Sweden's Second National Communication on Climate Change

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1. Foreword and summary

1.1 Foreword

In accordance with Article 12 of the UNFCCC, Sweden has prepared the present report. The Swedish Environmental Protection Agency, the Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Institute for Transport and Communications Analysis have participated in the preparation of the report. The report was adopted by the Swedish Government on 17 April 1997.

In the spring of 1996, while the authorities were working on the background studies for the national report, the Government invited the parities in the Riksdag to deliberations for the purpose of achieving a durable consensus on a long-range energy policy. The deliberations were concluded on the 4th of February 1997 with an agreement between the Social Democrats, the Centre Party and the Left Party on guidelines for a national energy policy.

The energy agreement calls for shutdown of the two nuclear power reactors in Barsebäck, equivalent to 1200 MW. The Government Bill “A Sustainable Energy Supply”[1] states that negotiations shall be commenced with the owner to close one reactor prior to 1 July 1998 and the other reactor prior to 1 July 2001. Since this report was written before the presentation of the aforementioned bill, the proposals made in the bill have not been taken into account in the report.

The premises in the report include the shutdown of one reactor prior to the year 2000. For the calculations of the capacity and production volume of the electricity generation system, we have assumed that the decommissioned reactor corresponds to an average capacity of 835 MW and an annual output of 5 TWh. It is further assumed that the other reactors will be used for their technical life, which is assumed to be 40 years.
Furthermore, all calculations of future emissions are based on the policy instruments that have been in effect since 1996.

The Government decided in December 1996 to propose in Gov. Bill 1996/97:53, “Infrastructure strategy for future transport”, a revised strategy for the long-term infrastructure plans. The proposal was based on the proposal put forth by the parliamentary Transport and Communications Committee and entails a continuation of the previously decided investment in expansion of the railway network. Besides creating a good infrastructure for passenger train transport, the investment programme will also improve conditions for freight train transport. For the road network, the strategy entails a reorientation from big investments in the national trunk roads to increased efforts to improve the existing road network as regards accessibility, environment and traffic safety. The Riksdag passed the Government Bill in March 1997. The new plans for the period 1998 - 2007 will now immediately be prepared by regional and central authorities. However, the forecast that has been used for carbon dioxide emissions from transportation in the national report does not

[1] Gov. Bill 1996/97:84

include the consequences of the Riksdag's decision regarding new investments in roads and railways after 1997.

The analysis shows that the effect of measures adopted during the 1990s will lead to a 23% reduction of carbon dioxide emissions by the year 2000 and a 26% reduction by 2010 compared with a reference scenario without such measures. Nevertheless, the forecast shows that carbon dioxide emissions are projected to increase by about 4% by 2000 and 12% by 2010, compared with the normal year 1990. The aggregate increase[2] by 2010 of carbon dioxide, nitrous oxide and methane is about 11% compared with the normal year 1990. The Government will counteract such an increase in emissions.

The Government therefore intends to call for stricter climate measures both in our national policy and as a result of the coming decisions in Kyoto, at the third Conference of the Parties to the UNFCCC.

The Government has proposed that the carbon dioxide tax on industry be doubled from 1 July 1997, at the same time as certain tax relief is introduced for energy-intensive industry. In February, the European Commission approved the Swedish applications for exemptions from Community law on this point.

New proposals in the area of energy taxation and for the transport sector will also be considered by the Government. A third of the carbon dioxide emissions in Sweden come from the transport sector. It is therefore particularly urgent to find policy instruments which hasten the reduction of fuel consumption by motor vehicles. One point of departure is the EU objective that the fuel consumption for new passenger cars should not exceed 5 litre/100 km as an average within the Union.

The Government also intends to submit proposals for measures to promote sustainable ecological development in the financial spring bill, with proposals for local and national investment programmes.

The local investment programme entails that municipalities or groups of municipalities, possibly also counties, are given an opportunity to propose local investment programmes which foster ecological sustainability in the community. The programmes will be judged and a number of municipalities/regions will be selected. In judging the programmes, importance will be attached to measures which reduce the environmental load, increase efficiency in the use of energy and natural resources, and promote the use of renewable raw materials. The Government estimates a total of SEK 5.4 billion for the period 1998–2000 for this purpose. The programmes for energy transformation are included among the national investment programmes. The Bill "A Sustainable Energy Supply" states that the transformation of the energy system is in line with Sweden's ambition to be a leading country in fostering ecologically sustainable development. The energy agreement entails that the two nuclear power reactors in Barsebäck are to be shut down. Draft legislation concerning the phase-out of nuclear power will be submitted to the Riksdag during 1997. The loss of electricity will be compensated for by more efficient energy use, conversion of plants, conservation of electricity, and input of electricity from other energy sources.

