become similar. Another reason for the difference seen in the Norwegian values is that the energy data for 1996 given in OECD/IEA (1998a) have been corrected since the reporting. The emissions are based on the corrected figures. This is however a minor source for the difference in the Norwegian values.

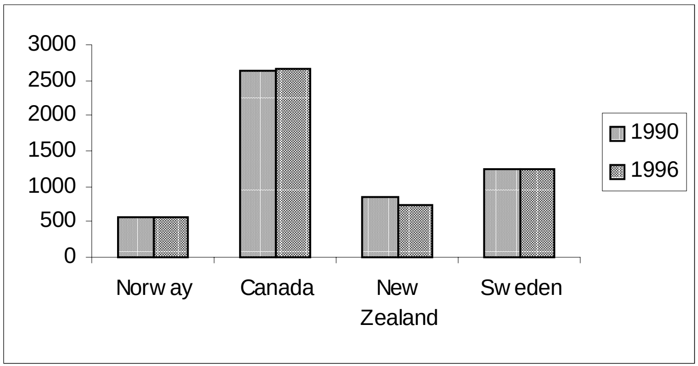
Figure 79. Emissions of CO_2 relative to energy use. Other sectors. ktonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Population
Emissions of CO_2 per capita are similar for the two years for Norway (Figure 80). The Norwegian values are however lower compared to the other countries.

Figure 80. Emissions of CO_2 relative to population. Other sectors. ktonnes CO_2/million capita. 1990 and 1996



Sources: UNFCCC

Indicator appraisal

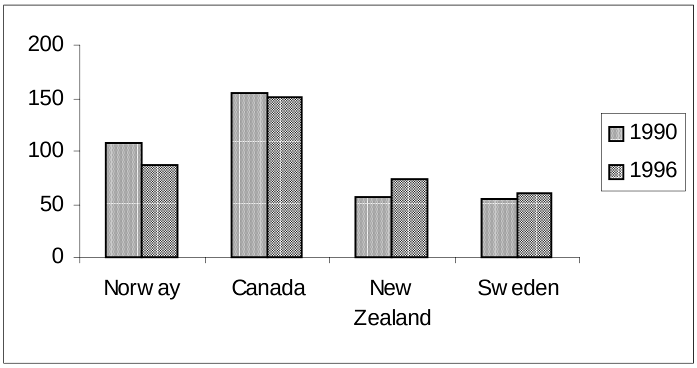
Energy use is suggested to be used as an indicator for testing the emissions of CO_2 reported by Norway. There are however up to 94 per cent difference between the highest and lowest emission intensity values (Table 34Table 34). This indicator is assumed to be better to use for the sub-sectors.

Table 34. Maximum percentage difference in the emission intensity values for the different indicators. Other sectors

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Energy use	55	94	94
Population	358	364	365

Emission intensity values of CH_4 and N_2O for the suggested indicator
The emission intensity values for CH_4 differ from one country to another (Figure 81), but the Norwegian values are however within the interval of the other countries' values. The fraction of fuel wood combustion in each country may effect the outcome and contribute to the variation seen between the countries. As mentioned above for CO_2, there is inconsistency between the energy and emission data for Norway. If fishing is excluded from the energy data, the Norwegian values become very similar for 1990 and 1996. Energy use seems to be a good indicator.

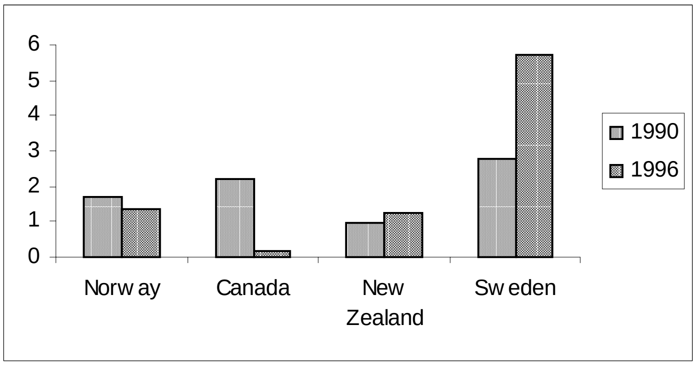
Figure 81. Emissions of CH_4 relative to energy use. Other sectors. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

Emissions of N_2O per unit energy use vary considerably between the countries (Figure 82). Again, as mentioned for CO_2 and CH_4, there is inconsistency between the energy and emission data. If fuel used for fishing is excluded, the Norwegian emission intensity values become nearly the same for both years. Energy use seems to be a good indicator.

Figure 82. Emissions of N_2O relative to energy use. Other sectors. kg N_2O/TJ. 1990 and 1996



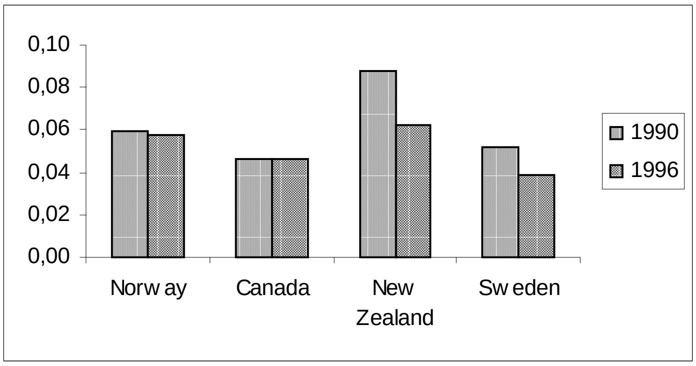
Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

3.4.2.2. Commercial/Institutional

Energy use

Emissions of CO_2 per unit energy used are quite similar between the countries, except for the high emission intensity value for New Zealand in 1990 (Figure 83). The Norwegian values are nearly the same in 1990 and 1996.

Figure 83. Emissions of CO_2 relative to energy use. Commercial/Institutional. ktonnes CO_2/TJ. 1990 and 1996

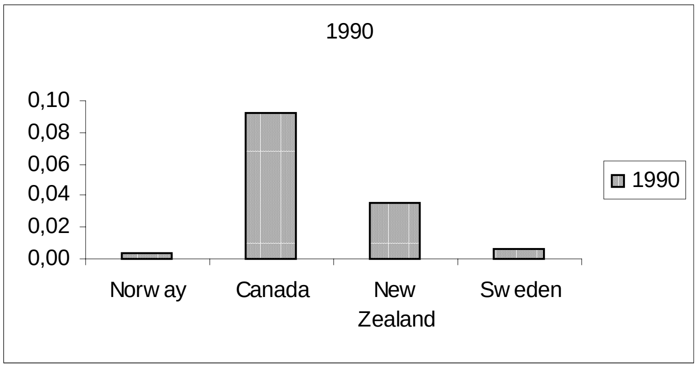


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added

Emissions of CO_2 per unit value added vary a lot between the countries (Figure 84), Norway having the lowest value and Canada the highest one. Due to lack of data, nothing can be said on the reliability over years of this indicator.

Figure 84. Emissions of CO_2 relative to value added. Commercial/Institutional. ktonnes CO_2/million USD. 1990



Sources: UNFCCC, UN (1997b)

Indicator appraisal

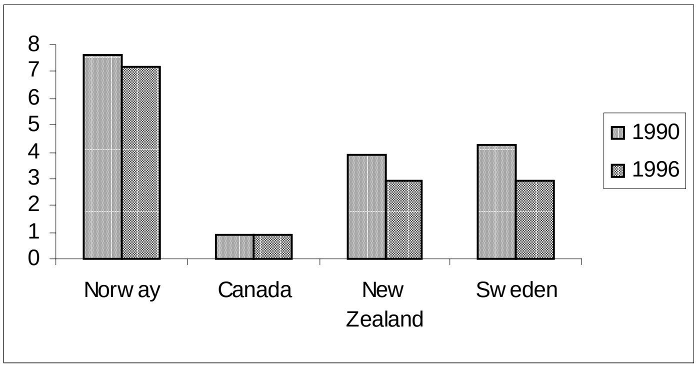
Energy use gives surprisingly large differences between the highest and lowest emission intensity values. The large percentage difference in 1990 is mainly due to the high value for New Zealand. Compared to value added, energy use is the best indicator to use.

Table 35. Maximum percentage difference in the emission intensity values for the different indicators. Commercial/Institutional

Indicator	Year		Pooled values
	1990	1996	1990 and 1996
Energy use	91	61	128
Value added	2690	-	-

Emission intensity values of CH_4 and N_2O for the suggested indicator[8]
Emissions of methane per unit energy used vary a lot between the countries (Figure 85). There is a small difference between the energy data and the emission data in 1990 concerning combustion of landfill gas in Norway. Emissions from combustion of this gas are included in the reported figure, but the amount combusted is not included in the energy data in 1990. Energy use is likely to be a good indicator.

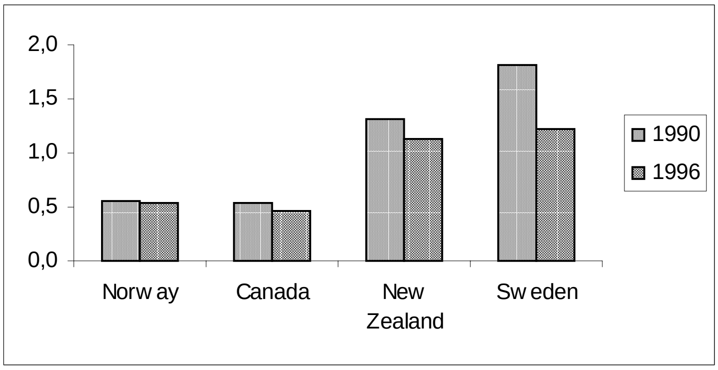
Figure 85. Emissions of CH_4 relative to energy use. Commercial/Institutional. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

Norway and Canada have similar values for emissions of N_2O per unit energy used (Figure 86). New Zealand and Sweden have also almost the same values, but higher compared to the other two countries. This may be due to use of different emission factors. Compared to Canada, the Norwegian estimated emissions seem reasonable.

Figure 86. Emissions of N_2O relative to energy use. Commercial/Institutional. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

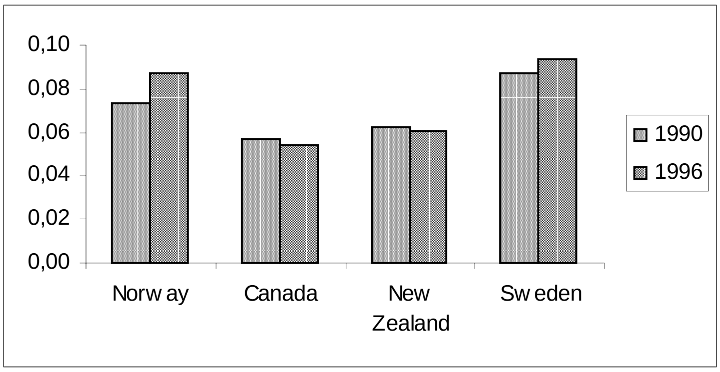
3.4.2.3. Residential

Energy use
The Norwegian and Swedish emissions of CO_2 per unit energy used are similar, while the emission intensity values for Canada and New Zealand are similar, but different from Norway and Sweden (Figure 87). The latter are however somewhat lower compared to the other two countries. The Norwegian emission intensity values are in the interval of those from the other countries, indicating that the Norwegian emissions reported seem reliable. However, the Norwegian value in 1996 is higher

[8] For Sweden decimal numbers available on data files from the Swedish Environmental Protection were used. The emission data reported to the UNFCCC on paper show zero emissions due to the lack of decimals.

than the one in 1990. This is, as the case is for other sectors as well, due to the fact that the energy data for 1996 given in OECD/IEA (1998a) have been corrected since the reporting. If the updated energy data for 1996 is used, the Norwegian values become similar.

Figure 87. Emissions of CO_2 relative to energy use. Residential. ktonnes CO_2/TJ. 1990 and 1996

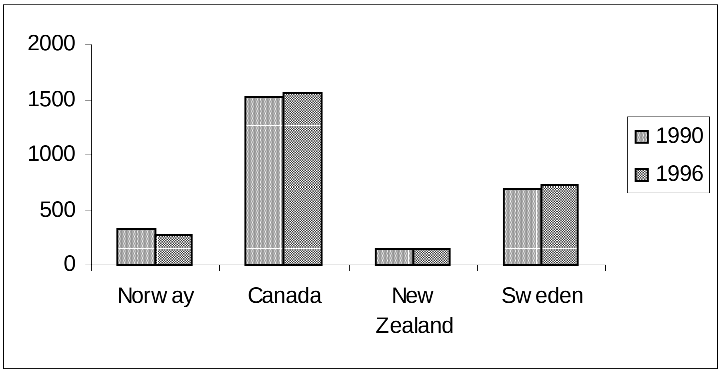


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Population

Emissions of CO_2 per capita vary a lot between the countries (Figure 88), this may be due to different shares of electricity used for household heating. Also differences in the use of wood fuel may be of importance, as CO_2 emissions from this source are not included in the inventory. It is hard to say if the Norwegian emissions are reliable by using this indicator.

Figure 88. Emissions of CO_2 relative to population. Residential. ktonnes CO_2/million capita. 1990 and 1996



Sources: UNFCCC

Indicator appraisal

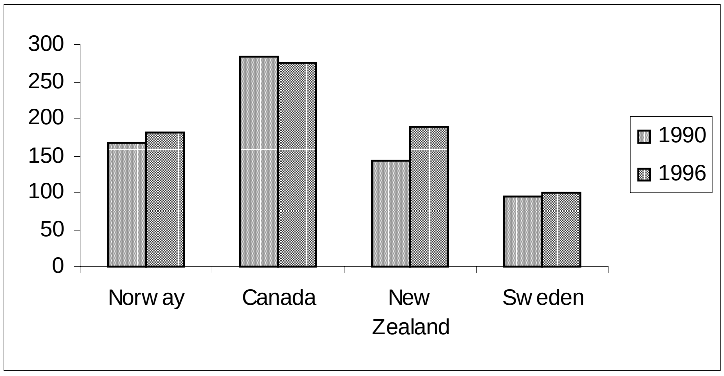
Energy use seems to be the first choice as an indicator for the Norwegian CO_2 emissions from the residential sector.

Table 36. Maximum percentage difference in the emission intensity values for the different indicators. Residential

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Energy use	55	73	73
Population	917	965	965

Emission intensity values of CH_4 and N_2O for the suggested indicator
Combustion of wood is included in the energy data when considering CH_4 and N_2O per unit energy used. Different fractions of wood fuel in the countries may effect the values and cause the variation seen. Since the Norwegian values lie in the interval of the others (Figure 89), it seems that the Norwegian emissions reported are reasonable. If updated energy figures for Norway in 1996 were used, the columns would obtain the same height.

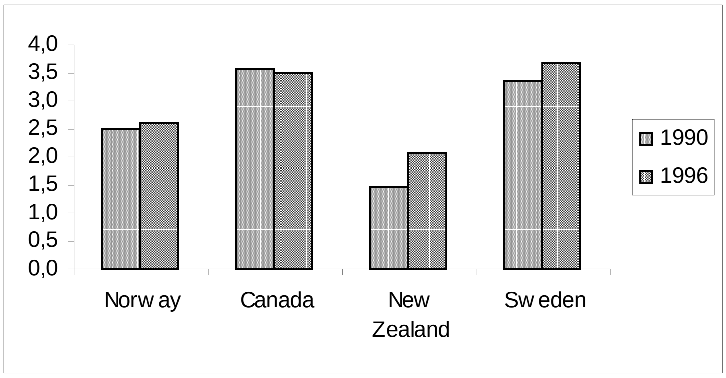
Figure 89. Emissions of CH_4 relative to energy use. Residential. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

The Norwegian N_2O emissions per unit energy used are consistent between the years (Figure 90), and they lie in the interval of the emission intensity values of the other countries, suggesting that the emissions reported by Norway are reasonable.

Figure 90. Emissions of N_2O relative to energy use. Residential. kg N_2O/TJ. 1990 and 1996

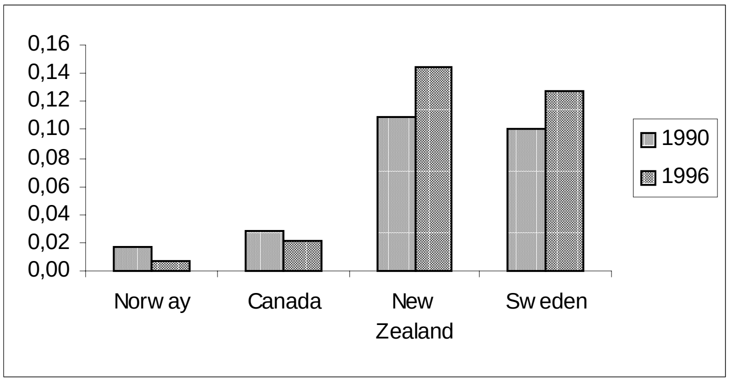


Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

3.4.2.4. Agriculture/Forestry/Fishing

Energy use
The emissions of CO_2 per unit energy used vary a lot between the countries (Figure 91). The Norwegian value is considerably lower in 1996 compared to 1990, indicating inconsistency between the energy and the emission data. Fuel used for fishing is included in the energy data but not in the emission data for Norway. Norwegian emissions from fishing are erroneously reported under *Navigation* to the UNFCCC by Norway. In the future this will be reported under *Agriculture/Forestry/Fishing*. If fuel used for fishing were excluded from the energy data, the Norwegian emission intensity values would become similar. The energy data reported by Norway for 1990 and 1996 are not consistent, as fuel used for fishing is included in *Internal Navigation* in 1990 and in *Agriculture* in 1996.

Figure 91. Emissions of CO_2 relative to energy use. Agriculture/Forestry/Fishing. ktonnes CO_2/TJ. 1990 and 1996

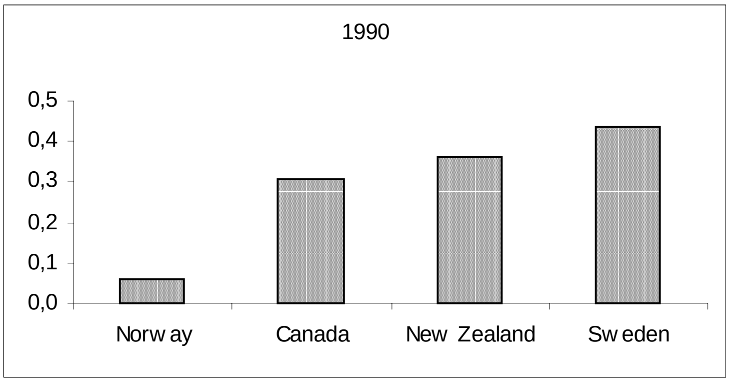


Sources: UNFCCC, OECD/IEA (1993a and 1998a)

Value added

The Norwegian emissions of CO_2 per unit value added are much lower than the other countries (Figure 92). Due to the large differences, it is difficult to use this as an indicator for testing the emissions reported by Norway. Besides, nothing can be said about the reliability of the indicator over years due to lack of data.

Figure 92. Emissions of CO_2 relative to value added. Agriculture/Forestry/Fishing. ktonnes CO_2/million USD. 1990



Sources: UNFCCC, UN (1997b)

Indicator appraisal

Even if energy use has the highest percentage difference between the highest and lowest emission intensity values (Table 37Table 37), it is suggested to use this as an indicator as the differences seen between the countries most likely are due to inconsistency between energy and emission data.

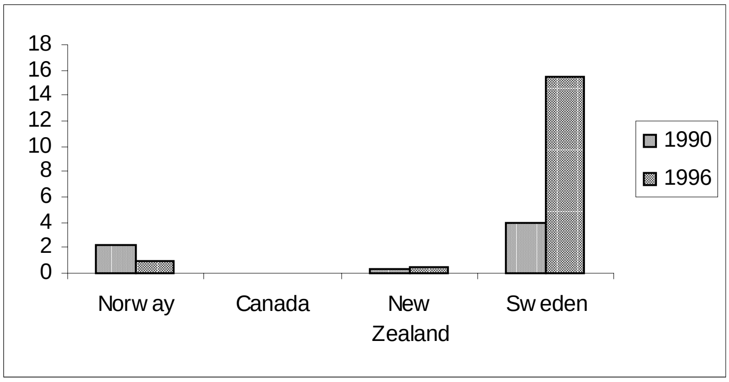
Table 37. Maximum percentage difference in the emission intensity values for the different indicators. Agriculture/Forestry/Fishing

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
Energy use	538	1919	1919
Value added	203	-	-

Emission intensity values of CH_4 and N_2O for the suggested indicator

Emissions of methane per unit energy used vary a lot between the countries (Figure 93). As mentioned for CO_2, there is inconsistency between the Norwegian energy and emission data. This may also be the case for the other countries. The variation between the countries may also be due to the use of different emission factors. If fishing is excluded from the energy data, the Norwegian values become more similar. Energy use is most likely a good indicator.