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[2] Counted as carbon dioxide equivalent, based on the IPCC's Greenhouse Warming Potential for a time horizon of 100 years.

The closure of the first reactor will mainly be compensated for by a reduced use of electricity in the district heating system. A precondition for the shutdown of the second reactor is that the loss of electricity production can be compensated for. A specific year when the last nuclear power reactor is to be decommissioned should not be set. This will provide sufficient time for the transformation of the energy system.

The Bill proposes that subsidies be granted for connection of electrically heated buildings to the district heating systems and for conversion from electric heating to heating with fuels. Subsidies for installation of equipment that permits a reduction of the electric power load will be granted to owners of single-family homes with electric heating.

It is further proposed that support be given to investments in wind power plants, small-scale hydropower plants and plants for combined heat and power (CHP) production with biofuels.

The investment support is to be supplemented by support for procurement of new electricity generation technology.

Conservation of energy will be stimulated through information, education, procurement of energy-efficient technology, marking and certification of energy-demanding equipment, and municipal energy counselling.

It is proposed that state initiatives for development of technology for the future energy system be strengthened and concentrated. Energy research is to be given greater resources and a new orientation, with an emphasis on research on the energy system and international cooperation with countries in the Baltic Sea Region in particular. The support to joint research and development of new energy technology by companies and industrial sectors is to be strengthened by allocation of additional funds to the Energy Technology Fund. An energy technology subsidy is to be introduced to support energy technology that needs to be developed by full-scale testing and demonstration, with reduced risk for the companies.

A new energy authority is proposed to be established as of 1 January 1998. The energy authority is to be invested with most state regulatory and oversight functions in the energy field. The authority will further be given the responsibility of implementing most of the transformation measures and coordinating the transformation work. Within the framework of its corporate profit-making form, Vattenfall AB shall allocate resources for the development of new electricity generation technology and thereby contribute to a Swedish electricity supply which is ecologically and economically sustainable.

A strategy is described for reducing the climate impact of the energy sector. Continued measures are proposed for bilateral and multilateral cooperation regarding activities implemented jointly under the Climate Convention. The programme for development of ethanol production based on forest raw material is to be strengthened.

Altogether, these activities will cost SEK 9 billion over a seven-year period.

1.2 Summary of the report

Basic data and national circumstances

Sweden had 8.8 million inhabitants in 1996. The nativity rate in 1995 was 11.7 births per 1,000 inhabitants. The mortality rate was 10.6 deaths per 1,000 inhabitants. Approximately 85% of the population live in urban areas.

Sweden joined the European Union on 1 January 1995.

The total area of Sweden is 450,000 km^2. Compared with other OECD countries, population density is low, on average 19 inhabitants per km^2. However, a large part of the population is concentrated in three major urban areas. Sweden has a long coastline and a very large number of lakes. Transport needs are high due to the low population density and the long distances.

Forest covers 62% of the total land area. The forest is one of Sweden’s most important natural resources. Historically, the forest industry, together with the iron and steel industry, has been the backbone of the Swedish economy.

Energy-intensive industries play a large role in the Swedish economy. As in other industrialized countries, the industrial sector has declined in importance during the last decade. Gross Domestic Product (GDP) per capital was SEK 171,000 in 1994. The average rate of growth of the economy was 1.8% during the period 1975 to 1990. After a deep recession, the Swedish economy has picked up during the last three years. GDP increased by 3% in 1995 and is expected to increase by 1.6% this year. Sweden currently has virtually no inflation. Exports continue to grow strongly, despite a considerable rise in the value of the Swedish currency (the krona) since the summer of 1995. Sweden has large and growing surpluses in foreign trade and barter.

Sweden’s climate is temperate, influenced by the Gulf Stream in the Atlantic Ocean. The annual average temperature is only +1.8°C, ranging from +7°C in the south to -2° in the north. The heating requirement for homes and other premises is considerable during the winter season.

Swedish energy demand has been more or less unchanged at 450 TWh/year during the past 25 years, according to the traditional Swedish way of calculating. With the method used in the EU or OECD, energy demand has increased by 25%. Since the oil crisis in 1973, the Swedish energy system has undergone great change. An expansion of nuclear power has reduced oil consumption considerably. Different programmes for more efficient energy utilization and oil substitution have had significant effects. The fossil fuel share of the total energy supply has fallen from 80% in 1970 to about 50% in 1995. During a normal year, nuclear and hydro power account for more than 90% of the total electricity generated.