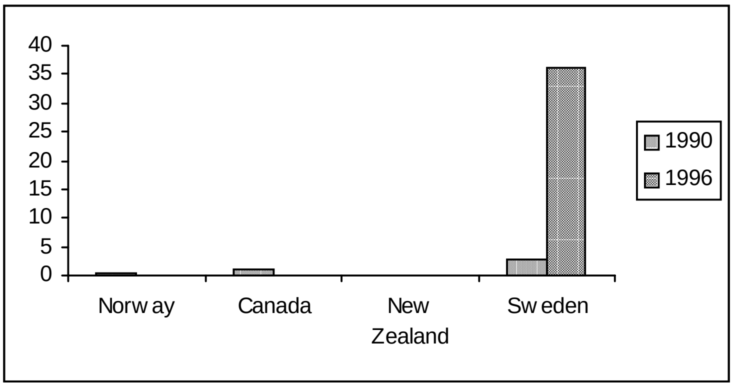
Figure 93. Emissions of CH_4 relative to energy use. Agriculture/Forestry/Fishing. kg CH_4/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)
No data from Canada available from the sources used due to too few decimals.

The picture is much the same for N_2O as for methane, large variations (Figure 94). However, the Norwegian values become more similar if fishing is excluded from the energy data. The variation between the countries may also be due to the use of different emission factors. Energy use is most likely a good indicator.

Figure 94. Emissions of N_2O relative to energy use. Agriculture/Forestry/Fishing. kg N_2O/TJ. 1990 and 1996



Sources: UNFCCC, OECD/IEA (1993a, 1993b and 1998a)

3.5. CO_2 from biomass

CO_2 emissions from biomass are not to be included in the national totals. They are reported as memo items. In the figures reported by Norway CO_2 emissions from the following sources are included:

- fuel wood
- wood waste
- black liquor
- waste disposal site
- burning of waste (only from the biomass part)
- fires/decay.

These emissions include CO_2 from combustion, non-energy and energy use and from processes.

There may, however, be possible that there are some differences in the reporting of CO_2 from biomass and waste from one country to another as it may be unclear if all countries follow the reporting guidelines strictly. It may also be differences as emissions of CO_2 from biomass from both combustion and processes may not be included.

3.5.1. Emissions

Emissions of CO_2 from biomass burned for energy for each country are given in Table 38Table 38. These emissions are not included in the national totals of CO_2 emissions. They are to be reported separately.

Table 38. Total CO_2 emissions from biomass. ktonnes and percentage. 1990 and 1996

Country	1990	1996
Norway	5292	5592
Canada	69400	67300
New Zealand	2687	2878
Sweden	21450	25833

Source: UNFCCC

3.5.2. Indicators

The following indicators have been used to compare the Norwegian emissions with the other countries.

Production/consumption of wood.

Reliability: Figures for indigenous production of other solid fuels, including peat, wood, wood waste municipal waste, industrial waste and black liquor in 1990 are available from OECD/IEA (1993b). These figures could however be incomplete. Production of solid and gas/liquids biomass and municipal waste are available for 1996 from OECD/IEA (1998a).
Production of wood and wood waste is the same as the amounts used for energy according to the energy statistics tables.

Validity: The indicator is assumed to reflect the emission data very well, based on the fact that the four countries are fairly similar and it is the fuel combustion that causes the emissions.

Population

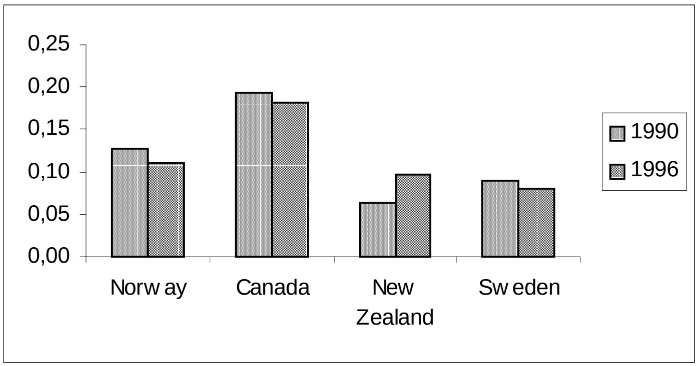
Reliability: The reliability of this indicator is presumed to be very good.

Validity Wood fuel is used in households in all the four countries. Since a considerable part of total wood burnt is used in households, population is assumed to be a good indicator.

Production/consumption of wood

Emissions of CO_2 per unit consumption vary between the countries (Figure 95). The Norwegian values lie in the interval of the others, which may indicate that the emissions reported by Norway are reasonable. The Norwegian value decreases however from 1990 to 1996. One reason for this may be that the energy data for 1990 could be incomplete. The differences between the countries may also be due to the use of different emission factors.

Figure 95. CO_2 emissions from biomass relative to production. ktonnes CO_2/TJ. 1990 and 1996

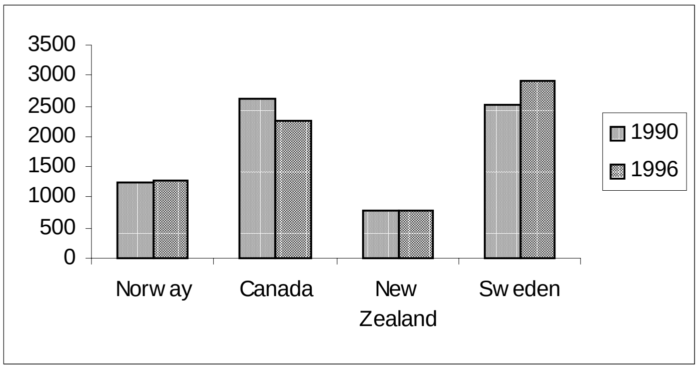


Sources: UNFCCC, OECD/IEA (1993b and 1998a)

Population

The emission intensity values differ between the countries (Figure 96). The Norwegian values are about the same for both years, and lie within the interval of the others. Since there is large variation between the countries, it will be difficult to use population as an indicator.

Figure 96. CO_2 emissions from biomass relative to population. ktonnes CO_2/million capita. 1990 and 1996



Sources: UNFCCC

3.5.2.1. Indicator appraisal

As seen in Table 39Table 39, production is suggested to be a better indicator than population when comparing the Norwegian emissions with the other countries' emissions.

Table 39. Maximum percentage difference in the emission intensity values for the different indicators. Other sectors

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	203	123	203
Population	228	267	267

3.6. Fugitive emissions from solid fuels

Norway has emissions from coal mining only, hence this is the only emission source considered in this chapter.

3.6.1. Emissions

Coal mining leads to CH_4 emissions and indirect CO_2 emissions from oxidation of the CH_4. Coal mining accounts for between 1 and 3 per cent of the CH_4 emissions in the three countries. All countries except Sweden extract coal. The Norwegian mines are located at Svalbard.

Table 40. Emissions from coal mining and percentage of total national emissions. ktonnes and percentage. 1990

	Emissions from coal mining (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	12	4		0.0	1.3	
Canada		91			2.6	
New Zealand		11			0.6	
Sweden						

Source: UNFCCC

Table 41. Emissions from coal mining and percentage of total national emissions. ktonnes. 1996

	Emissions from coal mining (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	9	3		0.0	0.9	
Canada		84			2.0	
New Zealand		19			1.2	
Sweden						

Source: UNFCCC

3.6.2. Indicators

Production (tonnes extracted) of coal is the only indicator we have tested.

Production

Reliability — The reliability of this indicator is presumed to be very good.

Validity — The production data may have quite low validity for the emission figures, due to different emissions levels whether the coal production is from underground or surface mines. One uncertainty is also rounding for countries with small production figures.

3.6.2.1. Coal mining

Production

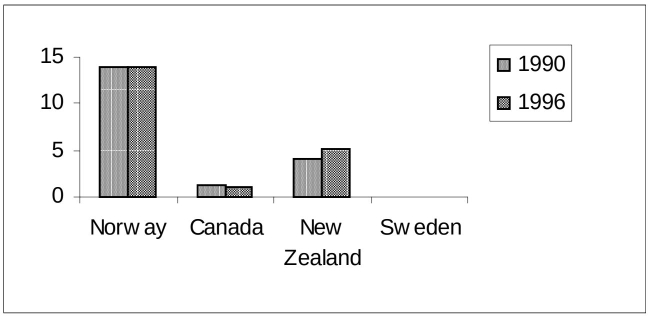
There are large differences between the values for the indicator (Figure 97). For 1996 the values vary from 1.1 tonne CH_4/ktonne coal for Canada (1996) to 14 tonnes CH_4/ktonne for Norway (both years). Different emission factors for underground mines and surface mines will lead to variations in emission intensity values between the countries.

The indicator for Norway is identical to the emission factor used to calculate the emissions. Norway uses an emission factor of 0.014 tonnes CH_4/tonne coal for both years. This factor includes both underground and post-mining emissions, and is calculated from IPCC recommended default emission factors. It is assumed that both underground and post-mining emissions are in the middle of the range of default emission factors. The reported value is known to be very uncertain.

New Zealand has seen an increase in the emissions as a function of production from 1990 to 1996. For Canada there has been a slight decrease. We do not know the reason for the differences between the two years for Canada and New Zealand, but they may origin from differences in the production processes for the two years. If the countries calculate emissions from both underground and surface mines, alterations in the production volumes from the two processes may lead to differences in the emission intensity values for the two years. The variations between the two years may also be effects of revisions of the production data.

Norway is the only country that reports CO_2 emissions from coal mining according to the revised IPCC guidelines. The emissions are not direct, but a result of oxidation of CH_4.

Figure 97. Emissions of CH_4 relative to production. Coal mining. Tonnes CH_4/ktonne coal. 1990 and 1996



Sources: OECD/IEA (1993a and 1998a) and UNFCCC

Indicator appraisal
The differences between the values in Table 42 are too large to give a verification of the emissions.

Table 42. Maximum percentage difference in the emission intensity values for the indicator. Coal mining

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Production	1008	1218	1220

3.7. Fugitive emissions from oil and natural gas

There are fugitive emissions of VOCs (CH_4 and NMVOC) from production and handling of oil and gas. In addition the countries are to report indirect emissions of CO_2 due to oxidation of CH_4 and NMVOC. In Norway flaring of natural gas is the only source of direct CO_2 emissions from oil or gas.

3.7.1. Emissions

Norway, Canada and New Zealand all report emissions from oil and gas production. The CO_2 emissions from this source account for between 1 and 5 per cent of the total CO_2 emissions. CH_4 from this source on the other hand accounts for up to 37 per cent (Canada 1996).

Table 43 and Table 44 show the emissions of CH_4 and CO_2 in each country. To get a better picture we treat the data for oil and gas separately in the chapters 3.7.2.2 and 3.7.2.3.

Table 43. Fugitive emissions from oil and natural gas and percentage of total national emissions. ktonnes and percentage. 1990

	Emissions from oil and gas production (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	1851	16		5.3	5.0	
Canada	9780	1100		2.1	31.4	
New Zealand	258	10		1.0	0.6	
Sweden	53					

Source: UNFCCC

Table 44. Fugitive emissions from oil and natural gas and percentage of total national emissions. ktonnes. 1996

	Emissions from oil and gas production (ktonnes)			Percentage of national emissions		
Country	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Norway	2020	24		4.9	7.1	
Canada	13400	1600		2.6	37.2	
New Zealand	311	9		1.0	0.5	
Sweden						

Source: UNFCCC

3.7.2. Indicators

We have used production of oil and/or gas to compare the emission data for Norway with corresponding data for Canada, New Zealand and Sweden, for 1990 and 1996.

Production

Reliability The reliability of this indicator is presumed to be good.

Validity The validity of the indicator is presumed to be not so good. This is because emissions may be reduced by for instance recovery of the VOC (which gives reduced indirect CO_2 emissions) and newer platforms give frequently less emissions.

For Norway all reported fugitive emissions of CO_2 from oil and gas except for flaring are indirect, that means the carbon in both NMVOC and CH_4 are accounted for as CO_2 (according to the 1996 revised IPCC guidelines). Differences in counting of indirect emissions can lead to differences in the values for the indicator. Further differences in processes may also lead to variations in the result. Norway has large emissions of NMVOC (and therefore indirectly also of CO_2) from oil loading at shuttle tankers at sea. If this process is not the dominant one in another country, the indicator will give a different result. Further differences in recovery of NMVOC will lead to differences in emissions.

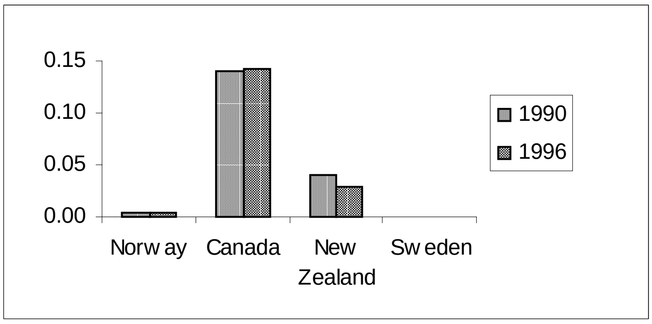
3.7.2.1. Total fugitive emissions from oil and gas production

We will only test the emission figures for oil and gas with the indicator *production*. In order to get an overall view of the comparability between the emissions and the indicator, we first consider total fugitive emissions from oil and gas production.

Production

Figure 98 shows the fugitive CH_4 emissions from oil and gas production (including venting and flaring) compared to production volumes for oil and gas. The results are highly variable. This is probably because the indicator is not suited for the comparison due to large variations in technology between the countries.

Figure 98. Emissions of CH_4 relative to oil and gas production (including venting and flaring). Oil and gas. ktonnes CH_4/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

3.7.2.2. Oil

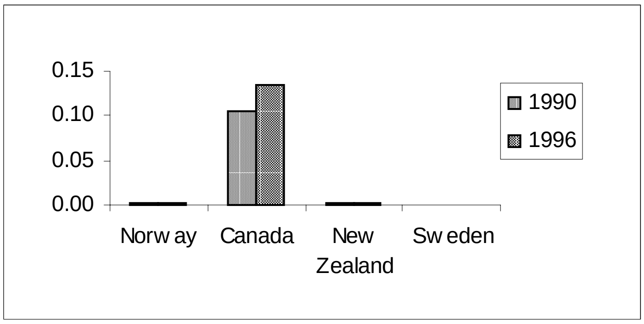
The Norwegian emission figures from this source include emissions from oil loading on shore and offshore. Indirect CO_2 emissions from storage and distribution of gasoline and fugitive emissions at refineries are also included.

Production

We will first test the indicator *production* for emissions of CH_4 and not CO_2. This is because (as mentioned above) only the CH_4 emissions are direct. In Figure 99 which shows the results for CH_4, we see that the values for Norway and New Zealand are comparable (between 0.002 and 0.003 tonnes/TJ), while Canada's value are much larger. The reason for this deviation may be use of different technological solutions with different relative emissions. Another possible explanation is variations from country to country in what sources that are included when reporting the emission figures. The Norwegian values seem reliable compared to the values from New Zealand, but this is not enough to verify the Norwegian values.

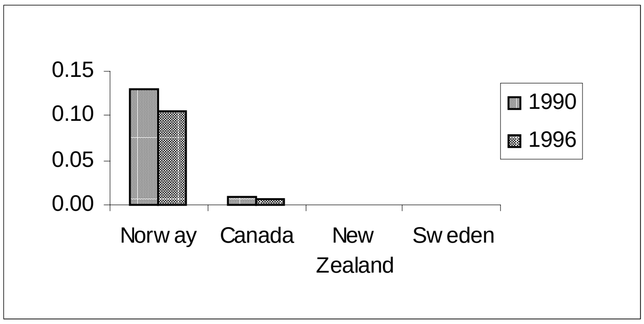
There are also large differences in the indicator for emissions of CO_2 from this source (Figure 100). It seems like Norway is the only country that has reported indirect CO_2 emissions of any extent from this source. This is probably the reason for the high values of the Norwegian indicators compared to Canada and New Zealand. The trend in the indicator is a decrease from 1990 to 1996. This is due to technological improvements which reduces the VOC emissions and therefore also the indirect CO_2 emissions.

Figure 99. Emissions of CH_4 relative to oil production. Oil. tonnes CH_4/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Figure 100. Emissions of CO_2 relative to oil production. Oil. tonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Table 45. Maximum percentage difference in the emission intensity values for the indicator. CH_4. Oil

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Production	5999	5972	7746

Table 46. Maximum percentage difference in the emission intensity values for the indicator. CO_2. Oil

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Production	1308	1270	1448

3.7.2.3. Gas

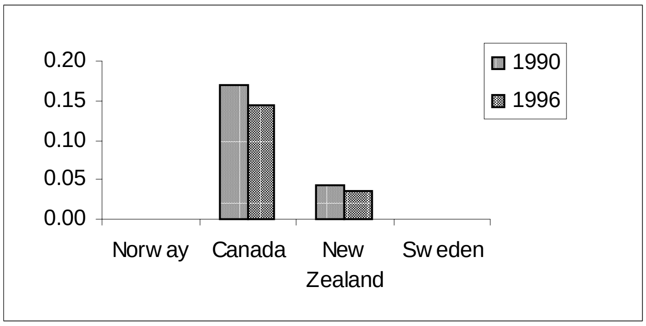
The Norwegian reported emission figures include emissions from two gas terminals.

Production

As for oil we will first test the indicator *production* for emissions of CH_4 and then for CO_2. Figure 101 shows the CH_4 emissions as a function of production volumes. The figure indicates no relationship between the values from the different countries. The values for Norway are too small to show in the figure (0.00066 in 1990 and 0.00032 in 1996). The large differences between the countries may be because different processes are involved in the countries. It may also be caused by differences in the reporting.

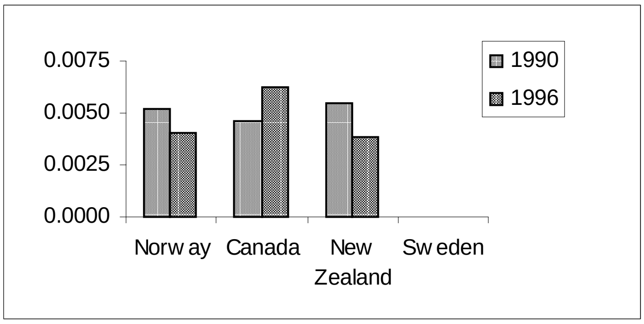
The same indicator for CO_2 is shown in Figure 102. The values for Norway lie between the other countries' values, which could indicate that the Norwegian emission estimate is reliable. But since the Norwegian estimates for CO_2 are partly derived from the CH_4 figures, this must be coincidental. For Norway and New Zealand there have been a decrease in this indicator from 1990 to 1996.

Figure 101. Emissions of CH_4 relative to gas production. Gas. tonnes CH_4/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Figure 102. Emissions of CO_2 relative to gas production. Gas. tonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Table 47. Maximum percentage difference in the emission intensity values for the indicator. CH_4. Gas

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	25460	44133	51903

Table 48. Maximum percentage difference in the emission intensity values for the indicator. CO_2. Gas

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	20	63	63

3.7.2.4. Venting and flaring

The Norwegian emission figures reported under *Venting and flaring* include diffuse and cold vent emissions on platforms and flaring on shore and offshore. Contrary to the CO_2 emissions reported under *Oil* and *Gas*, most of the CO_2 from *Venting and flaring* are direct emissions (97 per cent for Norway in 1996).

Production

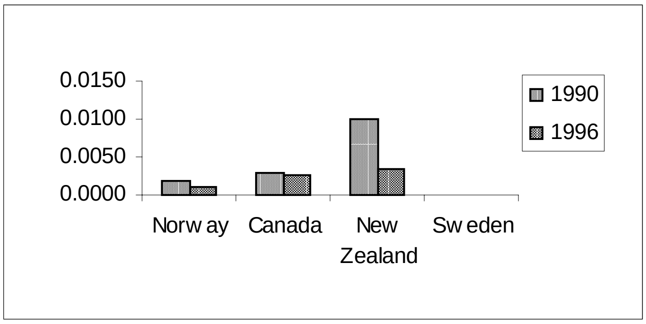
Figure 103 shows CH_4 emissions from venting and flaring as a function of oil and gas production. This source category is masking two different sources, venting and flaring, having very variable emission characteristics. There are large differences for the indicators from country to country. Norway has the lowest values, while the value for New Zealand in 1990 is highest. If we exclude the highest value, all values are between 0.001 and 0.003 tonnes CH_4/TJ. The variation may be caused by differences in the reporting.

The Norwegian Petroleum Directorate has made the Norwegian estimate of CH_4 from vented gas. The same estimate is used for both years. The reason for the relative low value is that Norway is flaring the gas, which leads to quite low CH_4 emissions.

The trend in the indicator is a decrease for all countries. This decrease may be caused by technological improvements as for instance increased recovery of VOC, reduced venting and better leakage control.