Inventory of greenhouse gases

An inventory of greenhouse gas emissions and uptake in sinks has been performed in accordance with the Intergovernmental Panel on Climate Change's (IPCC's) preliminary methodology. We have revised emissiondata since our last submission.

Carbon dioxide accounts for most of the greenhouse gas emissions in Sweden. Carbon dioxide contributes about 80% of the total greenhouse gas emissions calculated as GWP-100 (Global Warming Potential). The transport sector accounts for the largest portion, or 33%, of the total carbon dioxide emissions. Whereas emissions from the energy sector and the manufacturing industry have steadily declined, emissions from the transport sector have increased.

The agricultural sector and refuse landfills are the largest sources of methane emissions in Sweden.

Methodology for calculating emissions of nitrogen oxides is inadequate. Combustion of fuels and emissions from the transport sector are the most important sources.

The Swedish forest constitutes a sink for carbon today. The annual growth of the forest exceeds removals, which means that carbon dioxide is sequestered (accumulated) in the biomass. The net accumulation of carbon dioxide in Swedish forests has been estimated at 30 million tonnes/year. This corresponds to about half of the annual emissions of carbon dioxide from fossil sources.

However, most of the forest increment is anthropogenic, due to forest management practices which increase the stock of standing timber at a greater rate than would be the case in a natural forest. If silviculture were to cease, the timber volume would eventually return to its natural level.

Summary report for national greenhouse gas inventories

1990 Mg

	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC
TOTAL NATIONAL EMISSIONS	55445*	34368	324	9.2	336	1204	526
1 All Energy	51382		NO	6.3	313	1204	392
A Fuel combustion	51329		39	6.3	313	1204	366
1. Energy & Transformation Industries	8849		1	1.1	16	6	2
2. Industry	13051		5	2.1	23	28	6
3.Transport	18650		23	2.6	261	1046	216
4. Small Combustion	10672		10	0.5	13	123	142
5. Other	107		NE	NE	NE	NE	NE
6. Traditional biomass Burned for Energy	-		[1]	[1]	[1]	[1]	[1]
B Fugitive Emission from Fuels	53		NE	-	-	-	26
1. Solid fuels	NO		NO	-	-	-	NO
2. Oil and Natural Gas	53		NE	-	-	-	26
2 Industrial Processes	3787		NE	2.7	23	6	42
3 Solvent and Other Product Use	276		NO	-	-	-	92
4 Agriculture	NO		200	0.2	-	-	NE
5 Land Use Change &Forestry		34368	-	-	-	-	-
6 Waste	NO		85	NE	-	-	-
7 Other	-		-	-	-	-	-
International aviation and shipping transport	4207	-	0.1	NE	52	6.2	1.5

[1] Emissions from biomass are included in the different categories NO= does not occur NE= not estimated - = not applicable

* Normal year corrected value 57 620

1995 Mg

	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC
TOTAL NATIONAL EMISSIONS	58108*	NE	296	9.3	308	1089	457
1 All Energy	53401		NE	6.8	280	1040	337
A Fuel combustion	53385		38	6.8	280	1040	322
1. Energy & Transformation Industries	10493		2	1.1	12	11	5
2. Industry	13541		6	2.3	20	32	6
3.Transport	19341		20	2.9	239	873	179
4. Small Combustion	9903		10	0.5	9	124	132
5. Other	107		NE	NE	NE	NE	NE
6. Traditional biomass Burned for Energy	-		[1]	[1]	[1]	[1]	[1]
B Fugitive Emission from Fuels	16		NE	-	-	-	15
1. Solid fuels	NO		NO	-	-	-	NO
2. Oil and Natural Gas	16		NE	-	-	-	15
2 Industrial Processes	4458		NE	2.3	28	49	36
3 Solvent and Other Product Use	249		NO	-	-	-	83
4 Agriculture	NO		197	0.2	-	-	NE
5 Land Use Change &Forestry		NE	-	-	-	-	-
6 Waste	NO		61	NE	-	-	-
7 Other	-		-	-	-	-	-
International aviation and shipping transport	5367	-	0.1	NE	54	6.0	1.5

[1] Emissions from biomass are included in the different categories NO= does not occur NE= not estimated - = not applicable

* Normal year corrected value 58470

Measures to limit emissions of greenhouse gases

General policy

Sweden has implemented programmes and measures in response to climate change since 1988, when the issue was discussed in the Riksdag (parliament) for the first time. A more comprehensive programme was adopted by the Riksdag in May 1993, when the Bill regarding "Strategies against climate change" was passed. The goal established by the Riksdag is that emissions of carbon dioxide from fossil sources in the year 2000 shall have stabilized at the 1990 level and shall decline after that, in compliance with the UN Framework Convention on Climate Change (UNFCCC). Furthermore, emissions of methane from waste disposal shall decrease by 30% between 1990 and 2000.