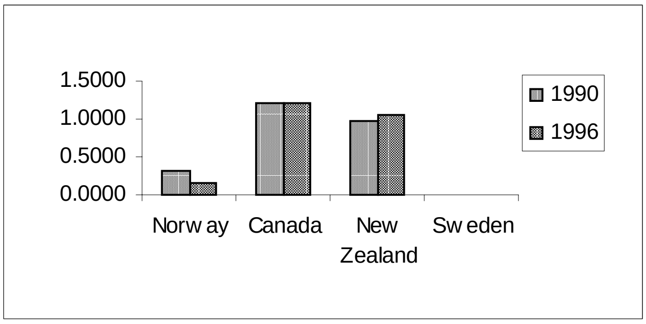
Figure 104 shows the CO_2 emissions from the same source. Norway has also here got the lowest value and the trend for all three countries is a decrease.

Figure 103. Emissions of CH_4 relative to oil and gas production. Venting and flaring. tonnes CH_4/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Figure 104. Emissions of CO_2 relative to oil and gas production. Venting and flaring. tonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1998a)

Table 49. Maximum percentage difference in the emission intensity values for the indicator. CO_2. Venting and flaring

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	287	668	668

Table 50. Maximum percentage difference in the emission intensity values for the indicator. CH_4. Venting and flaring

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	404	207	804

4. Industrial processes

Among possible indicators such as GDP, number of inhabitants, energy use and production, production volume is the only one that can be used for all industrial processes. The others are not relevant or too rough. For some sources, as for instance production of certain metals, amounts of coal and coke used as reducing agents can also be used. In this chapter the indicators are tested on as detailed level as data are available due to the large differences between the processes. The emissions from for instance metal production are therefore split in iron and steel, ferroalloys, aluminium etc.

4.1. Cement production

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

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

The CaO is heated to form clinker, and then crushed to produce cement.

4.1.1. Emissions

Non-combustion emissions from cement production are an important CO_2 source and contribute with between 1 and 3 per cent of the national totals, see Table 51.

Table 51. CO_2 emissions from cement production and percentage of total national emissions. ktonnes and percentage. 1990 and 1996

	Total emissions from cement (ktonnes)		Percentage of national emissions	
Country	1990	1996	1990	1996
Norway	653	872	1.9	2.1
Canada	5870	5530	1.3	1.1
New Zealand	367	503	1.4	1.6
Sweden	1620	1550	2.9	2.4

Source: UNFCCC

4.1.2. Indicators

Production. Production figures in tonnes are compared to emissions in tonnes.

Reliability — The reliability of this indicator is presumed not to be so good, since data are lacking for some countries for 1996.

Validity — This indicator is expected to be closely correlated with the emissions..

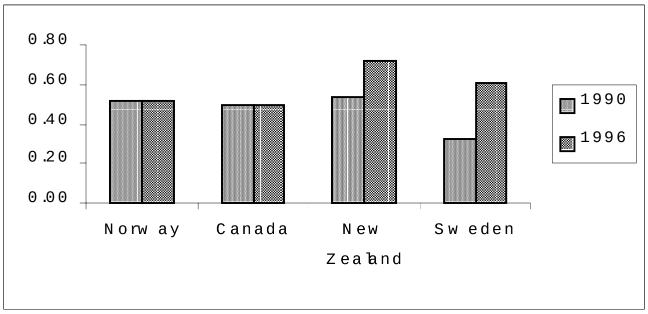
4.1.2.1. Total emissions from cement production

Production

IPCC recommends an emission factor of 0.4985 tonne CO_2/tonne cement (or 0.5071 tonne CO_2/tonne clinker) and the data for Norway and Canada are around this value for both years. The value for New Zealand in 1990 is also near the IPCC factor. Production data for 1996 were not available for Sweden and New Zealand. For these countries 1995 data were used. This may be the most important cause of the deviations for these countries shown in Figure 105. It is also important to notice that if different types of cement are produced, this may lead to differences in the emission intensity values of indicators.

We will not comment the trend in the indicators for Sweden and New Zealand since 1995 production figures have been used. The emission intensity values for Norway and Canada are stable. The Norwegian emission figures seem reliable.

Figure 105. Emissions of CO_2 relative to production. Cement. tonnes CO_2/tonne cement. 1990 and 1996[1]



[1] Production data for 1996 were not available for Sweden and New Zealand. For these countries 1995 data were used.

Sources: UNFCCC and UN (1998).

Table 52. Maximum percentage difference in the emission intensity values for the indicator. Cement

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Production	66	44	122

4.2. Nitric acid production

Production of nitric acid leads to N_2O emissions. Norway produces nitric acid only as a step in the production of fertilizer. In other countries (for example Sweden) nitric acid is an end product. Because nitric acid is not an "end product" in Norway, no production figures are given in the UN statistics. Therefore we have not found any suitable indicator for this emission source.

4.3. Carbide production

Norway is the only country included in this report that has carbide production. The emission figures for this source can therefore not be verified by using data from Canada, New Zealand and Sweden. We assume that production of carbide would have been a possible indicator for carbide production.

4.4. Iron and steel

In Norway CO_2 emissions from non-combustion processes in iron and steel production are estimated from the use of coal and coke as reported to Statistics Norway.

4.4.1. Emissions

Iron and steel production is an important emission source in some of the countries. The countries have reported non-combustion emissions of between 0.1 and 5.1 per cent of the national totals. In addition to the non-combustion emissions both Canada and Sweden have reported large energy emissions from the production. In Norway the production process for iron is of such a kind that the emissions have been reported as non-combustion emissions. The processes by which iron and steel are produced can however vary from country to country. Therefore the emission intensity values may also vary.

Table 53. Non-combustion CO_2 emissions from iron and steel production and percentage of total national emissions. ktonnes and percentage. 1990 and 1996

	Total emissions from iron and steel (ktonnes)		Percentage of national emissions	
Country	1990	1996	1990	1996
Norway	170	219	0.5	0.5
Canada	7590	8290	1.6	1.6
New Zealand	1328	1502	5.1	4.9
Sweden	54	51	0.1	0.1

Source: UNFCCC

4.4.2. Indicators

Production is also here a possible indicator. In addition UN statistics give data on consumption of coal and coke used for production of iron and steel. We assume that coal and coke are used as reducing agents in the production process. These data can be used as an indicator for the verification of the Norwegian emission inventory.

Production. Production figures in tonnes are compared to emissions.

Reliability The reliability of this indicator is presumed to be good.

Validity The validity of this indicator is presumed to be good for iron and steel

Consumption of energy (reducing agents).

Reliability The reliability of this indicator is presumed not to be good. One possibility for errors is that coal and coke used as raw materials may be mixed with coal and coke used as energy. In addition the OECD statistics for 1996 are based on "old" preliminary figures. The emission data will often be based on "newer" revised 1996 data.

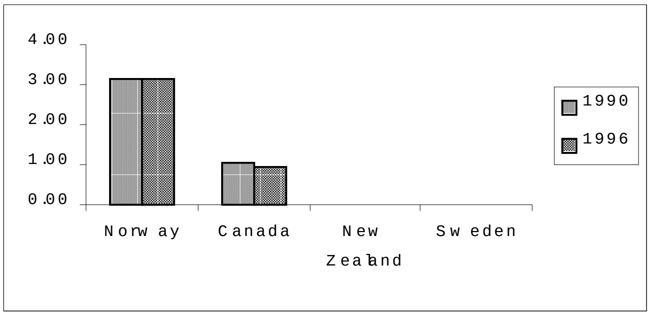
Validity The validity of this indicator is presumed to be less good than production, as the fuel is reported as energy for all metal production as a whole.

4.4.2.1. Total emissions from iron and steel

Production

New Zealand has not reported any production data and is therefore not included in the comparison for this indicator. The values for Norway are above 3 tonnes CO_2/tonne iron and steel while the values for Sweden are approximately 0.02 (Figure 106). The deviations between the three countries may be caused by errors in the reporting. Norway has very low emissions due to small production, hence rounding off figures may also introduce uncertainties.

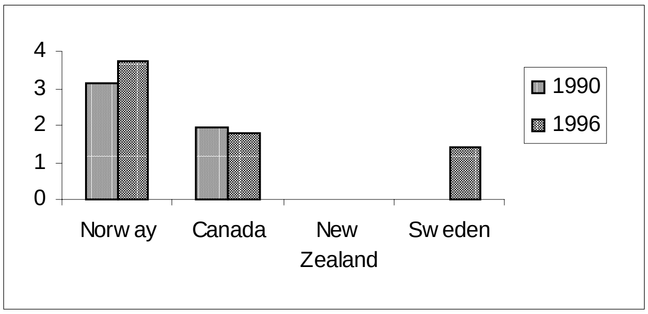
Figure 106. Non-combustion emissions of CO_2 relative to production. Iron and steel. Tonnes CO_2/tonne iron and steel. 1990 and 1996



Sources: UNFCCC and UN (1998).

Figure 107 shows both non-combustion and combustion emissions as a function of production. This figure gives a better picture than non-combustion emissions only, but there are still large deviations between the countries. As mentioned above, these deviations may be caused by differences in the production processes.

Figure 107. Non-combustion and combustion emissions of CO_2 relative to production. Iron and steel. Tonnes CO_2/tonne iron and steel. 1990 and 1996



Sources: UNFCCC and UN (1998)

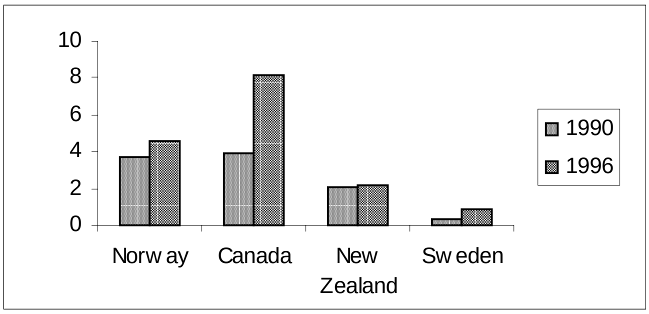
Consumption of energy carriers

Iron, steel and ferroalloys

Figure 108 shows emissions of CO_2 as a function of use of coal and coke as reducing agents. This is an uncertain indicator. The OECD energy statistics does not specify that this consumption is actually used as reducing agent. Furthermore there are uncertainties with the reporting of the emission data as combustion or non-combustion.

The emission intensity values for this indicator varies from Sweden at the bottom with a non-combustion emission of less than 1 tonne CO_2/tonne reducing agent up to Canada which in 1996 had a corresponding value of 8. There is an increasing trend in the emission intensity values for all countries. The reason for this is not known.

Figure 108. Non-combustion emissions of CO_2 relative to consumption of coal and coke assumed used as reducing agents. Iron, steel and ferroalloys. Tonnes CO_2/tonnes. 1990 and 1996



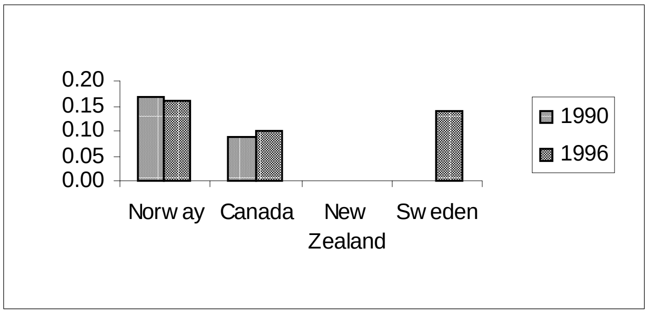
Sources: UNFCCC and OECD/IEA (1993a and 1999)

Due to the differences in the emission reporting (non-combustion vs. combustion) we have tried to make a mixed indicator for all emissions reported from iron and steel industry, both combustion and non-combustion. Because the consumption of energy in the OECD statistics are reported together with ferroalloys the emissions from this source are also included in this section.

Figure 109 shows a function of total CO_2 emissions from iron, steel and ferroalloys production (both combustion and non-combustion) and consumption of coal, coke, natural gas, blast furnace gas and other fossil energy carriers. New Zealand is not included in the figure because they do not split their energy emissions into industry sectors. The same is the case for Sweden in 1990.

The indicator shows an increasing trend for Canada and a decreasing trend for Norway. Differences in the production processes or variations in the sale of blast furnace gas may have caused the differences in the trend from the plants.

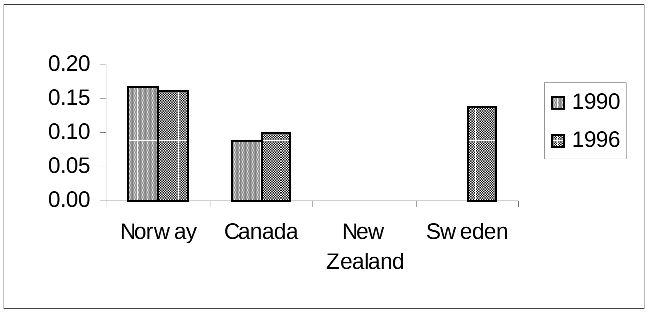
Figure 109. Combustion and non-combustion emissions of CO_2 relative to consumption of energy carriers. Iron, steel and ferroalloys. Tonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1999)

<u>Iron, steel, ferroalloys and non-ferrous metals</u>
Due to the difficulties described earlier, we have tried to make an even more aggregated indicator. We have aggregated emission data reported from iron and steel (non-combustion and combustion), ferroalloys (non-combustion), non-ferrous metal (combustion) and aluminium (non-combustion) and used energy consumption in the sectors *iron and steel* and *non-ferrous metals* from the OECD Energy statistics as an indicator. The result is shown in Figure 110. All emission intensity values for this indicator lie between 0.09 and 0.17. For Norway the indicator has been relatively stable from 1990 to 1996, while Canada has an increase.

Figure 110. Combustion and non-combustion emissions of CO_2 relative to consumption of energy carriers. Iron and steel, ferroalloys, aluminium and non-ferrous metal. Tonnes CO_2/TJ. 1990 and 1996



Sources: UNFCCC and OECD/IEA (1993a and 1999)

Indicator appraisal

There are large uncertainties for all indicators for iron and steel due to uncertainties in the reporting to both UNFCCC and OECD/IEA. All countries have reported emissions. Nevertheless, according to UN Industrial Commodity Statistics, New Zealand does not produce iron or steel. Some countries report the emissions as energy emissions, others as non-combustion emissions and others again as something between. In addition to this, there are uncertainties in the figures for blast furnace gas. In Norway some of this gas is sold to nearby industry. New Zealand does not report use of blast furnace gas at all. There are also uncertainties in the reporting of consumption of coal and coke. The industry sector *iron and steel* in the OECD statistics also includes ferroalloys.

Because of these uncertainties there is no very good indicator. If we should choose one, it must be the aggregated indicator of consumption of energy in the emission sectors *iron and steel*, *ferroalloys*, *non-ferrous metals* and *aluminium*. This indicator has the lowest deviation between the highest and the lowest emission intensity values in 1996. The indicator also has the lowest deviation if we look at both years together. Further work and more detailed knowledge are needed in these important sectors.

Table 54. Maximum percentage difference in the emission intensity values for the different indicators. Iron and steel and more (see footnotes)

Indicator	Year		Pooled values
	1990	1996	1990 and 1996
Production[1]	1237	849	2645
Production[2]	64	161	161
Energy[3]	1237	849	2645
Energy[4]	60	70	107
Energy[5]	89	63	89

[1] Non-combustion emissions and iron and steel production
[2] Combustion and non-combustion emissions and iron and steel production
[3] Non-combustion emissions and consumption of coal and coke (assumed to be used as a reducing agent) in production of iron, steel and ferroalloys.
[4] Non-combustion emissions and consumption of energy (all except electricity) in production of iron, steel and ferroalloys.
[5] Non-combustion emissions and consumption of energy (all except electricity) in production of iron, steel, ferroalloys, non-ferrous metals and aluminium.

4.5. Ferroalloys

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

4.5.1. Emissions

Both Sweden and Norway have reported emissions from production of ferroalloys. Sweden's emissions from ferroalloy production account for 0.4 per cent of the national totals while the corresponding value for Norway is more than 8 per cent. According to UN statistics also Canada have a small production. The emissions from this production may have been reported under *iron and steel*.

Table 55. CO_2 emissions from ferroalloy production and percentage of total national emissions. ktonnes and percentage. 1990 and 1996

Country	Emissions from ferroalloys (ktonnes)		Percentage of national emissions	
	1990	1996	1990	1996
Norway	2915	3526	8.3	8.6
Canada	0	0	0	0
New Zealand	0	0	0	0
Sweden	232	267	0.4	0.4

Source: UNFCCC

4.5.2. Indicators

Production is the only possible indicator for ferroalloys. This is because the consumption of coal, coke etc. in the sectors *Iron and steel* and *Ferroalloys* are reported as an aggregated value, see (also) section 4.4.

Production. Production figures in tonnes are compared to emissions.

Reliability The reliability of this indicator is presumed to be good.

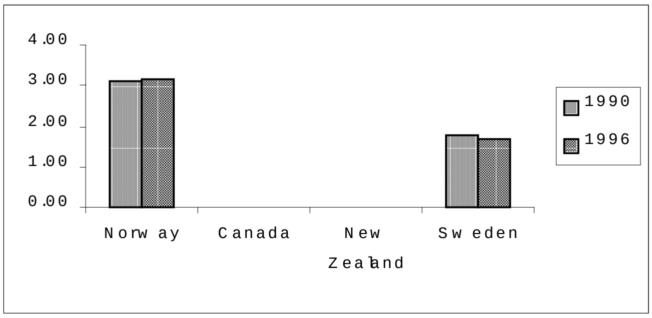
Validity The validity of this indicator is presumed to be good for ferroalloys

4.5.2.1. Total emissions from ferroalloys

Production

The emission intensity value for Norway is higher than the one for Sweden. The indicators are relatively stable from 1990 to 1996, with a small increase in Norway and a decrease in Sweden. The reasons for these trends are unknown, but may be changes in the mix of ferroalloys produced.

Figure 111. Emissions of CO_2 relative to production. Ferroalloys[1]. Tonnes CO_2/tonne ferroalloys. 1990 and 1996



[1] According to UN statistics Canada also produces some ferroalloys. The emissions from these production may have been reported under iron and steel.

Sources: UNFCCC and UN (1998)

We cannot verify the Norwegian emissions from ferroalloy production by only using the emission figures for one other country. Anyhow, Table 56 shows the percentage difference between the emission intensity values for the indicator.

Table 56. Maximum percentage difference in the emission intensity values for the indicator. Ferroalloys

Indicator	Year		Pooled values
	1990	1996	1990 and 1996
Production	76	88	88

4.6. Aluminium

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

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

4.6.1. Emissions

All four countries produce primary aluminium. The non-combustion emissions of CO_2 account for between 0.2 and 4.4 per cent of the national totals.

Table 57. CO_2 emissions from aluminium production and percentage of total national emissions. ktonnes and percentage. 1990 and 1996

	Total emissions from aluminium (ktonnes)		Percentage of national emissions	
Country	1990	1996	1990	1996
Norway	1560	1487	4.4	3.6
Canada	2640	3730	0.6	0.7
New Zealand	458	493	1.8	1.6
Sweden	110	139	0.2	0.2

Source: UNFCCC

4.6.2. Indicators

Production. Production figures in tonnes are compared to emissions.

Reliability The reliability of this indicator is presumed to be good.

Validity The validity of this indicator is presumed to be good for aluminium.

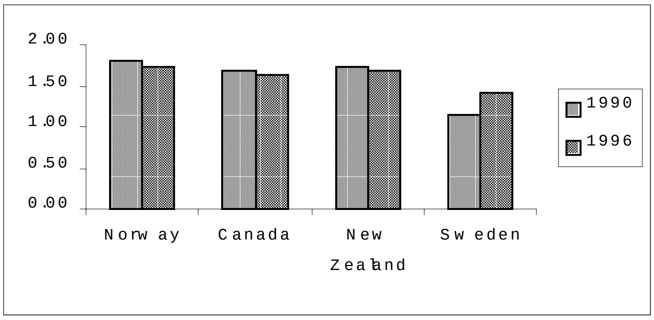
4.6.2.1. Total emissions from production of aluminium

Production

The emission intensity values for the indicator are nearly the same for Norway, Canada and New Zealand (Figure 112). The values for Sweden are somewhat lower. The emission data for Canada also include emissions from production of magnesium. If this were not the case, the emission intensity values for Canada in Figure 112 would have been lower.

The emission intensity values for this indicator show a slightly decreasing trend from 1990 to 1996 for all countries except Sweden where there is an increase. We do not know the reasons for the differences, but it may be due to use of more modern technology (e.g. use of prebaked technology rather than Søderberg).

Figure 112. Emissions of CO_2 relative to production. Aluminium[1]. Tonnes CO_2/tonne aluminium. 1990 and 1996



[1] The emission data used for this indicator for Canada also include emissions from production of magnesium.

Sources: UNFCCC and UN (1998)

Indicator appraisal

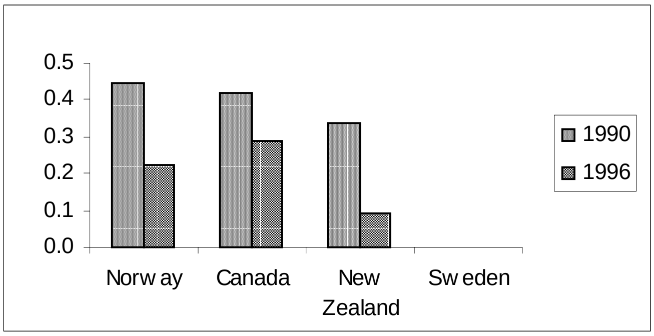
Production proves to be a good indicator and it has verified the Norwegian emission figures from this source.

Table 58. Maximum percentage difference in the emission intensity values for the indicator. Aluminium

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	58	22	58

Production of aluminium also causes emissions of PFCs (perfluorocarbons). As for CO_2, production volume is the only relevant indicator. Sweden has not reported emissions of PFCs and is therefore not included in Figure 113. The figure shows that the trend in the indicator is a strong decrease from 1990 to 1996. This may be due to technological improvements.

Figure 113. Emissions of PFCs relative to production. Aluminium. tonnes PFCs/tonne aluminium. 1990 and 1996



Sources: UNFCCC and UN (1998)

Table 59. Maximum percentage difference in the emission intensity values for the indicator. PFCs. Aluminium

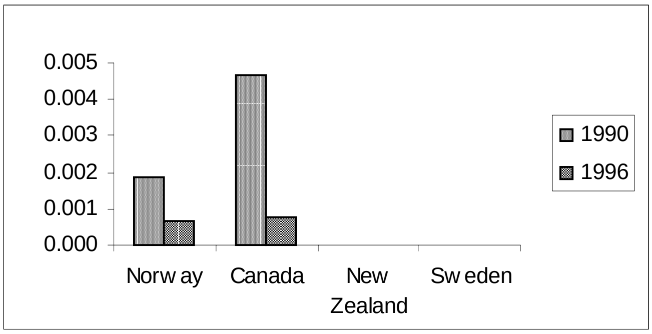
Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Production	32	212	385

4.6.2.2. Other metals

Norway is the only country that has reported CO_2 emissions from production of *other metals*. The emissions are mainly from production of magnesium, but production of nickel also causes some emissions in Norway. According to UN statistics, Canada also produces magnesium. The emissions from this production are included in the figures for aluminium production in the national emission inventory. If emission data were available, production of magnesium could possibly have been used as an indicator.

For SF_6 emitted from the magnesium production we can on the other hand make a comparison. We suppose that all SF_6 emissions reported from aluminium and magnesium production in Canada in fact origins from magnesium. Figure 114 shows the results for this indicator. The indicators for both Norway and Canada have decreased from 1990 to 1996. The decrease may be caused by reduced consumption of SF_6. In 1996 the emission intensity values for the two countries are nearly identical (Table 60).

Figure 114. Emissions of SF_6 relative to production. Magnesium. tonnes SF_6/tonne magnesium. 1990 and 1996



Sources: UNFCCC and UN (1998)

Table 60. Maximum percentage difference in the emission intensity values for the indicator. SF_6. Magnesium

Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Production	153	19	623

4.7. Consumption of halocarbons and sulphur hexafluoride

The sector *Consumption of halocarbons and sulphur hexafluoride* includes the following sub-sectors:

- Refrigeration and air conditioning equipment
- Foam blowing
- Fire extinguishers
- Aerosols
- Solvents
- Other (e.g. gas insulated switch gear).

According to the IPCC Guidelines (IPCC 1997), emissions are reported as potential emissions (Tier 1) or actual emissions (Tier 2). Potential emissions are calculated by either the Tier 1a or Tier 1b methods. Tier 1a only considers chemicals stored in bulks, while Tier 1b also includes chemicals in products. The Tier 2 method calculates emissions on a much more detailed level, based on consumption figures and emission characteristics related to specific processes and equipment.

Most of the countries have only reported their total potential emissions of HFCs, PFCs and SF_6 from this sector and not actual emissions by the sub-sectors listed above. We therefore have to consider total potential emissions from the sector, even though Norway has also reported actual emissions. This approach is very rough, but due to lack of data, we are currently not able to do a more refined analysis of the Norwegian emissions.

4.7.1. Emissions

The potential emissions of HFCs, PFCs and SF_6 from the sector *Consumption of halocarbons and sulphur hexafluoride* were quite modest and accounted for less than 1 per cent of total greenhouse gas emissions in 1990 and 1996 for all countries[9]. The use of these gases is, however, following an increasing trend. By comparing Table 61 and Table 62, we see that the emissions of these gases grew by a factor of about ten compared to the countries' other greenhouse gas emissions.

Table 61. Potential emissions from use of halocarbons and SF_6 and percentage of total national emissions. ktonnes and percentage. 1990

	Potential emissions of halocarbons and SF_6				Percentage of national emissions
Country	HFCs	PFCs	SF_6	CO_2-equivalents[1]	CO_2-equivalents
Norway	0.003	-	0.002	43.4	0.084
Canada	-	-	-	-	-
New Zealand	0.0002	-	0.001	22.7	0.031
Sweden	-	-	0.02 [2]	478.0	0.680

[1] Calculations of HFC emissions in CO_2 equivalents were performed with the Norwegian pooled GWP value for HFCs this year (=140).
[2] This value was only available from a digital version of the Swedish inventory
Source: UNFCCC

Table 62. Potential emissions from use of halocarbons and SF_6 and percentage of total national emissions. ktonnes and percentage. 1996

	Potential emissions of halocarbons and SF_6				Percentage of national emissions
Country	HFCs	PFCs	SF_6	CO_2-equivalents [1]	CO_2-equivalents
Norway	0.129	0.0003	0.002	304	0.547
Canada	2.648	-	-	5000	0.744
New Zealand	0.175	0.0120	0.001	435	0.572
Sweden	-	-	-	-	-

[1] For all countries except Canada, calculations of HFC emissions in CO_2 equivalents were performed with the Norwegian pooled GWP value for HFCs this year (=1888). Canada has reported their emissions in CO_2 equivalents, so it is the value given in first column that has been estimated by the pooled GWP.
Source: UNFCCC

4.7.2. Indicators

GDP measured in current prices and exchange rates.

Reliability The reliability of this indicator is presumed to be very good.

Validity The validity of GDP as an indicator of the potential emissions of HFCs, PFCs and SF_6 is presumed to be rather low. However, the pollutants are used in such a variety of products and for so very different purposes that GDP might not be (totally) unsuitable.

Population

Reliability The reliability of this indicator is presumed to be very good.

Validity The validity of population as an indicator of the potential emissions of HFCs, PFCs and SF_6 is presumed to be as questionable as GDP. However, since the sector is so very heterogeneous we need broad indicators and population is therefore suggested.

4.7.2.1. Potential emissions of HFCs, PFCs and SF_6

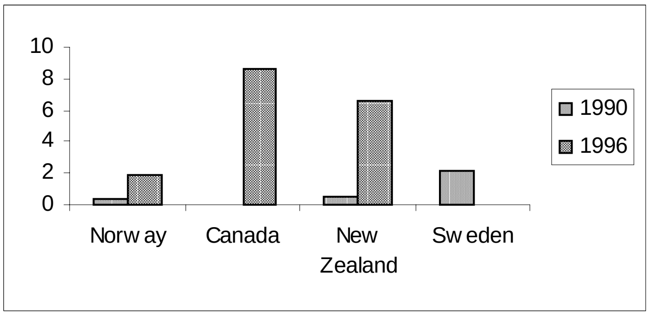
GDP

The use of HFCs, PFCs and SF_6 is, as expected, not very proportionate to GDP, see Figure 115. Potential emissions of ktonnes CO_2-equivalents per billion USD range from 0.4 to almost 9. The higher levels in 1996 compared to 1990 are due to the phasing in of HFCs to substitute ozone-depleting substances. Considering only the values for 1996, the range is from about 2 to 9. In both years the Norwegian emission intensity values are lower than for the other countries. However, due to

[9] Only potential emissions are considered because only Norway and Canada have estimated actual emissions.

the large differences between the four countries, this fact does neither strengthen nor weaken the reliability of the Norwegian potential emissions. More countries should be included in the comparison.

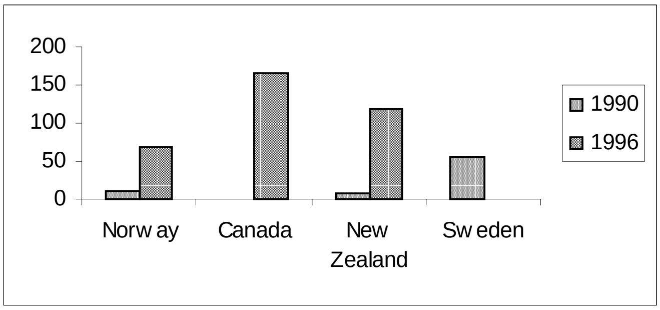
Figure 115. Potential emissions of HFCs, PFCs and SF_6 relative to GDP. Consumption of halocarbons and sulphur hexafluoride. ktonnes CO_2-equivalents/billion USD. 1990 and 1996



No data on potential emissions for Canada (1990) and Sweden (1996).
Sources: UNFCCC, OECD (1992a and 1998a)

Population
Potential emissions of HFCs, PFCs and SF_6 relative to population also show large variance. The values of ktonnes CO_2-equivalents per million capita range from about 7 to 170. As for GDP, population does not reflect the trend of increasing HFC emissions. Within years the differences in emission intensity values are smaller, ranging from about 70 to 170 in 1996. The emission intensity values in Norway lay in the range of the other countries in 1990, but in 1996 the Norwegian value is lower. There are, however, so large differences between the four countries that we find it hard to draw any conclusions.

Figure 116. Potential emissions of HFCs, PFCs and SF_6 relative to population. Consumption of halocarbons and sulphur hexafluoride. ktonnes CO_2-equivalents/million capita. 1990 and 1996



No data on potential emissions for Canada (1990) and Sweden (1996).
Sources: UNFCCC, OECD (1992a and 1998a)

Indicator appraisal
None of the evaluated indicators explain the trend in potential emissions of HFCs, PFCs and SF_6. The increasing emissions from 1990 to 1996 are mainly due to HFCs substituting ozone-depleting substances. This process is founded on political objectives and is not related to population size or GDP. As shown in Table 63, the indicators are more correlated with potential emissions within a given year. As ozone-depleting substances get phased out, both GDP and population might prove to have good credibility for trends.

Some of the variation found between countries might be due to different methods being used. Norway has estimated potential emissions according to Tier 1a, but it is not clear whether the other countries might have used Tier 1b. Since Tier 1b considers chemicals imported in products in addition to bulk chemicals, this method gives higher estimates of potential emissions than Tier 1a.

Different distributions of HFCs, PFCs and SF_6 between countries might also give confounding results. The GWP of SF_6 is very large (23900), so that small inaccuracies in this estimate have large influence. This is especially important for 1990 when emissions of halocarbons were low. In 1996 HFCs were more important, constituting more than 75 per cent of the emissions from this sector for all countries except Sweden. Since the different HFC compounds have GWPs ranging from 140 to 11700, the countries might have rather different pooled GWP values for HFCs. The use of the Norwegian pooled GWP for HFCs in calculations of CO_2-equivalents might therefore introduce inaccuracies.

Table 63. Maximum percentage difference in the emission intensity values for the different indicators. Consumption of halocarbons and sulphur hexafluoride

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
GDP	410 [1]	348 [2]	2003
Population	730 [1]	140 [2]	2380

[1] Canada not included
[2] Sweden not included

Due to the large range of emission intensity values, it is difficult to draw any conclusions regarding the emission estimates reported by Norway from this sector. Estimates of actual emissions would give more certain results. Also, reporting on a less aggregated level would open up for other, more specific indicators.

5. Solvent and other product use

Only Norway and Sweden have reported CO_2 emissions (indirect emissions) from *solvent and other product use*. The emissions account for about a half per cent of the national totals of CO_2 (Table 64). New Zealand has reported emissions of NMVOC from this sector, while Canada has reported emissions of N_2O (anaesthetic use).

Table 64. CO_2 emissions from solvents and percentage of total national emissions. ktonnes and percentage. 1990 and 1996

	Total emissions from solvents (ktonnes)		Percentage of national emissions	
Country	1990	1996	1990	1996
Norway	145	143	0.4	0.3
Sweden	276	250	0.5	0.4

Source: UNFCCC

N_2O from anaesthesia is not reported from Norway though this is an emission source (is presumed to be very small). Norway will do an assessment of this before the next reporting.

5.1. Indicators

The Norwegian emissions are only compared with the emissions in Sweden. The conclusion from such a comparison will be very uncertain.

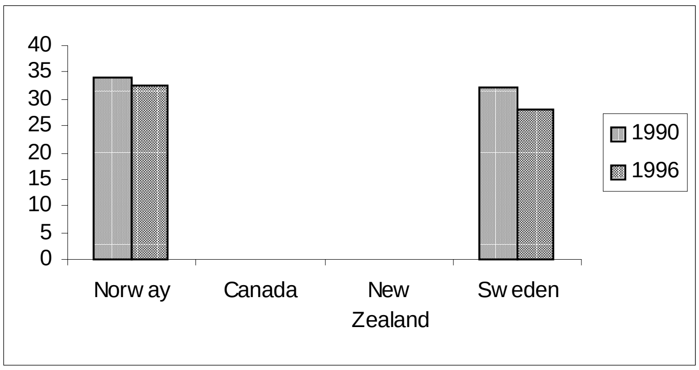
Population

Reliability: The reliability of this indicator is presumed to be very good.

Validity: Since a considerable part of the solvent and other products containing solvents is used in households, population is assumed to be a good indicator.

Emissions of CO_2 per million capita are very similar for Norway and Sweden (Figure 117). Based on the comparison with emissions from only one country, the Norwegian emissions seem sensible. As seen in Table 65, the highest emission intensity values are only 6-16 per cent higher than the lowest values.

Figure 117. CO_2 emissions from solvents relative to population. ktonnes CO_2/million capita. 1990 and 1996



Source: UNFCCC

Table 65. Maximum percentage difference in the emission intensity values for the different indicators. Solvent use

Indicator	Year		Average 1990-1996
	1990	1996	
Population	6	16	21

6. Agriculture

The 1996 IPCC Guidelines for National Greenhouse Gas Inventories divide greenhouse gases from agriculture into four sources:

- domestic livestock: enteric fermentation and manure management
- rice cultivation
- agricultural soils
- agricultural burning: prescribed savannah burning and burning of agricultural residues.

In Norway, only emissions from domestic livestock and agricultural soils are considered since rice is not cultivated and burning of agricultural residues is considered as insignificant. Agricultural soils may emit CO_2, but according to the IPCC standard this should be reported under the category *Land-use Change and Forestry*[10, 11]. Therefore only agricultural emissions of N_2O and CH_4 are considered in this chapter.

6.1. Emissions

Agriculture is an important source of CH_4 and N_2O emissions in the four countries considered in this report. Out of national emissions in the investigated countries, this sector contributes to about 30-90 per cent of the CH_4 emissions, and from 50 to almost 100 per cent of the N_2O emissions (Table 66 and Table 67). New Zealand differs from the other countries in that agriculture is the single dominant source of CH_4 and N_2O emissions.

Methane is emitted mainly through enteric fermentation and manure management. In most countries cattle is the most important methane source from enteric fermentation, due to their high numbers, large body size and ruminant digestive system. Emissions of CH_4 from management of manure are associated with storing or handling manure, and are usually smaller than emissions from enteric fermentation.

Nitrous oxide is directly emitted from agriculture soils through microbial processes in the soil. There are several sources of nitrogen input to the soil: e.g., synthetic fertilisers, animal excreta nitrogen, cultivation of histosols, biological nitrogen fixation and crop residues. In addition, droppings on pasture give direct emissions of N_2O. Nitrous oxide is also indirectly induced by agricultural activities through N losses by volatilisation, leaching and runoff and sewage production.

Table 66. Emissions from agriculture and percentage of total national emissions. ktonnes and percentage. 1990

	Total emissions from agriculture (ktonnes)		Percentage of national emissions)	
Country	CH_4	N_2O	CH_4	N_2O
Norway	101	9	32	54
Canada	950	110	29	58
New Zealand	1492	36	89	98
Sweden	160	17	56	65

Source: UNFCCC

[10] Norwegian CO_2 emissions from liming agricultural soils are reported in 2G *Industrial Processes, Other*.
[11] Canada reports CO_2 emissions from managed agricultural soils and emissions from liming in 4D *Agricultural Soils*.

Table 67. Emissions from agriculture and percentage of total national emissions. ktonnes and percentage. 1996

Country	Total emissions from agriculture (ktonnes)		Percentage of national emissions	
	CH_4	N_2O	CH_4	N_2O
Norway	108	9	31	56
Canada	1100	130	28	57
New Zealand	1431	37	90	97
Sweden	163	17	62	63

Source: UNFCCC

6.2. Indicators

We have used the following six indicators to compare total emission data for Norway with the corresponding data for Canada, New Zealand and Sweden in 1990 and 1996.

	CH_4	N_2O
Number of animals: cattle number	x	x
Meat production	x	x
Agricultural area:		
-- cultivated area (arable land and permanent crops)		x
-- cultivated area and permanent pasture		x
Crop production (harvest)		x
Fertiliser consumption		x
Agricultural output:		
-- total output		x
-- animal output	x	

A more detailed description of the various indicators is given in Appendix D. Here we give an initial assessment of the indicators.

Number of animals: cattle

Reliability The reliability of this indicator is presumed to be very good for these countries.

Validity Since "cattle" is the animal group that usually contributes most to CH_4 emissions, we use cattle number as an indicator rather than number of animals. However, since there are many sheep both in Norway and New Zealand, the validity is reduced. There exists no standard method for aggregating different animal species into one animal category.

CH_4: The validity will depend on the distribution of animal species used in husbandry. Differences in the amount of manure produced and how it is managed also reduce the validity of this indicator.

N_2O: Number of cattle may indicate emissions from animal waste only, and does not include emissions from important sources like synthetic fertilisers. For emissions from manure, the validity will also depend on the distribution of animal species.

Total meat production

Reliability The reliability is presumed to be very good

Validity CH_4: Aggregates relevant animal species better than the indicator "number of cattle". In other respects it has a poorer validity than "number of cattle", since emissions derive from live animals. In addition, this indicator does not include emissions from animals kept for other purposes than meat production.

N_2O: As for "number of cattle", this indicator does not include emission sources other than animals.

Agricultural area: with and without permanent pasture area

Reliability: The reliability of agricultural area without pasture area is presumed to be very good. Possible differences in definition of permanent pasture make the inclusion of pasture area more uncertain.

Validity: N_2O: We assess the validity of agricultural area to be fairly good, though the indicator is vulnerable to differences in cultivation intensity.

Crop production: cereals

Reliability: The reliability of cereal production is presumed to be very good.

Validity: N_2O: Production data on cereal relate to crops harvested for dry grain only. Other plant crops and cereal crops harvested for other purposes are not included. The validity thus depends on the similarity in cropping between the compared countries. Crop production neither includes emissions from animals on pasture. This might be critical for this comparison, since both Norway and New Zealand have many sheep.

Consumption of nitrous fertilisers

Reliability: The reliability of this indicator is presumed to be very good.

Validity: N_2O: As opposed to "cereal production", this indicator aggregates emissions related to different crop production. However, it does only include use of commercial fertilisers. Emissions from manure and droppings are omitted. The validity is not considered to be very good.

Total agricultural output and animal output[12,13]

Reliability: The reliability of this indicator is questionable. Output adjusted to PPP is more relevant for Norway, whose agriculture serves domestic needs, while exchange rates is more relevant for New Zealand since they have an export-oriented agriculture.

Validity: N_2O: Major advantage for total agricultural output is that it aggregates both animal and crop production, which both contributes to N_2O emissions. But it is still considered to have rather poor validity.

CH_4: Only animal output is considered as indicator for CH_4 emissions. Like meat production it aggregates animals into one category, but the validity is questionable.

In the following chapters we discuss the indicators' ability to explain a country's emissions from agriculture. We suggest an indicator for each sector/source within agriculture by comparing the different data, focusing on the gap between the lowest and highest values.

[12] We use agricultural output (and animal output) rather than value added to GDP from agriculture (animal husbandry) as indicators. This is because intermediate consumption (of seeds, fertilisers and costs connected to maintenance etc.) which also relates to emission, get subtracted in calculation of value added.

[13] Output is given in 1990 PPPs

6.2.1. Total emissions from agriculture

We first consider emissions from agriculture at the most aggregated level. This means that emissions from both enteric fermentation and manure management are included in the CH_4 emissions, and emissions from manure management and agricultural soils are included in the N_2O emissions.