The main strategy to achieve the carbon dioxide goal is to limit the need for fossil fuels and replace them with renewable energy sources, along with better management and more efficient use of energy. Measures to improve efficiency include technology procurement and development of electricity-efficient products, processes and system in homes, on other premises and in industry. Measures to increase the use of renewable energy are being focused primarily on increasing the use of biofuel.

Economic instruments were introduced in Swedish environmental policy in the mid-1970s, and since then their use has expanded and been progressively refined. In response to the threat of climate change, the Government has devoted great attention to carbon taxes and other forms of energy taxes as a way of reducing carbon dioxide emissions.

In contrast to other countries, Sweden has very few options for reducing greenhouse gases through changes in the electricity sector. Less than five percent of electricity generation is based on fossil fuels today. The marginal cost of a further reduction of carbon dioxide emissions in Sweden is high, compared to other OECD countries. As a part of our national programme, we have taken the initiative in the Baltic States and Eastern Europe in the funding of programmes having to do with renewable energy, energy saving and certain supporting measures. The option of joint implementation of similar environmental activities with other countries is of great importance for Sweden.

Measures adopted in the energy and transport sectors

Within these areas taxes and economic incentives have been the main measures. As from January 1991, a carbon dioxide tax is levied on fossil fuels. The introduction of this tax coincided with a major tax reform aimed at reducing taxes on income and capital and increasing taxes on the environment. Value-added tax (VAT) is levied since then on all energy forms (fuels, heat, electricity). The carbon dioxide tax was initially set at SEK 250 per tonnes of carbon dioxide. The existing energy taxes were reduced by 50% at the same time.

The carbon dioxide tax and the energy tax act as consumption taxes on fossil fuels (oil, coal and natural gas) with the exception of fuels for electricity generation. In order to adjust the Swedish taxes in areas subject to international competition the taxation system was changed

1993. The general carbon dioxide tax rate was raised from SEK 250 to 320 per tonne of carbon dioxide. A lower tax rate of SEK 80 per tonne was introduced for the manufacturing industry, which was simultaneously exempted from energy taxes. A system of exemptions, mainly for energy-intensive industry, existed up until 1993, under which individual companies could apply for tax abatements. Under that ordinance, the tax burden on companies was limited to a certain percentage of the value of the goods produced. A similar system, which applies to a smaller number of companies, and only for coal and natural gas, is still in force.

A new law entered into force as of 1 January 1995, the “Energy Tax Act”. It changes the taxation to harmonize with the EU’s mineral oil directive.

From 1 January 1996, the carbon dioxide tax was raised to SEK 360 per tonne of carbon dioxide. As of 1 September 1996, the energy tax on all fuels and electricity, plus the special tax on nuclear power, were raised. The energy tax on the fossil fuels oil, coal, natural gas and LP gas was raised by about 11%. The increase for petrol and diesel oil was about 3%, and for electricity the increase varied between 15 and 35%, depending on customer category.

The Riksdag has passed several programmes in order to promote and stimulate the introduction of renewable energy sources and increased efficiency in energy use. Among them is a programme for energy conservation and promotion of biofuels, wind power and solar energy. NUTEK (the National Board for Industrial and Technical Development) is in charge of these programmes, which were launched in 1991.

Energy programmes, SEK million

	Budget	Programme period
Investment support		
CHP, bio	1,000	1991-1996
Wind power	340	1991-1996
Solar power	138	1991-1996
District heating	150	1993-1996
Development and demonstration	approx. 72 per year	1988-1991
Energy Technology Fund (incl. transportation)[1)]	approx. 170-200 per year	1991-1996
	approx. 72 per year	1996-1997
FABEL - electricity from biofuels	625	1992-1997
Ethanol from cellulose raw materials		
More efficient use of energy	1,000	1991-1998

1) The Swedish Transport and Communications Research Board’s investment for demonstration in fleets for ethanol and biogas is included in the Energy Technology Fund.

Two strategies have so far been adopted to limit emissions from the transport sector: Higher taxation of petrol, and research and development work. During the past four years, two broad R&D programmes have been initiated: one concerns the use of alternative fuels, and the other concerns hybrid and electrical vehicles.

Measures adopted in forestry and agriculture

Many measures that have been adopted in the forestry since 1990 affect the carbon balance. Several different measures are aimed at switching to sustainable silviculture practices and extending the life of forest products, for example by reducing the size of clear-cut areas, reducing pre-regeneration cleaning and introducing gentler soil scarification methods.