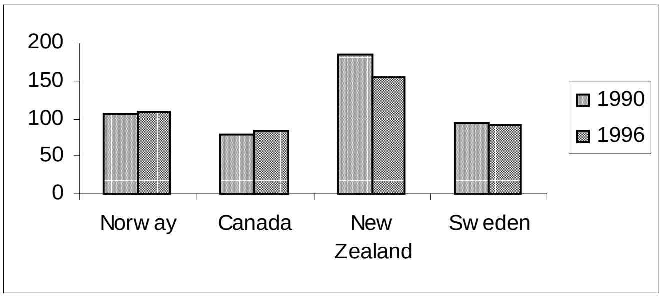
6.2.1.1. CH_4 emissions

All CH_4 emissions are related to animal production, and are reported under the categories *Enteric fermentation* and *Manure management*. Here we consider the aggregated level, i.e. total emissions of CH_4 from agriculture. Only three indicators are applied: cattle number, total meat production, and economic output from animal husbandry (animal output).

Number of animals: cattle

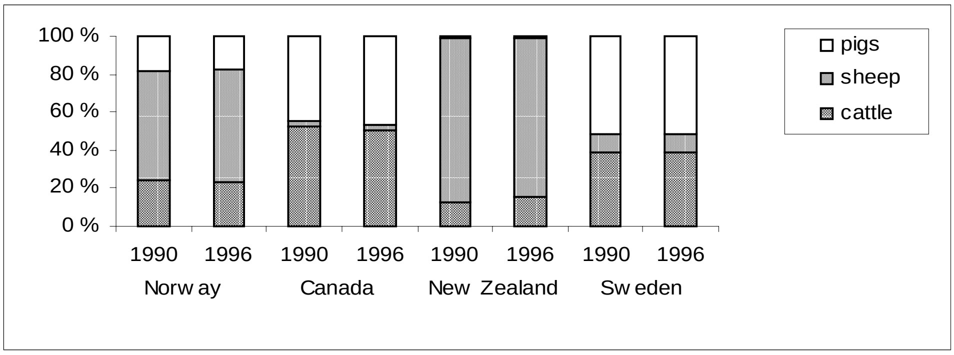
The Norwegian CH_4 emission estimates per cattle lay between the intervals of the other countries, but there is considerable variation in the emission intensity values (Figure 118). The variation is probably to a large extent related to differences in the distribution of animal species in the four countries (Figure 119). Like New Zealand, Norway has a large fraction of sheep within animal husbandry, making the relative importance of cattle in CH_4 emissions less than for Sweden and Canada. The emission intensity values seem to reflect time variation in CH_4 emissions fairly well.

Figure 118. Total emissions of CH_4 from agriculture compared to number of cattle. kg CH_4/cattle. 1990 and 1996



Sources: UNFCCC, FAO (1992 and 1997)

Figure 119. Relative distributions of three major animal species in husbandry. 1990 and 1996



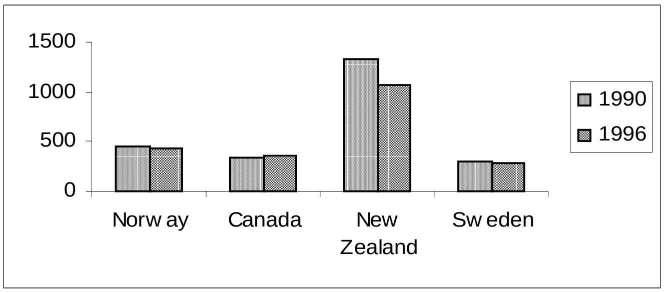
Sources: FAO (1992 and 1997)

Meat production

Using meat production as an indicator of CH_4 emissions gives a quite large range of emission intensity values (Figure 120). As opposed to cattle number, meat production aggregates different husbandry animals into one category. However, a weakness with this indicator is that it does not necessarily reflect the actual stocks. Animals kept for other purposes than meat production are not included, besides that lifetimes for various husbandry animals differ.

The large emission intensity values of New Zealand may be explained by a large fraction of CH_4 emissions from sheep that mainly are kept for wool production. For example, New Zealand produced 200 kg wool (greasy) per tonne meat in 1996, while the corresponding figures in Norway and Canada were approximately 20 kg/tonne and 0.5 kg/tonne, respectively (FAO 1992 and 1997). Excluding New Zealand, the emission intensity values are comparable.

Figure 120. Total emissions of CH_4 from agriculture compared to meat production. kg CH_4/Mtonnes meat. 1990 and 1996

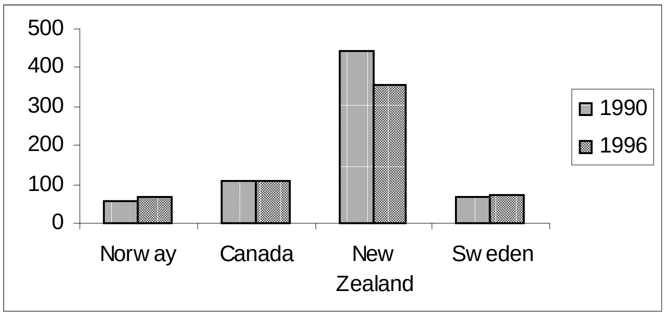


Sources: UNFCCC, FAO (1992 and 1997)

Animal output

Emissions of CH_4 from agriculture relative to animal output are smaller for Norway than for the other countries, but at a similar level as Sweden and Canada. Also here, New Zealand differs from the other countries. This might be due to different economic output from different forms of production (e.g. meat production versus wool production). Also, measuring output in 1990 PPP might introduce differences between the countries.

Figure 121. Total emissions of CH_4 from agriculture compared to animal output. kg CH_4/million USD. 1990 and 1996



Sources: UNFCCC, OECD (1998b).

Indicator appraisal

None of the proposed indicators assessed total emissions of CH_4 from agriculture very well. The best indicator seems cattle number, which gave a deviation of 139 per cent between highest and lowest emission intensity value in 1990 and 1996. Taking into account that sheep is an important source of CH_4 emissions in Norway, the emission estimates given for Norway seem reasonable.

The observed differences in emission intensity values between countries can to a large extent be explained by differences in animal distribution and production. Hence, the proposed indicators might prove to give more even results for other countries than those considered.

Table 68. Maximum percentage difference in the emission intensity values for the different indicators. Total CH_4 emissions from agriculture

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Number of cattle	139	85	139
Meat production	329	268	359
Animal output	662	448	662

6.2.1.2. N_2O emissions

Agricultural N_2O emissions occur both from animal and crop production. Except for "agricultural output", all proposed indicators are mainly related to one part of the emission source, either animal production or crop production.

Norway reports N_2O emissions in the categories *Agricultural Soils* and *Other*. The emissions reported under *Other* should be reported under *Agricultural Soils* (see subsection 6.2.4 Agricultural soils). Also, as opposed to the other countries, Norway does not report N_2O emissions from manure management. The manure management systems used in Norway are in the categories: *Liquid Systems, Solid Storage and Dry Lot*, *Daily Spread* and *Pasture Range and Paddock*. Emissions from *Liquid Systems* and *Solid Storage and Dry Lot* before spreading should be reported under manure management, but this is not calculated in the Norwegian inventory[14]. This N_2O emission is however small, only about 0.2 Gg.

We first consider emissions of N_2O from agriculture in total.

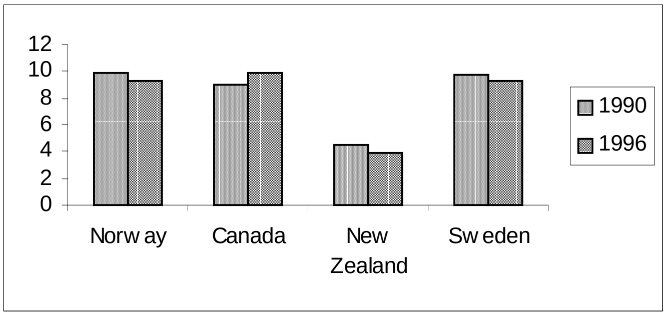
Number of animals: cattle

N_2O emissions per cattle are surprisingly even for the four countries, taking into account that the indicator only reflects emissions from cattle excreta (manure and droppings). In Norway N_2O direct emissions caused by animal droppings and manure count for less than 20 per cent of the total N_2O emissions in agriculture.

The emission intensity values in Norway are similar to the values of Canada and Sweden, indicating that our emission estimates are reasonable. However, the fact that almost 25 per cent of the Norwegian N_2O emissions in agriculture are caused by synthetic fertilisation, limits the validity of this indicator.

N_2O emissions per cattle are rather stable between years. The reduction in the Norwegian relative emissions in 1996 is due to a higher number of cows combined with stable consumption of fertilisers.

Figure 122. Total emissions of N_2O from agriculture compared to number of cattle. kg N_2O/cattle. 1990 and 1996



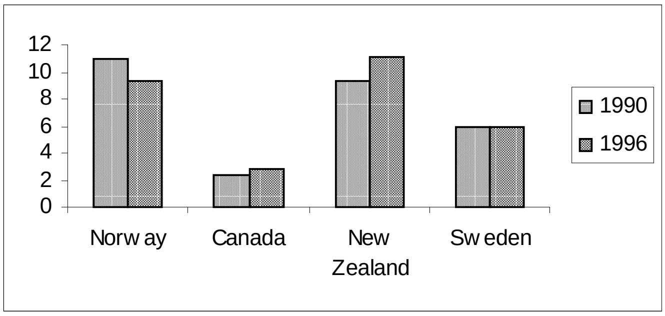
Sources: UNFCCC, FAO (1992 and 1997)

[14] The Norwegian inventory is partly in accordance with table 4-22 in the IPCC Reference Manual (1996). There it says that emissions from *Solid storage and Dry Lot* are to be reported under agricultural soils *and* emissions are assumed not to occur before spreading. This is probably a mistake in the table, because it does not correspond to the text.

Agricultural area
In 1990 Norway has the highest N_2O emissions per cultivated area, although at a similar level as New Zealand. The emission intensity values may indicate actual differences in extent and methods of fertilising (see later subsection). But, the high values of Norway and New Zealand might also be due to emissions from animals on pasture. Low consumption of synthetic fertilisers in New Zealand compensate for higher amounts of animals on pasture compared to Norway, so that the two countries end in about the same values.

There is some variation between years for all countries except Sweden. In Norway the cultivated area has increased with about 15 per cent, but this in not reflected in a proportionate increase in N_2O emissions.

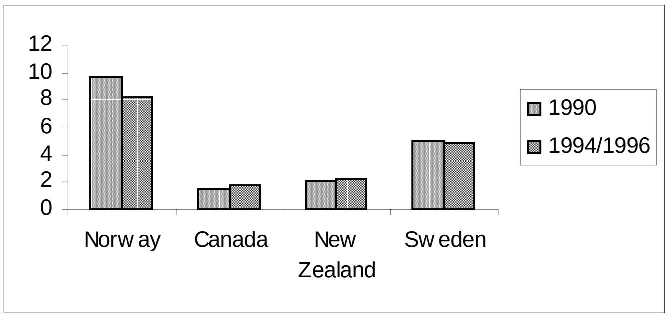
Figure 123. Total emissions of N_2O from agriculture compared to cultivated area. kg N_2O/ha cultivated area. 1990 and 1996



Sources: UNFCCC, FAO (1992) and (1997)

Adding permanent pasture to the cultivated area, New Zealand's emission intensity values are considerably reduced (Figure 124). Now, Norway has the highest emissions of N_2O per agricultural area. The high emission intensity values in Norway might be due to high amounts of sheep grazing on outlying fields not included in permanent pasture area.

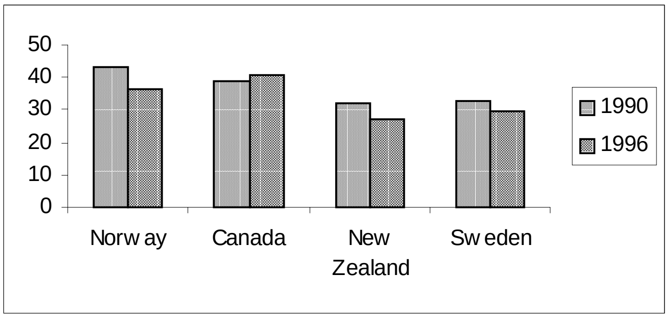
Figure 124. Total emissions of N_2O from agriculture compared to agricultural area. kg N_2O/ha agricultural area. 1990 and 1994/1996 [1]



[1] Pasture area for 1994 is added to area cultivated land, since this is the last year data on permanent pasture area is reported.
Sources: UNFCCC, FAO (1992), (1995) and (1997).

Meat production
Values of N_2O emissions per kg produced meat are surprisingly equal for the four countries. As for the indicator "cattle number", meat production is not considered to have high validity, because it misses emissions that are not caused by animals (like crop residues, nitrogen fixation and synthetic fertilisers). Different factors for different countries probably outweigh each other, so that the even values are rather coincidental.

Figure 125. Total emissions of N_2O from agriculture compared to meat production. kg N_2O/Mtonnes meat. 1990 and 1996

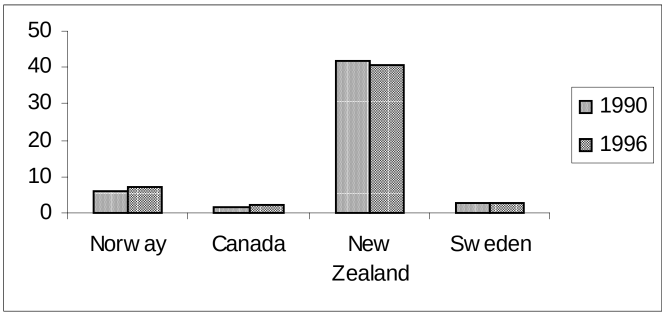


Sources: UNFCCC, FAO (1992) and (1997)

Crop production

Norway has N_2O emissions per kg cereal production that are at the same level, but somewhat higher than Sweden and Canada. Crop production does not cover emission sources like direct emissions from grazing animals. This might explain why New Zealand's values differ in magnitude and why Norway has larger values than Canada and Sweden.

Figure 126. Total emissions of N_2O from agriculture compared to crop production. kg N_2O/Mtonnes cereal. 1990 and 1996

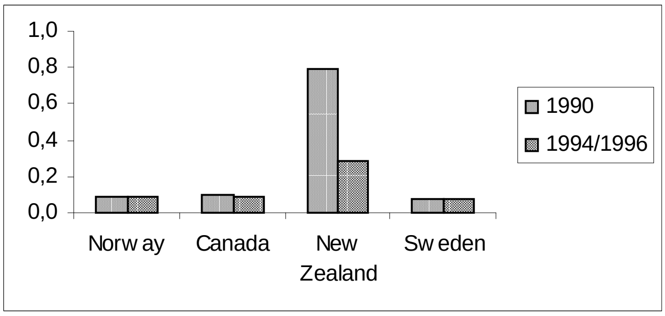


Sources: UNFCCC, FAO (1992) and (1997)

Consumption of synthetic fertilisers

Emissions of N_2O relative to fertiliser consumption give rather even values for Norway, Sweden and Canada. As for crop production, consumption of synthetic fertilisers does not include emission sources like direct emissions from grazing animals, which is an important N_2O emission source in New Zealand.

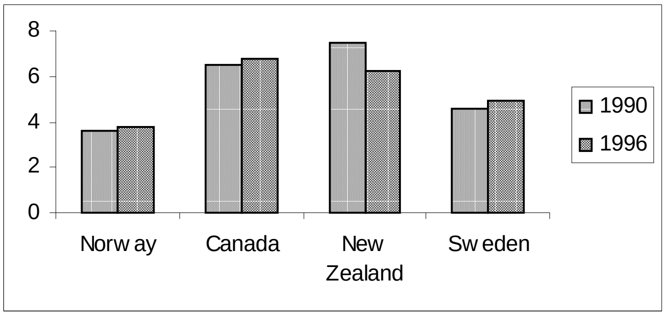
Figure 127. Total emissions of N_2O from agriculture compared to consumption of nitrogenous fertilisers. kg N_2O/kg N in fertilisers. 1990 and 1994/1996 [1)]



1) Data on consumption of nitrogenous fertilisers is from 1994
Sources: UNFCCC, OECD (1997)

Agricultural output
Since using agricultural output to verify emissions is a very rough approach, the evenness of the values is rather unexpected. The main advantage of using agricultural output as an indicator is that all sources of emissions are aggregated. If the compared countries have rather different distributions of N_2O emission sources within agriculture, this advantage may outweigh the fact that the contributions from primary sources differ between countries.

Figure 128. Total emissions of N_2O from agriculture compared to agricultural output. kg N_2O/million USD. 1990 and 1996



Sources: UNFCCC, OECD (1998b).

Indicator appraisal
Using meat production as an indicator gives the least difference between highest and lowest emission intensity values. This indicator was not assumed to have high validity, and the good result might be a matter of coincidence.

The conclusion is that verification of agricultural N_2O emissions on this aggregated level is only convenient for countries that have very similar agricultural production. Differences both in relative importance of crop production compared to animal husbandry and in intensity of cultivation might give confounding results. Also future reporting of more detailed data of N_2O from agricultural soils will facilitate verification.

Table 69. Maximum percentage difference in the emission intensity values for the different indicators. Total N_2O emissions from agriculture

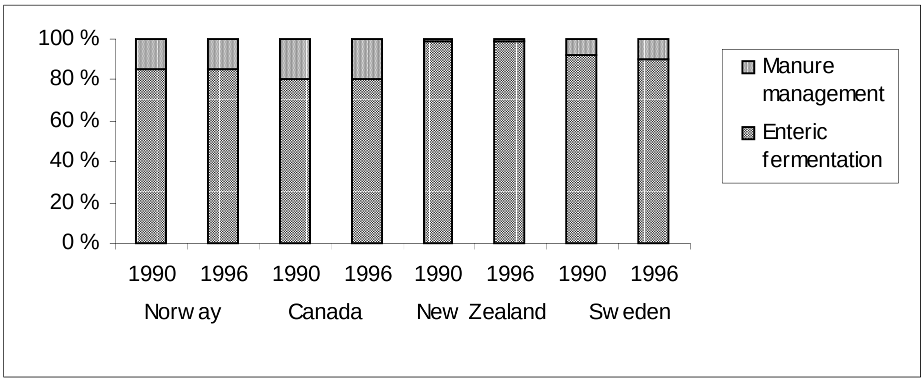
Indicator	Year		Pooled values 1990 and 1996
	1990	1996	
Number of cattle	122	150	153
Agriculture area: - cultivated	359	290	365
- including perm. pasture	555	363	555
Meat production	34	51	59
Crop production	2120	1715	2120
Fertiliser consumption	898	266	928
Agricultural output	107	79	107

6.2.2. Enteric fermentation

In this section we consider emissions of CH_4 from enteric fermentation only. The same indicators as for total emissions of CH_4 are used, see subsection 6.2. All countries calculate CH_4 emissions from the number of animals of various kinds. In the sectoral reports for agriculture, estimates of emissions from each animal category are specified. However, we do not consider indicators at this detailed level.

Enteric fermentation is the main source category for total CH_4 emissions from agriculture (Figure 129). The results and discussions presented in this section are thus rather similar to those in Subsection 6.2.1.1.

Figure 129. The contribution of enteric fermentation and manure management in total CH_4 emissions from agriculture. Percentage

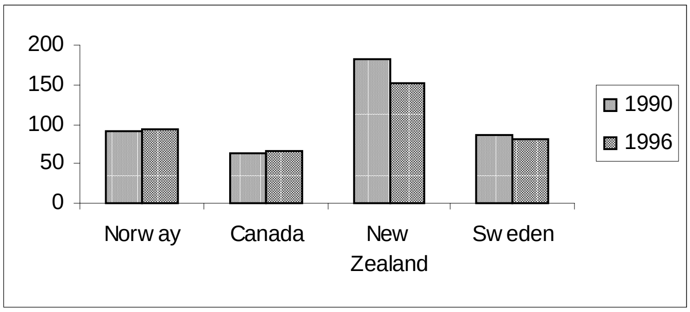


Source: UNFCCC

Number of animals: cattle

Norway's emissions of CH_4 per cattle lay between the interval of the other countries' values. Differences between the countries are probably mainly due to differences in distribution of husbandry animals (Figure 119). Taking that into account, the Norwegian emission estimates seem reasonable.

Figure 130. Emissions of CH_4 from enteric fermentation compared to number of animals. kg CH_4/cattle. 1990 and 1996

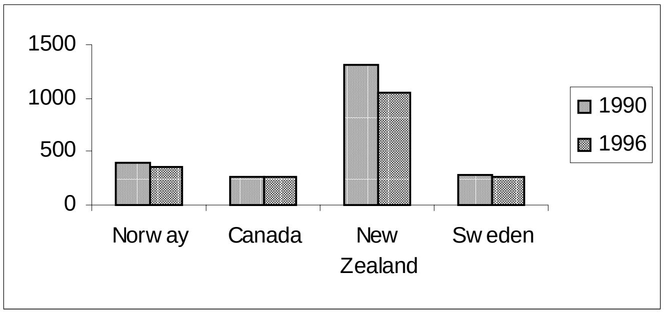


Sources: UNFCCC, FAO (1992) and (1997)

Meat production

Using meat production gives a similar pattern as for cattle number, but with larger variance (Figure 131). Also here differences might be explained by distributions of husbandry animals (Figure 119).

Figure 131. Emissions of CH_4 from enteric fermentation compared to meat production. kg CH_4/Mtonnes meat. 1990 and 1996

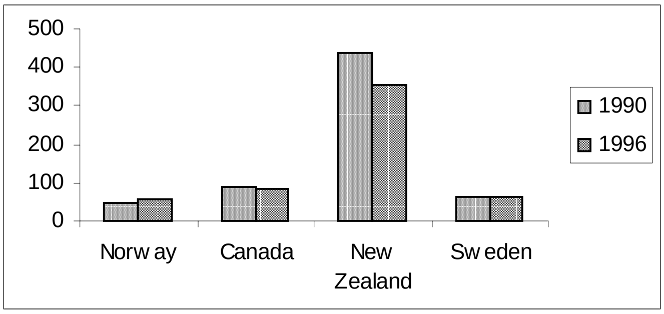


Sources: UNFCCC, FAO (1991) and (1997)

Animal output

Emissions of CH_4 relative to animal output give values at comparable levels for all countries except New Zealand. The high value of New Zealand might be explained by lower economic income from animal production (e.g. meat production versus wool production). Also, the conversion of currencies into one by the use of PPPs, might introduce differences.

Figure 132. Emissions of CH_4 from enteric fermentation compared to animal output. kg CH_4/million USD. 1990 and 1996



Sources: UNFCCC, OECD (1998b).

Indicator appraisal
None of the proposed indicators assessed CH_4 emissions from enteric fermentation very well. As for total emissions from agriculture cattle number was the best indicator, but here the deviation was even larger.

Table 70. Maximum percentage difference in the emission intensity values for the different indicators. CH_4 emissions from enteric fermentation

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
Number of cattle	195	134	195
Meat production	389	305	404
Animal output	782	535	782

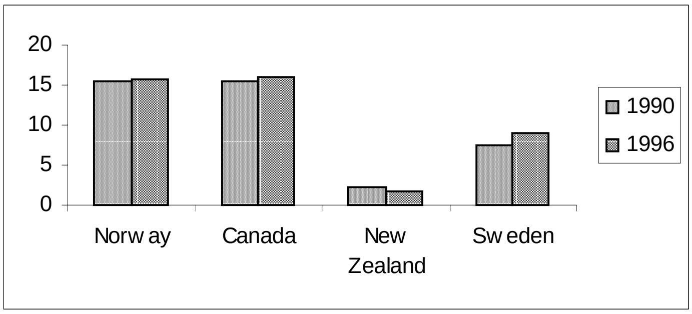
6.2.3. Manure management

Since Norway has not reported N_2O emissions from manure management, see subsection 6.2.1.2, only emissions of CH_4 are considered here. The same indicators as for total emissions are used, see Subsection 6.2. In the sectoral reports for agriculture CH_4 emissions from manure management are calculated from number of animals. However, in this report the indicators are not evaluated at a more detailed level.

As shown in Figure 129, manure management constitutes a minor source of CH_4 emissions from agriculture. The relative importance is somewhat different in the countries compared, so the results given here differ significantly from the ones for total emissions from agriculture, see subsection 6.2.1.1.

Number of animals: cattle
Together with Canada, Norway has the highest emission of CH_4 per cattle. New Zealand has very low emission intensity values. The variation might be explained by differences in animal waste management systems together with differences in livestock.

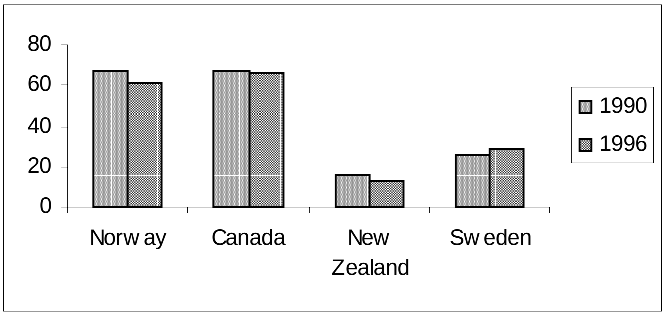
Figure 133. Emissions of CH_4 from manure management compared to number of cattle. kg CH_4/cattle. 1990 and 1996



Sources: UNFCCC, FAO (1992) and (1997)

Meat production
Using meat production as an indicator gives a similar pattern as with cattle number. Norway and Canada have the highest values, while New Zealand has the lowest. The variation is however smaller.

Figure 134. Emissions of CH_4 from manure management compared to meat production. kg CH_4/Mtonnes meat. 1990 and 1996

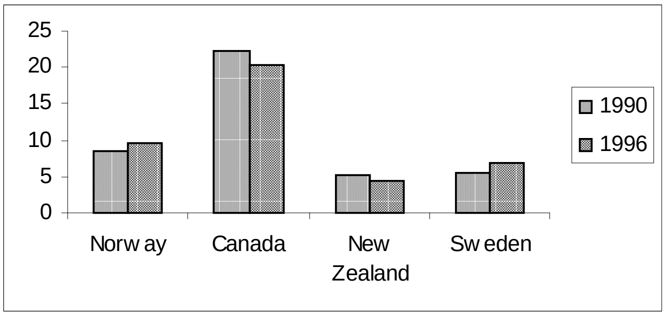


Sources: UNFCCC, FAO (1992) and (1997)

Animal output

Emissions of CH_4 from manure management relative to animal output in Norway lay between the other countries' values. Different distribution of animal waste management systems might explain some of the variation between the countries.

Figure 135. Emissions of CH_4 from manure management compared to animal output. kg CH_4/million USD. 1990 and 1996



Sources: UNFCCC, OECD (1998b).

Indicator appraisal

Emissions from manure management were not assessed very well by any of the proposed indicators. The large difference in emission intensity values might probably to a large extent be explained by different systems for waste treatment and different distribution of animals within husbandry. Comparison of data between more countries is needed in order to draw any definite conclusions.

Table 71. Maximum percentage difference in the emission intensity values for the different indicators. Total CH_4 emissions from agriculture

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
Number of cattle	603	761	761
Meat production	323	420	425
Animal output	321	378	417

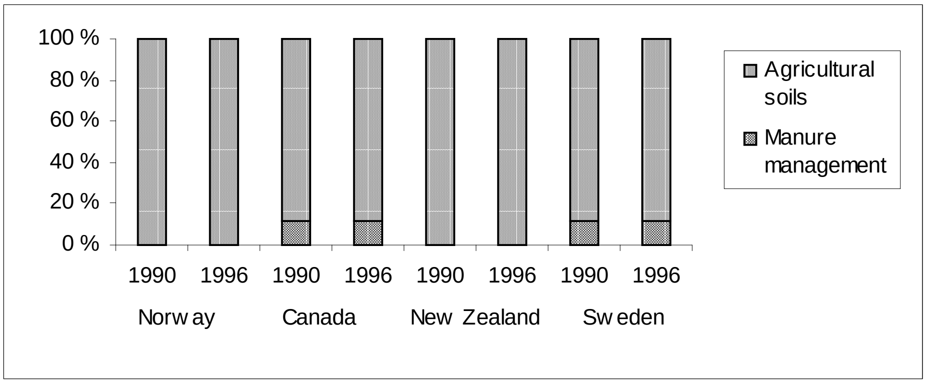
6.2.4. Agricultural soils

Norway reports N_2O emissions in the categories *Agricultural soils* and *Other*. The emissions reported under *Other* are emissions from N-fixation, crop residues, atmospheric deposition of N losses by volatilisation, leaching and runoff. According to IPCC Guidelines for National Greenhouse Gas

Inventories (1996), these emissions should be reported under *Agricultural soils*. Norway's total N_2O emissions from agriculture are therefore used in this section.

As shown in Figure 136 emissions from agricultural soils account for more than 90 per cent of total N_2O emissions from agriculture. Emissions from agricultural soils relative to the various indicators are therefore almost equal to the results given for total N_2O emissions from agriculture. We therefore only present an indicator appraisal.

Figure 136. The contribution from different source categories to total N_2O emissions from agriculture. per cent



Source: UNFCCC

Indicator appraisal

As for agriculture in total, meat production gives the most even emission intensity values. Since meat production does not include important sources of emissions like fertilisers, crop residues or animals kept for other purposes than meat production, the results seem coincidental.

N_2O emissions from agricultural soils include emissions from both animal and crop production, and it is difficult to find indicators that capture both sources. Agricultural output is the only indicator proposed here that aggregates animal and crop production, but as discussed earlier the validity might be questionable.

Table 72. Maximum percentage difference in the emission intensity values for the different indicators. N_2O emissions from agricultural soils

	Year		Pooled values
Indicator	**1990**	**1996**	**1990 and 1996**
Number of cattle	122	137	154
Agriculture area: - cultivated	415	359	421
- including perm. pasture	635	448	635
Meat production	49	36	62
Crop production	2384	2038	2384
Fertiliser consumption	1011	303	1032
Agricultural output	106	66	106

7. Waste

In this chapter only emissions from *Solid Waste disposal on Land* are considered. Norway also reports emissions from *Wastewater Handling*, but these amounts are insignificant (see Appendix A).

7.1. Solid waste disposal on land

Solid waste disposal covers the sources *Managed waste disposal on land*, *Unmanaged waste disposal sites* and *Other*. In the Norwegian inventory the sub-category *Other* covers manufacturing waste deposition and there are no emissions from unmanaged waste disposals. For this sector only emissions on an aggregated level are evaluated.

7.1.1. Emissions

CH_4 is emitted during biological decomposition of waste. The CH_4 generation takes place for several decades after the waste is disposed of. However, most of the emissions occur the first years after disposal.

In 1990 and 1996 emissions of CH_4 from waste accounted for respectively 57 and 56 per cent of the total Norwegian CH_4 emissions. The corresponding values for New Zealand are only 7 and 8 per cent. In both Sweden and Canada waste contributed 23 per cent of national totals in 1996.

Table 73. CH_4 emissions from solid waste disposal and percentage of total national emissions. ktonnes and percentage. 1990 and 1996

	Total emissions from waste disposal (ktonnes)		Percentage of national emissions	
Country	1990	1996	1990	1996
Norway	182	194	57	56
Canada	830	920	24	21
New Zealand	137	110	8	7
Sweden	85	61	30	21

Source: UNFCCC

7.1.2. Indicators

The amount of municipal waste disposed on landfills is a possible indicator for this emission source. Disposal data are given by OECD (1997). Other indicators can be GDP or population.

Disposed amounts of municipal waste

Reliability The reliability is assumed to be good

Validity We expect the indicator to reflect the emission data quite well even if differences between the countries will occur because of burning of methane.

GDP measured in current prices and exchange rates.

Reliability The reliability of this indicator is presumed to be very good.

Validity The validity of GDP as an indicator of emissions from waste disposal is questionable. Some countries effectively use recycling of materials, waste incineration or burning of methane to reduce the methane emissions. Differences in the values for this indicator may reflect differences in use of such measures.

Population

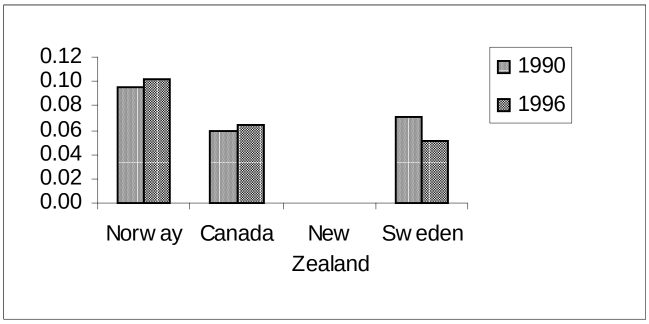
Reliability The reliability of this indicator is presumed to be very good.

Validity The validity of population as an indicator of emissions from waste disposals is questionable. Some countries effectively use recycling of materials, waste incineration or burning of methane to reduce the methane emissions. Differences in the values for this indicator may reflect differences in use of such measures.

Disposal of waste

Figure 137 shows that the emission intensity values for the indicator *Disposal of waste* varies from 0.05 tonnes CH_4 per tonne waste for Sweden in 1996 up to 0.10 for Norway in 1996. We will not comment the trend because the waste amounts used for 1996 are from other years (the latest year available for each country).

Figure 137. Emissions of CH_4 relative to disposal of municipal waste on landfills. Waste. Tonnes CH_4/tonne waste. 1990 and 1996[1]



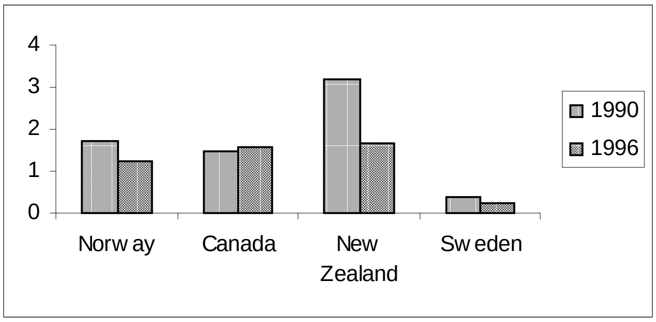
[1] Waste data from 1995 (Norway), 1992 (Canada) and 1994 (Sweden). OECD gives no data for New Zealand.

Sources: UNFCCC and OECD (1997)

GDP

GDP used as an indicator for CH_4 emissions is shown in Figure 138. We see that the emission intensity values for Norway and Canada for both years and New Zealand for 1996 are quite similar. The values deviate both years for Sweden and for New Zealand in 1990. Anyhow, it seems that the Norwegian emission values are in the right magnitude compared with Canada (1990 and 1996) and New Zealand (1996) if we use GDP for a comparison.

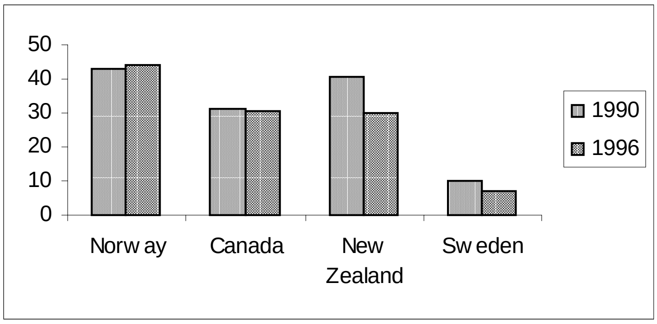
Figure 138. Emissions of CH_4 relative to GDP. Waste. ktonnes CH_4/billion USD. 1990 and 1996



Sources: UNFCCC OECD (1992a) and OECD (1998a)

Population
Figure 139 shows the emission intensity values of the indicator *population*. The values lie between 30 and 45 tonnes CH_4/1000 inhabitants for all countries except Sweden. The corresponding values for Sweden are 10 and 7 for 1990 and 1996 respectively. The emission intensity values for Norway are higher than for the other countries. Differences between the countries may be due to different fractions of waste being combusted or recycled.

Figure 139. Emissions of CH_4 relative to population. Waste. Tonnes CH_4/1000 inhabitants. 1990 and 1996



Sources: UNFCCC, OECD (1992a) and OECD (1998a)

Indicator appraisal
It seems that *Disposal of waste* is the best indicator for verifying the emission level, but not the trend. This is because waste statistics is not available for all years, and the years for which there are figures varies from country to country. None of the indicators are good enough to be recommended for verification of trends.

There may be several reasons for the variations in the emission intensity values between the countries. One is CH_4 generated from private disposals in the manufacturing industries. Methane emissions from this source are highly uncertain. In addition the contribution may be left out in the emission inventories of some countries. Furthermore the indicators would probably have given a clearer verification of the Norwegian emission figures if we had used data on total generated CH_4 instead of the emissions. This is because the countries combust some of the methane. The part of the total generated CH_4 that is combusted will of course vary from country to country. Also the emission estimates are very dependent on the estimation method used (if delays in emissions are taken into account).

To get a clearer verification of the CH_4 emissions from this source, it may be an idea that the countries gives details on both generated and emitted CH_4.

Table 74. Maximum percentage difference in the emission intensity values for the indicator. CH_4. Waste

Indicator	Year 1990	Year 1996	Pooled values 1990 and 1996
Disposal of waste	64	102	102
GDP	759	587	1220
Population	331	548	548

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Appendix A: Summary tables for greenhouse gas inventories

Table 75. Summary report. Norway. 1990

Norway 1990						
	Emissions			**Pot. emissions**		
Source categories	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**
			Gg			
Total national emissions	**35 203**	**317.1**	**17.5**	**0.003**	**0.385**	**0.092**
1 Energy	**28 303**	**33.1**	**1.0**			
A Fuel combustion (sectoral approach)	**26 403**	**13.2**	**1.0**			
1 Energy industries	7 396	2.2	0.1			
2 Manufacturing and construction	3 043	0.4	0.1			
3 Transport	13 533	3.7	0.7			
4 Other sectors	2 431	6.8	0.1			
5 Other						
B Fugitive emissions from fuels	**1 900**	**20.0**	**0.0**			
1 Solid fuels	12	4.2				
2 Oil and natural gas	1 889	15.7	0.0			
2 Industrial processes	**6 718**	**1.0**	**6.7**			
A Mineral products	653					
B Chemical industry	1 096	1.0	6.7			
C Metal production	4 769				0.385	0.089
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6				0.003[1]	0.0	0.002
G Other	200					
3 Solvent and other product use	**144**					
4 Agriculture	**0**	**100.8**	**9.5**			
A Enteric Fermentation		86.1				
B Manure management		14.7				
C Rice cultivation						
D Agricultural soils			3.6			
E Prescribed burning of savannas						
F Field burning of agricultural residues						
G Other			5.9			
5 Land-use change and forestry	**0**	**0.0**	**0.0**			
A Changes in forest and woody biomass						
B Forest and grassland conversion						
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste	**37**	**182.1**	**0.4**			
A Solid waste disposal on land	37	181.7				
B Wastewater Handling		0.4	0.4			
C Human sewage						
D Other						
7 Other						
CO2 Emissions from biomass	5292					

[1] Reported actual emissions (calculated according to Tier 2) are 0.13 tonnes (Mg)

Table 76. Summary report. Norway. 1996

Norway 1996						
	Emissions			**Pot. emissions**		
Source categories	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**
			Gg			
Total national emissions	**41 140**	**345.4**	**16.5**	**0.129[1]**	**0.193**	**0.022**
1 Energy	**33 274**	**42.0**	**1.6**			
A Fuel combustion (sectoral approach)	**31 245**	**14.4**	**1.6**			
1 Energy industries	9 953	3.1	0.1			
2 Manufacturing and construction	3 816	0.4	0.1			
3 Transport	14 964	3.4	1.3			
4 Other sectors	2 512	7.5	0.1			
5 Other						
B Fugitive emissions from fuels	**2 029**	**27.7**	**0.0**			
1 Solid fuels	9	3.2				
2 Oil and natural gas	2 020	24.4	0.0			
3 Geothermal						
2 Industrial processes	**7 684**	**1.0**	**5.2**			
A Mineral products	872					
B Chemical industry	1 215	1.0	5.2			
C Metal production	5 396				0.193	0.020
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6				0.129[1]	0.0003[2]	0.002
G Other	201					
3 Solvent and other product use	**143**					
4 Agriculture		**108.1**	**9.3**			
A Enteric Fermentation		92.3				
B Manure management		15.8				
C Rice cultivation						
D Agricultural soils			3.7			
E Prescribed burning of savannas						
F Field burning of agricultural residues						
G Other			5.6			
5 Land-use change and forestry	**0**	**0.0**	**0.0**			
A Changes in forest and woody biomass						
B Forest and grassland conversion						
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste	**40**	**194.3**	**0.4**			
A Solid waste disposal on land	40	193.9	0.0			
B Wastewater Handling	0	0.4	0.4			
C Human sewage						
D Other						
7 Other						
CO2 Emissions from biomass	5592					

[1] Reported actual emissions (calculated according to Tier 2) are 0.028 Gg

[2] Reported actual emissions (calculated according to Tier 2) are 0 Gg

Table 77. Summary report. Canada. 1990

Canada
1990

Source categories	Emissions CO_2	CH_4	N_2O	Pot. emissions HFCs	PFCs	SF_6
	Gg			Gg CO2 Equivalent		
Total national emissions	**470 000**	**3 300.0**	**190.0**	**0**	**0**	**3000**
1 Energy	**422 000**	**1 500.0**	**37.0**			
A Fuel combustion (sectoral approach)	**412 000**	**260.0**	**37.0**			
1 Energy industries	133 000	1.6	2.7			
2 Manufacturing and construction	62 300	1.6	1.6			
3 Transport	147 000	23.0	29.0			
4 Other sectors	69 900	230.0	3.2			
5 Other	0	0.0	0.0			
B Fugitive emissions from fuels	**9 780**	**1 200.0**				
1 Solid fuels		91.0				
2 Oil and natural gas	9 780	1 100.0				
2 Industrial processes	**31 900**	**0.0**	**37.0**	**0**	**0**	**3000**
A Mineral products	8 160					
B Chemical industry	3 130		37.0			
C Metal production	10 200					3000
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other	10 400					
3 Solvent and other product use	**0**		**1.4**			
4 Agriculture	**6 920**	**950.0**	**110.0**			
A Enteric Fermentation		760.0				
B Manure management		190.0	13.0			
C Rice cultivation		0.0				
D Agricultural soils	6 920		98.0			
E Prescribed burning of savannas		0.0	0.0			
F Field burning of agricultural residues		0.0	0.0			
G Other		0.0	0.0			
5 Land-use change and forestry	**9 000**	**70.0**	**4.0**			
A Changes in forest and woody biomass	0					
B Forest and grassland conversion	1 000					
C Abandonment of managed lands						
D CO_2 emissions and removals from soil	4 000					
E Other	4 000	70.0	4.0			
6 Waste	**299**	**850.0**	**3.0**			
A Solid waste disposal on land		830.0				
B Wastewater Handling		17.0	2.8			
C Human sewage	299	0.0	0.2			
D Other		0.0	0.0			
7 Other						
CO2 Emissions from Biomass	**69 400**					