As yet, no measures have been taken within the agricultural sector for the express purposes of reducing the production of greenhouse gases. Some of the measures that have been adopted for other purposes have had an effect on the greenhouse gases. One example of is measures against nitrogen leaching. With today's knowledge it is difficult to quantify the effects of the measures on emissions on methane and nitrous oxides.

Within the agriculture there has been an increase in cultivation of energy crops the recent years. Cultivation of Salix lower the amount of carbon dioxide in the atmosphere and reduces the use of fossil fuels. Salix also increases soil carbon content, which can be seen as a long term increase of the sink for carbon dioxide. Salix is grown in approximately 16 000 ha in Sweden today. An increased use of energy crops is also a part of the Swedish energy policy.

Forecasts and effects of measures

Assumptions for forecast emissions 1995-2010

The premises for the forecast consist of projections of Sweden's future economic development, certain assumptions concerning developments on the international energy markets and an analysis of the future trend in energy supply and energy use.

In the calculations we assume that the gross domestic product, GDP, will grow by 1.9% per annum during the period 1995-2010. Industrial production is assumed to grow by 2.2% annually. Private consumption is assumed to grow by an average of 2.2% per annum. We further assume that the international prices of fuel and electricity will rise in real terms during the period. We assume that today's taxes and charges will apply during the forecast period.

Total energy use

Total energy use is projected to increase during the period 1995–2010. It was 469 TWh in 1995. It is expected to be 487 TWh in 2000, 500 TWh in 2005 and 515 TWh in 2010. This growth will not be evenly distributed over the period. Energy use is expected to grow slightly faster at the beginning and end of the period. Altogether it is primarily energy use in industry and transportation that are expected to increase the most.

Total electricity use is projected to increase by about 0.4% per annum. It amounted to just over 141 TWh in 1995. It is expected to amount to just over 145 TWh in 2000, just under 148 TWh in 2005 and just over 152 TWh in 2010.

ASSUMPTIONS IN THE ENERGY FORECAST

	1995	**2010**
Crude oil price USD/barrel	17	23
GDP growth	1.9% per annum	
Population growth	0.3% per annum	
Electricity price, household	SEK 860/MWh	SEK 970/MWh
Electricity price, heavy industry	SEK 240/MWh	SEK 300/MWh
Specific energy use within industry	0.158 kWh/SEK	0.128 kWh/SEK
Specific energy use for passenger cars	-0.7% per annum	
Specific energy use for trucks	-0.25% per annum	
Industrial production SEKbn (1991 prices)	925	1291
Number of dwelling units	3,955,000	4,227,000

Future energy use in industry

Energy use in industry is expected increase by 0.8% per annum, from 146 TWh in 1995 to 154 TWh in 2000 and to 165 TWh in 2010.

Electricity use in industry is expected to increase by about 0.9% per annum. It was just under 52 TWh in 1995. It is expected to be 54 TWh in 2000 and just under 59 TWh in 2010. Industrial production is expected to increase by about 40% during the period. Specific energy use, i.e. energy use in relation to the value of production, is projected to decline by 1.4% per annum. Specific electricity use, i.e. electricity use in relation to production value, is projected to decline by 1.3% per annum. According to the calculations, an expected structural transformation towards less energy-intensive sectors and products will dampen the increase of energy use attributable to production growth.

Carbon dioxide emissions from combustion within industry amounted to about 13.1 million tonnes in 1990. They are expected to increase by about 4% by the year 2000 and by about 7% by 2010. Carbon dioxide emissions from industrial processes amounted to about 3.8 million tonnes in 1990. They are expected to increase by about 20% by 2000 and by about 40% by 2010.

Residential, commercial and institutional premises

Energy use in the residential, commercial and institutional sector is expected to remain more or less constant during the period. It was about 159 TWh (temperature-corrected) per annum in 1995, and is expected to be between 160 and 161 TWh during the forecast period. Energy use is expected to decrease slightly between 2005 and 2010. Electricity use is projected to increase by about 0.3% per annum. It was about 72 TWh in 1995, and is expected to be just under 74 TWh in 2000 and just over 75 TWh in 2010.

There will be a changeover to other energy carriers. Oil use within the sector is expected to decline by about 5 TWh, while district heat use is expected to increase by about 3 TWh during the period 1995–2010. Besides conversion to electricity, the reduced oil use is due to some conversion to district heating as well.

As a consequence of energy efficiency improvements, fuel switching and connection to district heating, emissions are expected to decrease sharply in this sector. Emissions amounted to 11.8 million tonnes (normal-year-corrected) in 1990 and are expected to decrease by more than 20% by the turn of the century and nearly 30% by 2010.

Transportation

In the transport sector, transport activity is projected to increase by an average of 1.6% per annum between 1990 and 2010. The largest absolute portion of the increase is passenger car traffic, while air traffic represents the largest relative increase. Domestic energy use for transportation is expected to increase by about 0.9% per annum. It was 87 TWh in 1995, and is expected to reach 90 TWh in 2000 and 100 TWh in 2010. The rate of increase is thus expected to be slower than during the period 1970–1995, when energy use grew at an annual rate of 1.8%. This is due in part to an assumed shift in industrial structure towards sectors with less heavy goods transport, efficiency improvements in fuel consumption and a slower growth of car ownership.

Despite assumptions of efficiency improvements, emissions from domestic transportation are expected to increase relatively much. They amounted to about 18.8 million tonnes in 1990 and are expected to increase by about 6% by 2000 and nearly 20% by 2010.

Electricity and district heat production

District heating is expected to increase during the period 1995–2010. It was just over 48 TWh in 1995 and it expected to amount to 51 TWh in 2000 and 54 TWh in 2010. Use of electricity for district heat production is expected to decrease. The total input of fuels in district heat production is expected to increase. Biofuels, peat etc. are the fuel categories expected to increase the most.

During a year with normal precipitation, hydropower generates 63.8 TWh of electricity. Production can vary considerably, however. In a dry year it can be 10–15 TWh below normal-year production, and in a wet year about 10 TWh above. In the forecast, normal-year production is projected to be 64 TWh in 2000 and 2005 as a result of efficiency improvements and minor capacity expansions. In 2010, normal-year production is assumed to amount to 66 TWh as a result of further efficiency improvements and capacity expansions.

The annual production capacity of nuclear power is about 72 TWh today. In the forecast it is assumed that the production capacity of nuclear power will be reduced by the capacity of one average reactor from the year 2000. This is equivalent to a reduction of power output by 835 MW or a reduction of production capacity by 5 TWh. It is therefore assumed in the forecast that the production capacity of nuclear power amounts to 67 TWh from the year 2000.

CHP (combined heat and power) in industry produced just over 4 TWh of electrical energy in 1995. During the period up to 2010, production is expected to amount to just over 4 TWh per annum. CHP in the district heating networks produced just under 5 TWh in 1995. Due to greater utilization of existing plants and construction of new ones, it is projected that the CHP-plants will produce more than 8 TWh in 2000 and 2005, and more than 9 TWh in 2010.

Wind power produced just over 0.1 TWh in 1995. As a result of expansion, production is expected to be 0.4 TWh in 2000, 0.5 TWh in 2005 and 1.5 TWh in 2010.

It is assumed that oil condensing plants will contribute around 1 TWh per annum to Sweden's electricity supply during the forecast period.

Aggregate emissions in the electricity and district heat production sector are expected to increase faster than in any other sector. Carbon dioxide emissions in this sector amounted to about 9.8 million tonnes (normal-year-corrected) in 1990 and are expected to increase by more than 25% by 2000 and about 40% by 2010. With the measures announced by the Government, the emissions increase from this sector will be dampened.

Total emissions of greenhouse gases

On the basis of normal-year corrected values, emissions of carbon dioxide are projected to increase by just over 12% by 2010, counting from the 1990 level. The equivalent increase by the turn of the century is expected to be 4% with 1996 policy instruments. Emissions of methane are projected to decrease by 20%, and emissions of nitrous oxide are projected to increase by 30% by 2010. Emissions of the indirect greenhouse gases nitrogen oxides, carbon monoxide and hydrocarbons are projected to decline by 40-65%, while emissions of nitrous oxides and fluorocarbons (HFCs and FCs) are assumed to increase. Altogether, emissions of all greenhouse gases – calculated according to the GWP index for 100 years – are projected to increase by 5% by the turn of the century and by 11% by 2010.

Carbon dioxide emissions and sinks (removals), million tonnes 1990-2010
Normal-year-corrected emissions values

	1990	1995	2000	2005	2010
Fuel combustion Energy and Transformation Industries	9.8	10.6	12.5	12.9	13.8
Fuel combustion Industry	13.1	13.5	13.6	13.7	14.0
Fuel combustion Residential, commercial and institutional sector	11.8	10.1	9.2	9.0	8.6
Domestic transportation	18.8	19.4	20.0	21.3	22.3
Fugitive fuel emissions	0.05	0.02	0.02	0.02	0.02
Industrial processes	3.8	4.5	4.6	5.0	5.4
Solvents	0.3	0.2	0.2	0.2	0.2
Agriculture	--	--	--	--	--
Waste disposal	--	--	--	--	--
Total emissions	**57.6**[1]	**58.5**[2]	**60.1**	**62.1**	**64.3**
Removals in forest (sinks)	34	--[3]	29	26	22
International air and shipping transportation	4.2	5.4	5.9	6.3	6.8
CO_2-Equivalents (GWP 100 year)	68.7	69.5	71.9	74.0	76.4

1 Actual value 55.4   2 Actual value 58.1   3 Not Estimated

Effects of the measures adopted

It is difficult to predict the effects of measures that have been taken to counteract climate change. All projections are associated with uncertainty and should be interpreted with great caution.