Table 78. Summary report. Canada. 1996

Canada **1996**						
		Emissions		**Pot. emissions**		
Source categories	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**
		Gg		**Gg CO2 Equivalent**		
Total national emissions	**523 000**	**4000.0**	**230.0**	**5000**[1]	**0**	**1000**
1 Energy	**467 000**	**1900.0**	**59.0**			
A Fuel combustion (sectoral approach)	**454 000**	**280.0**	**59.0**			
1 Energy industries	14 000	1.7	2.9			
2 Manufacturing and construction	66 900	1.8	1.8			
3 Transport	167 000	21.0	51.0			
4 Other sectors	79 900	260.0	3.7			
5 Other	0	0.0	0.0			
B Fugitive emissions from fuels	**13 400**	**1700.0**				
1 Solid fuels		84.0				
2 Oil and natural gas	13 400	1600.0				
2 Industrial processes	**39 200**	**0.0**	**40.0**	**5000**[1]	**0**[2]	**1000**
A Mineral products	7 840					
B Chemical industry	4 130		40.0			
C Metal production	12 000				[2]	1000
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6	15 200			5000[1]		
G Other						
3 Solvent and other product use	**0**		**1.5**			
4 Agriculture	**1 650**	**1100.0**	**130.0**			
A Enteric Fermentation		860.0				
B Manure management		210.0	15.0			
C Rice cultivation		0.0				
D Agricultural soils	1 650		110.0			
E Prescribed burning of savannas		0.0	0.0			
F Field burning of agricultural residues		0.0	0.0			
G Other		0.0	0.0			
5 Land-use change and forestry	**10 000**	**40.0**	**3.0**			
A Changes in forest and woody biomass	0					
B Forest and grassland conversion	3 000					
C Abandonment of managed lands						
D CO_2 emissions and removals from soil	5 000					
E Other	6 000	40.0	3.0			
6 Waste	**324**	**940.0**	**3.2**			
A Solid waste disposal on land		920.0				
B Wastewater Handling		18.0	3.0			
C Human sewage	324	0.0	0.2			
D Other		0.0	0.0			
7 Other						
CO2 Emissions from Biomass	**67 300**					

[1] Reported actual emissions are 500 Gg CO_2 equivalents

[2] Reported actual emissions (from metal production) are 6000 Gg CO_2 equivalents

Table 79. Summary report. New Zealand. 1990

New Zealand
1990

Source categories	Emissions CO_2	CH_4	N_2O	Pot. emissions HFCs	PFCs	SF_6
			Gg			
Total national emissions	**26 115**	**1 672.8**	**37.1**	**0.0002**	**0.000**	**0.001**
1 Energy	**22 855**	**35.4**	**0.6**			
A Fuel combustion (sectoral approach)	**22 240**	**10.6**	**0.6**			
1 Energy industries	6 040	0.3	0.0			
2 Manufacturing and construction	4 710	0.4	0.1			
3 Transport	8 645	7.1	0.4			
4 Other sectors	2 733	2.7	0.1			
5 Other	113	0.1	0.0			
B Fugitive emissions from fuels	**615**	**24.8**				
1 Solid fuels		11.9				
2 Oil and natural gas	258	10.4				
3 Geothermal	357	2.5				
2 Industrial processes	**2 386**	**0.1**		**0.0002**	**0.000**	**0.001**
A Mineral products	448					
B Chemical industry	152	0.1				
C Metal production	1 786					
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6				0.0002	0.000	0.001
G Other						
3 Solvent and other product use						
4 Agriculture		**1 492.2**	**36.3**			
A Enteric Fermentation		1 474.4				
B Manure management		17.8	0.1			
C Rice cultivation						
D Agricultural soils			36.1			
E Prescribed burning of savannas						
F Field burning of agricultural residues		0.1	0.0			
G Other						
5 Land-use change and forestry	**874**	**3.8**	**0.0**			
A Changes in forest and woody biomass						
B Forest and grassland conversion	874	3.8	0.0			
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste		**141.2**	**0.2**			
A Solid waste disposal on land		137.0				
B Wastewater Handling		4.2				
C Human sewage			0.2			
D Other						
7 Other						
CO2 Emissions from biomass	**2 687**					

Table 80. Summary report. New Zealand. 1996

New Zealand
1996

Source categories	Emissions CO_2	Emissions CH_4	Emissions N_2O	Pot. emissions HFCs	Pot. emissions PFCs	Pot. emissions SF_6
			Gg			
Total national emissions	**30 498**	**1 592.8**	**37.5**	**0.175**	**0.012**	**0.001**
1 Energy	**26 267**	**42.1**	**0.7**			
A Fuel combustion (sectoral approach)	**25 594**	**10.8**	**0.7**			
1 Energy industries	6 271	0.2	0.0			
2 Manufacturing and construction	5 646	0.5	0.1			
3 Transport	10 972	7.0	0.5			
4 Other sectors	2 624	2.9	0.1			
5 Other	81	0.1	0.0			
B Fugitive emissions from fuels	**672**	**31.3**				
1 Solid fuels		20.1				
2 Oil and natural gas	311	8.6				
3 Geothermal	362	2.6				
2 Industrial processes	**2 742**	**0.1**		**0.175**	**0.012**	**0.001**
A Mineral products	581					
B Chemical industry	167	0.1				
C Metal production	1 994					
D Other production						
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6				0.175	0.012	0.001
G Other						
3 Solvent and other product use						
4 Agriculture		**1 430.9**	**36.5**			
A Enteric Fermentation		1 413.7				
B Manure management		17.1	0.1			
C Rice cultivation						
D Agricultural soils			36.4			
E Prescribed burning of savannas						
F Field burning of agricultural residues		0.1	0.0			
G Other						
5 Land-use change and forestry	**1 489**	**5.7**	**0.0**			
A Changes in forest and woody biomass						
B Forest and grassland conversion	1 489	5.7	0.0			
C Abandonment of managed lands						
D CO_2 emissions and removals from soil						
E Other						
6 Waste		**114.0**	**0.2**			
A Solid waste disposal on land		109.7				
B Wastewater Handling		4.3				
C Human sewage			0.2			
D Other						
7 Other						
CO2 Emissions from biomass	**2 878**					

Table 81. Summary report. Sweden. 1990

Sweden **1990**						
	Emissions			**Pot. missions**		
Source categories	**CO_2**	**CH_4**	**N_2O**	**HFCs**	**PFCs**	**SF_6**
		Gg				
Total National Emissions	**55 443**	**284**	**26**	**0**	**0.06**	**0.02**
1 All Energy (Fuel Combustion + Fugitive)	**51 381**	**40**	**6**			
A Fuel Combustion	**51 328**	**40**	**6**			
1 Energy industries	8 849	1	1			
2 Manufacturing and construction	13 050	5	2			
3 Transport	18 650	23	3			
4 Other sectors	10 672	10	1			
5 Other	107	0	0			
B Fugitive Emissions from Fuels	**53**	**0**				
1 Solid Fuels		0				
2 Oil and Natural Gas	53	0				
2 Industrial Processes	**3 786**	**0**	**3**	**0**	**0.06**	**0.02**
A Mineral products	2 018					
B Chemical industry	0	0	3			
C Metal production	396	0	0			
D Other production	31					
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						*0.02*[1]
G Other	1 341	0	0			
3 Solvent and Other Product Use	**276**		**0**			
4 Agriculture		**160**	**17**			
A Enteric Fermentation		147				
B Manure Management		13	2			
C Rice Cultivation		0				
D Agricultural Soils			15			
E Prescribed Burning of Savannas		0	0			
F Field Burning of Agricultural Residues		0	0			
G Other		0	0			
5 Land Use Change & Forestry	**0**	**0**	**0**			
A Changes in Forest and Other Woody Biomass Stocks	0					
B Forest and Grassland Conversion	0	0	0			
C Abandonment of Managed Lands						
D Other	0					
6 Waste		**85**	**0**			
A Solid Waste Disposal on Land		85				
B Wastewater Treatment		0	0			
C Waste Incineration						
D Other Waste		0	0			
7 Other						
CO2 Emissions from Biomass	**21 450**					

[1] Only available from a digital version received from the Swedish Environmental Protection Agency

Table 82. Summary report. Sweden. 1996

Sweden
1996

Source categories	Emissions CO_2	CH_4	N_2O	Pot. emissions HFC	PFC	SF_6
		Gg				
Total National Emissions	**63 352**	**261**	**26**	**0**	**0**	**0**
1 All Energy (Fuel Combustion + Fugitive)	**59 391**	**38**	**7**			
A Fuel Combustion	**59 391**	**38**	**7**			
1 Energy industries	14 295	2	2			
2 Manufacturing and construction	14 400	5	3			
3 Transport	19 573	19	2			
4 Other sectors	11 016	11	1			
5 Other	107	0	0			
B Fugitive Emissions from Fuels	**0**	**0**				
1 Solid Fuels		0				
2 Oil and Natural Gas		0				
2 Industrial Processes	**3 711**	**0**	**3**	**0**	**0**	**0**
A Mineral products	1 953					
B Chemical industry	0	0	3			
C Metal production	457	0	0			
D Other production	31					
E Production of halocarbons and SF_6						
F Use of halocarbons and SF_6						
G Other	1 271	0	0			
3 Solvent and Other Product Use	**250**		**0**			
4 Agriculture		**163**	**17**			
A Enteric Fermentation		146				
B Manure Management		16	2			
C Rice Cultivation		0				
D Agricultural Soils			15			
E Prescribed Burning of Savannas		0	0			
F Field Burning of Agricultural Residues		0	0			
G Other		0	0			
5 Land Use Change & Forestry	**0**	**0**	**0**			
A Changes in Forest and Other Woody Biomass Stocks	0					
B Forest and Grassland Conversion	0	0	0			
C Abandonment of Managed Lands						
D Other						
6 Waste		**61**	**0**			
A Solid Waste Disposal on Land		61				
B Wastewater Treatment		0	0			
C Waste Incineration						
D Other Waste		0	0			
7 Other						
CO2 Emissions from Biomass	**25 833**					

Appendix B: Emission tables for the energy sector

Table 83. Sectoral report for energy. Norway. 1990

Norway 1990 **Sectoral Report: Energy (Gg)**			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**28303**	**33.1**	**1.0**
A Fuel combustion activities (sectoral)	**26403**	**13.1**	**1.0**
1 Energy industries	**7328**	**2.2**	**0.1**
a Public electricity and heat	161	0.1	0.001
b Petroleum refining	1722	0.1	0.01
c Solid fuels and other energy	5445	2.1	0.04
2 Manufacturing and construction	**3110**	**0.4**	**0.1**
a Iron and steel	88	0.002	0.001
b Non-ferrous metals	275	0.01	0.002
c Chemicals	763	0.1	0.003
d Pulp, paper and print	235	0.2	0.1
e Food processing, beverages and tobacco	444	0.02	0.004
f Other	1305	0.1	0.03
3 Transport	**13533**	**3.7**	**0.7**
a Civil aviation	949	0.03	0.03
b Road transportation	7893	3.0	0.2
c Railways	96	0.01	0.04
d Navigation	3623	0.3	0.1
e Other	972	0.3	0.3
4 Other sectors	**2431**	**6.8**	**0.1**
a Commercial/institutional	865	0.1	0.01
b Residential	1416	6.7	0.1
c Agriculture/forestry/fishing	150	0.02	0.002
5 Other			
B Fugitive emissions from fuels	**1900**	**20.0**	**0.01**
1 Solid fuels	**12**	**4.2**	**-**
a Coal mining	12	4.2	-
b Solid fuel transformation			
2 Oil and natural gas	**1889**	**15.7**	**0.01**
a Oil	452	6.1	-
b Natural gas	6	0.7	-
c Venting and flaring	1431	8.9	0.01
3 Other			
CO_2 emissions from biomass	**5292**		

Table 84. Sectoral report for energy. Norway. 1996

Norway 1996 **Sectoral Report: Energy (Gg)**			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**33 274**	**42.0**	**1.6**
A Fuel combustion activities (sectoral)	**31 245**	**14.4**	**1.6**
1 Energy industries	**9 953**	**3.1**	**0.1**
a Public electricity and heat	314	0.1	0.003
b Petroleum refining	1 929	0.1	0.01
c Solid fuels and other energy	7 710	2.9	0.1
2 Manufacturing and construction	**3 816**	**0.4**	**0.1**
a Iron and steel	42	0.001	0.000
b Non-ferrous metals	311	0.01	0.003
c Chemicals	740	0.1	0.003
d Pulp, paper and print	758	0.2	0.1
e Food processing, beverages and tobacco	529	0.02	0.005
f Other	1 435	0.1	0.03
3 Transport	**14 964**	**3.4**	**1.3**
a Civil aviation	1 198	0.04	0.04
b Road transportation	8 870	2.7	0.8
c Railways	70	0.004	0.03
d Navigation	3 833	0.3	0.1
e Other	992	0.4	0.3
4 Other sectors	**2 512**	**7.5**	**0.1**
a Commercial/institutional	1 131	0.1	0.01
b Residential	1 193	7.3	0.1
c Agriculture/forestry/fishing	189	0.02	0.002
5 Other			
B Fugitive emissions from fuels	**2 029**	**27.7**	**0.01**
1 Solid fuels	9	3.2	-
a Coal mining	9	3.2	-
b Solid fuel transformation			
2 Oil and natural gas	**2 020**	**24.4**	**0.01**
a Oil	700	14.8	-
b Natural gas	7	0.6	-
c Venting and flaring	1 313	9.1	0.01
3 Other			
CO_2 emissions from biomass	**5592**		

Table 85. Sectoral report for energy. Canada. 1990

Canada 1990 **Sectoral Report: Energy (Gg)**			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**422000**	**1500**	**37**
A Fuel combustion activities (sectoral)	**412000**	**260**	**37**
1 Energy industries	**133000**	**1.6**	**2.7**
a Public electricity and heat	94500	0.9	2.3
b Petroleum refining	21000	0.1	0.1
c Solid fuels and other energy	17500	0.6	0.3
2 Manufacturing and construction	**62300**	**1.6**	**1.6**
a Iron and steel	6560	0.2	0.4
b Non-ferrous metals	3470	0.0	0.1
c Chemicals	6270	0.2	0.1
d Pulp, paper and print	11500	0.5	0.5
e Food processing, beverages and tobacco			
f Other	34400	0.7	0.5
3 Transport	**147000**	**23**	**29**
a Civil aviation	10300	0.7	1.0
b Road transportation	102000	20	24
c Railways	6310	0.6	0.9
d Navigation	5720	0.3	0.8
e Other	16200	1.5	2.1
f Pipeline transport	6670	0.2	0.1
4 Other sectors	**69900**	**230**	**3.2**
a Commercial/institutional	26000	0.5	0.3
b Residential	40700	230	2.9
c Agriculture/forestry/fishing	3130	0.0	0.1
5 Other	**0**	**0**	**0**
B Fugitive emissions from fuels	**9780**	**1200**	**0**
1 Solid fuels	**0**	**91**	**0**
a Coal mining		91	
b Solid fuel transformation			
2 Oil and natural gas	**9780**	**1100**	**0**
a Oil	33	410	
b Natural gas	19	700	
c Venting and flaring	9720	23	
3 Other			
CO_2 emissions from biomass	**69400**		

Table 86. Sectoral report for energy. Canada. 1996

Canada 1996 **Sectoral Report: Energy (Gg)**			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**467000**	**1900**	**59**
A Fuel combustion activities (sectoral)	**454000**	**280**	**59**
1 Energy industries	**140000**	**1.7**	**2.9**
a Public electricity and heat	100000	0.9	2.6
b Petroleum refining	21800	0.1	0.1
c Solid fuels and other energy	18100	0.6	0.3
2 Manufacturing and construction	**66900**	**1.8**	**1.8**
a Iron and steel	7140	0.2	0.5
b Non-ferrous metals	3550	0.0	0.1
c Chemicals	7010	0.2	0.1
d Pulp, paper and print	10800	0.6	0.5
e Food processing, beverages and tobacco			
f Other	38400	0.8	0.6
3 Transport	**167000**	**21**	**51**
a Civil aviation	11600	0.6	1.1
b Road transportation	113000	17	46
c Railways	5580	0.5	0.8
d Navigation	5210	0.3	0.8
e Other	19100	1.8	2.6
f Pipeline transport	12100	0.3	0.1
4 Other sectors	**79900**	**260**	**3.7**
a Commercial/institutional	30100	0.6	0.3
b Residential	46900	260	3.3
c Agriculture/forestry/fishing	2860	0.0	0.0
5 Other	**0**	**0**	**0**
B Fugitive emissions from fuels	**13400**	**1700**	**0**
1 Solid fuels	**0**	**84**	
a Coal mining		84	
b Solid fuel transformation			
2 Oil and natural gas	**13400**	**1600**	**0**
a Oil	37	650	
b Natural gas	39	900	
c Venting and flaring	13400	29	
3 Other			
CO_2 emissions from biomass	**67300**		

Table 87. Sectoral report for energy. New Zealand. 1990

New Zealand 1990 **Sectoral Report: Energy (Gg)**			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**22 855**	**35.4**	**0.6**
A Fuel combustion activities (sectoral)	**22 240**	**10.6**	**0.6**
1 Energy industries	**6 040**	**0.3**	**0.03**
a Public electricity and heat	3 493		
b Petroleum refining	775		
c Solid fuels and other energy	1 772		
2 Manufacturing and construction[1]	**4 710**	**0.4**	**0.1**
a Iron and steel			
b Non-ferrous metals			
c Chemicals			
d Pulp, paper and print			
e Food processing, beverages and tobacco			
f Other			
3 Transport	**8 645**	**7.1**	**0.4**
a Civil aviation	781	0.02	0.01
b Road transportation	7 565	7.0	0.3
c Railways	77	0.02	0.003
d Navigation	221	0.05	0.006
4 Other sectors	**2 733**	**2.7**	**0.09**
a Commercial/institutional	1 168	0.06	0.02
b Residential	508	2.4	0.02
c Agriculture/forestry/fishing	1 057	0.3	0.04
5 Other[2]	**113**	**0.1**	**0.01**
B Fugitive emissions from fuels	**615**	**24.8**	
1 Solid fuels		**11.9**	
a Coal mining		10.8	
b Solid fuel transformation		1.1	
2 Oil and natural gas	**258**	**10.4**	
a Oil		0.2	
b Natural gas	1	7.6	
c Venting and flaring	257	2.6	
3 Other (geothermal)	**357**	**2.5**	
CO_2 emissions from biomass[3]	**2 687**		

The following notation has been used: no = not occurring and ne = not estimated.

1 A further breakdown of this sector is not currently available.

2 Includes emissions from some coal use and non-CO_2 emissions from LPG used in transport.

3 Non-CO_2 emissions from biomass are included in *fuel combustion activities*.

Table 88. Sectoral report for energy. New Zealand. 1996

New Zealand 1996 Sectoral Report: Energy (Gg)			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**26 267**	**42.1**	**0.7**
A Fuel combustion activities (sectoral)	**25 594**	**10.8**	**0.7**
1 Energy industries	**6 271**	**0.2**	**0.04**
a Public electricity and heat	4 659		
b Petroleum refining	883		
c Solid fuels and other energy	728		
2 Manufacturing and construction[1]	**5 646**	**0.5**	**0.1**
a Iron and steel			
b Non-ferrous metals			
c Chemicals			
d Pulp, paper and print			
e Food processing, beverages and tobacco			
f Other			
3 Transport	**10 972**	**7.0**	**0.5**
a Civil aviation	830	0.02	0.01
b Road transportation	9 754	6.9	0.4
c Railways	148	0.03	0.007
d Navigation	240	0.05	0.006
4 Other sectors	**2 624**	**2.9**	**0.09**
a Commercial/institutional	936	0.05	0.02
b Residential	535	2.6	0.03
c Agriculture/forestry/fishing	1 153	0.3	0.05
5 Other[2]	**81**	**0.1**	**0.01**
B Fugitive emissions from fuels	**672**	**31.3**	
1 Solid fuels		**20.1**	
a Coal mining		18.8	
b Solid fuel transformation		1.3	
2 Oil and natural gas	**311**	**8.6**	
a Oil		0.2	
b Natural gas	1	7.4	
c Venting and flaring	310	1.0	
3 Other (geothermal)	**362**	**2.6**	
CO_2 emissions from biomass[3]	**2 878**		

[1] A further breakdown of this sector is not currently available.
[2] Includes emissions from some coal use and non-CO_2 emissions from LPG used in transport.
[3] Non-CO_2 emissions from biomass are included in *fuel combustion activities*.