To get an idea of how the policy instruments introduced after 1 January 1990 have influenced carbon dioxide emissions, calculations have been carried out with the computer model MARKAL-MACRO. The policy instruments that were in effect on 1 January 1990 have been compared with those that were in effect on 1 September 1996. The calculations suggest that the latter instruments lead to an energy system that results in both a lower level and a slower rate of increase of carbon dioxide emissions.

The difference in the change in carbon dioxide emissions between the 1990 and 1996 policy instruments is shown in the table below.

Calculation of difference in carbon dioxide emissions between 1996 and 1990 policy instruments, broken down by sector and policy instruments, million tonnes per annum

	2000	2005	2010
Sector			
Energy and Transformation Industries	-7.2	-8.2	-10.8
Industry	1.2	2.1	2.3
Residential. commercial, institutional	-7.8	-11.3	-11.0
Transportation	-3.7	-4.1	-4.2
Total	-17.5	-21.5	-23.7
Policy instruments			
Investment support	-0.7	-0.7	-0.7
Programme for more efficient energy use[1)]	-0.2	-0.2	-0.2
Carbon dioxide and energy tax, transportation	-3.4	-3.9	-4.3
Industry- and energy sectors[2)]	-13.2	-16.7	-18.5
Total	-17.5	-21.5	-23.7

1) The expected effect of the programme within the residential sector.
2) Including the effect of VAT

According to the model it is primarily the difference in the fuel composition in district heating and CHP plants that explains the difference in carbon dioxide emissions. With the 1996 policy instruments, much more biofuel and less coal and oil are used compared with the 1990 instruments.

Also according to the model, the difference in carbon dioxide emissions in the residential, commercial and institutional sector is explained by the fact that the 1996 policy instruments lead to a faster and larger-scale implementation of conservation measures within space heating and other electricity use than the 1990 instruments. Energy conservation is achieved in part by means of technical measures such as supplementary insulation and more efficient household appliances, and in part by means of changed priorities such as a lower indoor temperature and fewer heated rooms.

The difference in carbon dioxide emissions in the transport sector is explained by the fact that the 1996 policy instruments result in higher fuel prices than the 1990 instruments and thereby a lower demand for transport.

The model calculations primarily provide an idea of the influence of the policy instruments on carbon dioxide emissions from the different sectors. The calculations also provide guidance when it comes to determining the influence of individual instruments on carbon dioxide emissions. In combination with supplementary estimates of the influence of the investment supports on carbon dioxide emissions, an overall picture of the effects of the policy instrument packages and the relative effectiveness of the different instruments is obtained. The table shows that for all forecast years, more than 90% of the difference in carbon dioxide emissions can be attributed to the energy and environmental taxes plus VAT on energy. It is important to note that the lower taxation of industry's energy use leads to a slight increase in emissions from this sector. This increase is, however, compensated for by greater reductions in other sectors.

Evaluation of vulnerability to climate change

In our previous report to the Climate Convention, it was noted that subarctic ecosystems such as those we have in Sweden are sensitive due to long generation times, slow growth and irregular reproduction. Climate changes are expected to affect the mountain regions to start with. The adaptability of these ecosystems is limited. The Baltic Sea is another vulnerable area. It could be affected in three different ways: through sea level rise, through warmer water temperatures and finally through reduced salinity. Climate models predict more precipitation in the wintertime, leading to an increase in the runoff of surface water to the Baltic Sea. In this case, the salinity of the Baltic could fall. If the flow of oxygen-rich and high-salinity water from the Atlantic into the Baltic were affected, this could have serious consequences.

Increasing air temperature and precipitation could lead to faster growth of forests. However, some species are adapted to cold winters, and a higher temperature might also increase the risk of damage by insects and disease. Spruce forests are assumed to be more vulnerable to rapid climate changes. The forest's long rotation time makes it complicated for forest owners to adapt their cultivation methods to all changes in conditions.

In this report we have analyzed the impact of climate change on technical systems.

The sensitivity analysis of technical systems indicates that corrosion will increase both in a milder and damper climate, and in a milder climate with unchanged precipitation. Corrosion is strongly linked to acid deposition, which means that the stress on our technical systems will be great for a long time to come.