Table 89. Sectoral report for energy. Sweden. 1990

Sweden 1990 **Sectoral Report: Energy (Gg)**			
Source and sink categories	**CO_2**	**CH_4**	**N_2O**
Total energy	**51382**	**40**	**6**
A Fuel combustion activities (sectoral)	**51329**	**40**	**6**
1 Energy industries	**8849**	**1**	**1**
a Public electricity and heat			
b Petroleum refining			
c Solid fuels and other energy			
2 Manufacturing and construction	**13050**	**5**	**2**
a Iron and steel			
b Non-ferrous metals			
c Chemicals			
d Pulp, paper and print			
e Food processing, beverages and tobacco			
f Other			
3 Transport	**18650**	**23**	**3**
a Civil aviation	682	0.1	ne
b Road transportation	16227	21	0.9
c Railways	96	0	ne
d Navigation	652	2	ne
e Other	993	0.6	2
4 Other sectors	**10672**	**10**	**0.5**
a Commercial/institutional	2982	0.3	0.1
b Residential	5900	10	0.4
c Agriculture/forestry/fishing	1790	0.07	0.05
5 Other	**107**	**0**	**0**
B Fugitive emissions from fuels	**53**	**0**	**0**
1 Solid fuels	**0**	**0**	**0**
a Coal mining			
b Solid fuel transformation			
2 Oil and natural gas	**53**	**0**	**0**
a Oil	53		
b Natural gas			
c Venting and flaring			
3 Other			
CO_2 emissions from biomass	**21450**		

Table 90. Sectoral report for energy. Sweden. 1996

Sweden 1996 Sectoral Report: Energy (Gg) Source and sink categories	CO_2	CH_4	N_2O
Total energy	**59391**	**38**	**7**
A Fuel combustion activities (sectoral)	**59391**	**38**	**7.1**
1 Energy industries	**14295**	**2.3**	**1.5**
a Public electricity and heat	11829	2.2	1.4
b Petroleum refining	1650	0.04	0.1
c Solid fuels and other energy	816	0.01	0.02
2 Manufacturing and construction	**14400**	**5.4**	**2.8**
a Iron and steel	4424	0.07	0.6
b Non-ferrous metals	238	0.00	0.02
c Chemicals	472	0.01	0.02
d Pulp, paper and print	2871	4.1	0.9
e Food processing, beverages and tobacco	1004	0.03	0.06
f Other	5391	1.2	1.2
3 Transport	**19573**	**19**	**2**
a Civil aviation	1302	0.09	
b Road transportation	16592	17	1
c Railways	101		
d Navigation	446	2	0
e Other	1132	0.2	0.4
4 Other sectors	**11016**	**11**	**1**
a Commercial/institutional	2404	0.2	0.08
b Residential	6487	11	0.4
c Agriculture/forestry/fishing	2125	0.3	0.6
5 Other	**107**		
B Fugitive emissions from fuels	**0**	**0**	**0**
1 Solid fuels	**0**	**0**	**0**
a Coal mining		0	
b Solid fuel transformation			
2 Oil and natural gas	**0**	**0**	**0**
a Oil		0	
b Natural gas		0	
c Venting and flaring		0	
3 Other			
CO_2 emissions from biomass	**25833**		

Appendix C: Emission tables for industrial processes

Table 91. Sectoral report for industrial processes. Norway. 1990

Norway 1990									
Sectoral Report: Industrial Processes (Gg)									
Source and sink categories	**CO_2**	**CH_4**	**N_2O**		**HFCs**		**PFCs**		**SF_6**
				pot	**act**	**pot**	**act**	**pot**	**act**
Total industrial processes	**6718**	**1**	**7**	**0.003**	**0.0001**	**0.000**	**0.385**	**0.002**	**0.089**
A Mineral products	**653**								
1 Cement production	653								
2 Lime production									
3 Limestone and dolomite use									
4 Soda ash production and use									
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other									
B Chemical industry	**1096**	**1**	**7**						
1 Ammonia production									
2 Nitric acid production	646		7						
3 Adipic acid production									
4 Carbide production	447	1							
5 Other	2								
C Metal production	**4769**						**0.385**		**0.089**
1 Iron and steel production	171								
2 Ferroalloys production	2915								
3 Aluminium production	1560						0.385		
4 SF_6 in aluminium foundries									
5 Other	123								0.089
D Other production									
1 Pulp and paper									
2 Food and drink									
E Production of HFCs, PFCs and SF_6									
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6				**0.003**	**0.0001**	**0.000**	**0.000**	**0.002**	**ne**
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other	**200**								

Table 92. Sectoral report for industrial processes. Norway. 1996

Norway 1996 **Sectoral Report: Industrial Processes (Gg)**									
Source and sink categories	**CO_2**	**CH_4**	**N_2O**	**HFCs**		**PFCs**		**SF_6**	
				pot	**act**	**pot**	**act**	**pot**	**act**
Total industrial processes	**7 684**	**1**	**5**	**0.129**	**0.028**	**0.0003**	**0.193**	**0.002**	**0.020**
A Mineral products	**872**								
1 Cement production	872								
2 Lime production									
3 Limestone and dolomite use									
4 Soda ash production and use									
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other									
B Chemical industry	**1 215**	**1**	**5**						
1 Ammonia production									
2 Nitric acid production	839		5						
3 Adipic acid production									
4 Carbide production	373	1							
5 Other	2	0							
C Metal production	**5 396**						**0.193**		**0.020**
1 Iron and steel production	773								
2 Ferroalloys production	2 972								
3 Aluminium production	1 487						0.193		0.001
4 SF_6 in aluminium foundries									
5 Other	163								0.019
D Other production									
1 Pulp and paper									
2 Food and drink									
E Production of HFCs, PFCs and SF_6									
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6				**0.129**	**0.028**	**0.0003**	**0.0000**	**0.002**	**ne**
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other	**201**								

Table 93. Sectoral report for industrial processes. Canada. 1990

Canada 1990									
Sectoral Report: Industrial Processes		**(Gg)**		**(Gg CO_2 Equivalent)**					
Source and sink categories	**CO_2**	**CH_4**	**N_2O**		**HFCs**		**PFCs**		**SF_6**
				pot	**act**	**pot**	**act**	**pot**	**act**
Total industrial processes	**31900**	**0**	**37**	**0**	**0**	**0**	**6000**	**3000**	**3000**
A Mineral products	**8160**								
1 Cement production	5870								
2 Lime production	1850								
3 Limestone and dolomite use	371								
4 Soda ash production and use	68								
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other									
B Chemical industry	**3130**		**37**						
1 Ammonia production	3130								
2 Nitric acid production			2.5						
3 Adipic acid production			35						
4 Carbide production									
5 Other									
C Metal production	**10200**						**6000**	**3000**	**3000**
1 Iron and steel production	7590								
2 Ferroalloys production									
3 Aluminium production	2640						6000		
4 SF_6 in aluminium foundries							0	3000	3000
5 Other									
D Other production									
1 Pulp and paper									
2 Food and drink									
E Production of HFCs, PFCs and SF_6									
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6				**0**	**0**				
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other	**10400**								

Table 94. Sectoral report for industrial processes. Canada. 1996

Canada 1996									
Sectoral Report: Industrial Processes		(Gg)		(Gg CO_2 Equivalent)					
Source and sink categories	CO_2	CH_4	N_2O	HFCs		PFCs		SF_6	
				pot	act	pot	act	pot	act
Total industrial processes	**39200**	**0**	**40**	**5000**	**500**	**0**	**6000**	**1000**	**1000**
A Mineral products	**7840**								
1 Cement production	5530								
2 Lime production	1970								
3 Limestone and dolomite use	279								
4 Soda ash production and use	64								
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other									
B Chemical industry	**4130**		**40**						
1 Ammonia production	4130								
2 Nitric acid production			2.6						
3 Adipic acid production			37						
4 Carbide production									
5 Other									
C Metal production	**12000**						**6000**	**1000**	**1000**
1 Iron and steel production	8290								
2 Ferroalloys production									
3 Aluminium production	3730						6000		
4 SF_6 in aluminium foundries							0	1000	1000
5 Other									
D Other production									
1 Pulp and paper									
2 Food and drink									
E Production of HFCs, PFCs and SF_6									
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6				**5000**	**500**				
1 Refrigeration and air cond. equipment				5000	400				
2 Foam blowing				10	10				
3 Fire extinguishers									
4 Aerosols				20	20				
5 Solvents									
6 Other									
G Other	**15200**								

Table 95. Sectoral report for industrial processes. New Zealand. 1990

New Zealand 1990									
Sectoral Report: Industrial Processes (Gg)									
Source and sink categories	**CO_2**	**CH_4**	**N_2O**		**HFCs**		**PFCs**		**SF_6**
				pot	**act**	**pot**	**act**	**pot**	**act**
Total industrial processes	**2 386**	**0.120**	**no**	**0.0002**	**ne**	**0.000**	**0.089**	**0.001**	**ne**
A Mineral products	**448**								
1 Cement production	367								
2 Lime production	82								
3 Limestone and dolomite use	ne								
4 Soda ash production and use									
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other (glass)									
B Chemical industry	**152**	**0.120**							
1 Ammonia production[1]		0.120							
2 Nitric acid production									
3 Adipic acid production									
4 Carbide production									
5 Other[2]	152								
C Metal production	**1 786**					**ne**	**0.089**	**ne**	**ne**
1 Iron and steel production	1 328								
2 Ferroalloys production									
3 Aluminium production	458					ne	0.089		
4 SF_6 in aluminium foundries								ne	ne
5 Other (gold and silver)	ne								
D Other production									
1 Pulp and paper									
2 Food and drink									
E Production of HFCs, PFCs and SF_6									
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6[3]				**0.0002**	**ne**	**0.000**	**ne**	**0.001**	**ne**
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other									

1 CO_2 emitted during ammonia production is used in the plant's subsequent urea production.
2 Includes CO_2 emissions from hydrogen production.
3 A further breakdown is not currently available. However, most halocarbon use occurs in refrigeration and air conditioning equipment.

Table 96. Sectoral report for industrial processes. New Zealand. 1996

New Zealand 1996

Sectoral Report: Industrial Processes (Gg)

Source and sink categories	CO_2	CH_4	N_2O		HFCs		PFCs		SF_6
				pot	act	pot	act	pot	act
Total industrial processes	**2 742**	**0.102**	**no**	**0.175**	**ne**	**0.012**	**0.027**	**0.001**	**ne**
A Mineral products	**581**								
1 Cement production	503								
2 Lime production	78								
3 Limestone and dolomite use	ne								
4 Soda ash production and use									
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other (glass)									
B Chemical industry	**167**	**0.102**							
1 Ammonia production[1]		0.102							
2 Nitric acid production									
3 Adipic acid production									
4 Carbide production									
5 Other[2]	167								
C Metal production	**1 994**					**ne**	**0.027**	**ne**	**ne**
1 Iron and steel production	1 502								
2 Ferroalloys production									
3 Aluminium production	493					ne	0.027		
4 SF_6 in aluminium foundries								ne	ne
5 Other (gold and silver)	ne								
D Other production									
1 Pulp and paper									
2 Food and drink									
E Production of HFCs, PFCs and SF_6									
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6[3]				**0.175**	**ne**	**0.012**	**ne**	**0.001**	**ne**
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other									

1 CO_2 emitted during ammonia production is used in the plant's subsequent urea production.
2 Includes CO_2 emissions from hydrogen production.
3 A further breakdown is not currently available. However, most halocarbon use occurs in refrigeration and air conditioning equipment.

Table 97. Sectoral report for industrial processes. Sweden. 1990

Sweden 1990 **Sectoral Report: Industrial Processes (Gg)**									
Source and sink categories	**CO_2**	**CH_4**	**N_2O**		**HFCs**		**PFCs**		**SF_6**
				pot	**act**	**pot**	**act**	**pot**	**act**
Total industrial processes	**3786**	**0**	**3**	**0**	**0**	**0.06**	**ne**	**0.02**	**ne**
A Mineral products	**2018**		**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Cement production	1620								
2 Lime production	350								
3 Limestone and dolomite use									
4 Soda ash production and use									
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other	48								
B Chemical industry	**0**		**3**	**0**	**0**	**0**	**0**	**0**	**0**
1 Ammonia production									
2 Nitric acid production			3						
3 Adipic acid production									
4 Carbide production									
5 Other									
C Metal production	**396**		**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and steel production	54								
2 Ferroalloys production	232								
3 Aluminium production	110								
4 SF_6 in aluminium foundries									
5 Other									
D Other production	**31**		**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Pulp and paper	31								
2 Food and drink									
E Production of HFCs, PFCs and SF_6	**0**			**0**	**0**	**0**	**0**	**0**	**0**
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6	**0**			**0**	**0**	**0**	**0**	**0.02**[1]	**0**
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other	**1341**		**0.1**						

[1] The value was only available from a digital version received by the Swedish Environmental Agency

Table 98. Sectoral report for industrial processes. Sweden. 1996

Sweden 1996 Sectoral Report: Industrial Processes (Gg)									
Source and sink categories	**CO_2**	**CH_4**	**N_2O**		**HFCs**		**PFCs**		**SF_6**
				pot	**act**	**pot**	**act**	**pot**	**act**
Total industrial processes	**3711**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**
A Mineral products	**1953**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Cement production	1550								
2 Lime production	339								
3 Limestone and dolomite use									
4 Soda ash production and use									
5 Asphalt roofing									
6 Road paving with asphalt									
7 Other	65								
B Chemical industry	**0**	**0**	**3**	**0**	**0**	**0**	**0**	**0**	**0**
1 Ammonia production									
2 Nitric acid production			3						
3 Adipic acid production									
4 Carbide production									
5 Other									
C Metal production	**457**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Iron and steel production	51								
2 Ferroalloys production	267								
3 Aluminium production	139								
4 SF_6 in aluminium foundries									
5 Other									
D Other production	**31**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Pulp and paper	31								
2 Food and drink									
E Production of HFCs, PFCs and SF_6	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 By-product emissions									
2 Fugitive emissions									
3 Other									
F Use of halocarbons and SF_6	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1 Refrigeration and air cond. equipment									
2 Foam blowing									
3 Fire extinguishers									
4 Aerosols									
5 Solvents									
6 Other									
G Other	**1270.5**								

Appendix D: Indicators tested in this report

Table 99. Explanations of indicators tested in this report

GDP (Gross Domestic Product)	Refers to the national product measured in US$ using current prices and exchange rates. Indicator source: OECD
Population	Includes all national present or temporarily absent from a country, and aliens permanently settled in the country Indicator source: OECD
Electricity produced from fossil fuels	Electricity produced from hard coal, lignite, sub-bituminous coal, peat, coke oven, blast furnace gas, liquid fuel, refinery gas, natural gas and gas works gas. Indicator source: OECD/IEA
Energy used	The use of different energy commodities given in joule. If not available from the data source, the amount of energy is calculated from volume by standard converting factors. Indicator source: OECD/IEA
Production of oil and gas	Production of crude oil, natural gas and natural gas liquids (NGL). Indicator source: OECD/IEA
Value added	The sectoral contributions to GDP. Data is calculated into US$ based on current exchange rates. Indicator source: OECD
Transport activity	Transport activity measured in tonne-km (tkm) and passenger-km (pkm). Passenger-km is converted into tonne-km by using a conversion factor of 0.0864 pkm/tkm. Indicator source: UN and OECD
Production of coal	Production of coal is given in the OECD/IEA statistics. Indicator source: OECD/IEA
Production/production volume (of different industrial products)	Production data in metric units are given in the UN Industrial commodity statistics yearbook. Indicator source: UN
Consumption of energy carriers (reducing agents)	Consumption of coal and coke is given in the OECD/IEA statistics. We assume the coal and coke in iron and steel production are used as reducing agents and not for heating. Indicator source: OECD/IEA
Number of animals: cattle	Refers to cattle enumerated between 1 October previous year and 30 September current year. Includes all age groups. Indicator source: FAO
Meat production	Refers to total meat production from both commercial and farm slaughter. Includes all animals slaughtered

	within national boundaries irrespective of their origin. Data are given in dressed carcass weight. Indicator source: FAO
Agricultural area -- *cultivated area* -- *included pasture area (that is total agricultural area)*	*Cultivated area* is defined as arable land plus land under permanent crops. This includes land under both temporary crops replanted after harvest and more permanent crops (fruit trees etc.). Also included are temporary meadows for mowing or pasture, kitchen garden etc. *Pasture area* refers to meadows and pastureland that are used permanently (five years or more) for herbaceous forage crops, either cultivated or wild growing. Indicator source: FAO
Crop production: cereals	Relates to crops harvested for dry grain only, which, among others, exclude crops harvested green for food and silage. Indicator source: FAO
Consumption of nitrogenous fertilisers	Refers to consumption of commercial, nitrogenous fertilisers. The enumerating year is from 1 July current year to 30 June next year. Indicator source: FAO
Agricultural output -- *total agricultural output* -- *animal output*	Total agricultural output refers to gross product from agriculture. Outputs in 1990 PPPs are used. Animal output is only the part of agricultural output given by animal production. Indicator source: OECD
Disposal of waste	Disposal of municipal waste on landfills given in tonnes. Indicator source: OECD

Appendix E: Errors in the Norwegian reporting to UNFCCC

During this analysis we found some smaller reporting errors in the Norwegian emission inventory. These errors are summarised in Table 100. Most errors relate to reporting in wrong categories and therefore appear twice in the table (both where the emissions are reported and where it should have been reported).

Table 100. Norwegian reporting errors.

Sectors and sub-sectors		Error
1. Energy		
1A1. Energy Industries	*c. Manufacture of solid fuels and other energy*	Fuel-based emissions from transportation of gas in pipelines should not be reported here but under 1A3e.
1A3. Transport		
	d. Navigation	Emissions from fishing should not be included here but reported under 1A4c.
	e. Other	Fuel-based emissions from transportation of gas in pipelines should be included here and not under 1A1c.
1A4. Other sectors	*c. Commercial/ Institutional*	Emissions from military fuel use should not be reported here but under 1A5.
	c. Agriculture/ forestry/ fishing	Emissions from fishing should be reported here and not under 1A3d.
1A5. Other		Emissions from military fuel use, which are reported under 1A4c, should be reported here.
2. Industrial processes		
2A.. Mineral products	3 Limestone and dolomite use	Emissions related to liming waste disposals and watercourses, which are reported under 2G, should be reported here.
2G. Other		Emissions from liming agricultural soils should be reported under *5. Land-use change and forestry*, while other emissions related to liming should be reported under 2A3.
3. Solvent and other product use		
3D. Other		N_2O emissions from anaesthesia are not reported.
4. Agriculture		
4B. Manure management		N_2O emissions from manure before application on fields are not included in the inventory.
4D. Agricultural soils		N_2O emissions reported under *4G Other* should be included here.
4G. Other		Direct N_2O emissions caused by biological N-fixation, crop residues and cultivation, and indirect emissions due to leaking and run-off should be reported under *4D Agricultural soils*.
5. Land-use change and forestry		
5D. CO_2 emissions and removals from soils		Emissions from liming agricultural soils, which are reported under *2G*, should be reported here.

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Title
Verification of the Norwegian emission inventory -
Comparing emission intensity values with similar countries

Summary
It is mandatory for the success of the Kyoto protocol and its implementation mechanisms (e.g. emission trading) that the countries report high quality emission data. This mandatory includes routines for quality control as well as verification.

The main goals of this work have been to suggest possible statistical data to use as indicators for comparing emission figures between countries on a general basis and, secondly, to test the method on the Norwegian national emission estimates.

In this report we verify emission estimates by comparing emission intensity values. The emission intensity values are compiled by normalising the emission rates using various statistical data. We have checked the quality of the Norwegian emission estimates reported to UNFCCC by comparing them with the estimates from Sweden, Canada and New Zealand. We have also checked the trend estimates by comparing the emission intensities for both 1990 and 1996.

The method is based on the official emission estimates reported from the countries to UNFCCC and activity data (for example GDP, population, energy statistics or production) from official sources like OECD or UN. For each sector where Norway has reported emissions we have calculated emission intensity values of each pollutant per various type of statistical data, for example emissions per TJ energy. These values are compared with those of the other countries in question with regard to both level and trend. Comparisons are made at different levels of aggregation of the IPCC summary tables. Conclusions have been made on what statistical data is best suited for each emission source. This is based on the analytical soundness of the indicator, data quality and the output values.

4 subject words	
Greenhouse gases	Emisssion intensity values
Verification	Level
	Trend