Evaporation increases in a warmer climate, which can affect not only water available for irrigation, but also drinking water quality.

With more occasions with extreme precipitation, the risk of flooding may increase. The settlements along the mayor rivers in the north of Sweden are in the risk zones. A work to investigate this risk has started. This mapping will eventually serve as a basis for recommendations in local in connection with physical planning. The risk also leads to a greater risk of ground collapse and landslides, and the design values for dams may have to be changed.

In a warmer climate, periods with heavy wet snow may become more frequent. This increases the risk of power failure, which can have far-reaching consequences for society. A greater number of salt storms, especially on the west coast but also on the northeast coast where salt is carried by the winds in over the mountains, may also cause power failures.

Sea level rise will be compensated for along the coast of the Gulf of Bothnia by postglacial land uplift, while the southern Baltic coast and the west coast may suffer erosion problems and transport problems in certain ports. In lowlying settlements in southern Sweden sea level rise can affect the sewage treatment system.

The overall result of the sensitivity analysis for technical systems and the possible effects of a milder climate show that no great changes will occur in a short perspective that might entail a greater risk to man. In a longer perspective, however, it is important to begin now to build up the emergency preparedness that may be required to deal with the effects of a changed climate in the future.

Financial support and contribution to the financial mechanism

Financial support through bilateral initiatives

Sweden's foreign aid policy goals include prudent management of natural resources and consideration for the environment. With these principles as a point of departure, Swedish International Development Cooperation Agency (SIDA) pursues environmental work along two main lines. One is to integrate environmental aspects and environmental thinking in all of its activities wherever possible. The second main line is a concentration on strategically important areas. SIDA also has a special environmental appropriation which is supposed to be used primarily for method development, trials and pilot programmes, and for strategically important activities for which country framework funds cannot be used. The appropriation for special environmental initiatives for the years 1995/96 was over SEK 300 million and for 1997 over SEK 200 million. In addition, SIDA also has a multilateral environmental appropriation of SEK 25 million for certain activities within the framework of the UNFCCC.

Contribution to the financial mechanism

Sweden's contribution to the financial mechanism provided for in the UNFCCC, the Global Environmental Facility (GEF), is paid from the multilateral appropriation. Sweden has contributed a total of about SEK 650 million to the facility during the pilot phase and through 1997. Negotiations are currently being held concerning replenishment of the facility, and Sweden intends to continue to give strong support to GEF.

Climate-related research in Sweden

Scientific research on global climate change is being coordinated through two international programmes: the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP). The IGBP is mainly concerned with biological and chemical processes, while the WCRP focuses on physical processes related to climate change. In Sweden the research is coordinated by the Swedish National Committee for the IGBP/WCRP.

Up until 1995, funding was provided mainly via the Natural Science Research Council (NFR), the Swedish Environmental Protection Agency (NV), the Swedish Council for Forestry and Agricultural Research (SJFR) and the National Board for Industrial and Technical Development (NUTEK). In recent years, other funding sources have come into play, such as the EU and the Foundation for Strategic Environmental Research (MISTRA). However, the national budget crisis has necessitated a cut in the appropriation to the Swedish Environmental Protection Agency, which will mean one less funding agency in the future.

MISTRA was started with money from the wage-earner funds in 1994. Its main purpose is to support response option research, but both basic research and effect research are included in its programme.
Four of the MISTRA programmes are climate-related:

1) Development of solar cells (MSEK 35), until 2000.
2) Batteries and Fuel Cells for a Better Environment (MSEK 20), until 2000.
3) Remote Sensing for the Environment (RESE) (MSEK 45), until 1999.
4) SWECLIM, Swedish Regional Climate Modelling (MSEK 33), until 1999.

Technical research surrounding climate change is mainly concerned with various practical measures. The energy research programme and the programme for transport research are concentrated on renewable energy sources. A large portion of the programme has to do with different measures for improving efficiency of energy use, but also reducing oil dependence, reducing emissions of acidifying and toxic substances, etc. The transport programme also includes development and demonstration of alternative fuels and electric-powered vehicles.

Education and awareness-raising of the public

In 1993, the Riksdag (Swedish parliament) voted to allocate funds for climate-related information and education. The purpose was to inform the public concerning the effects of climate change, what must be done to limit the risks, and the importance of individual behaviour. In 1994, within the framework of this assignment, the Swedish Environmental Protection Agency published a study kit on the risk of climate change with facts about climate change and with linkages to lifestyle questions. The material was mainly aimed at teachers and students in grades 6-9 of compulsory school and in upper-secondary school, but also at adult education associations and others who worked with education. The study kit was called "Imagine the weather in 25 years…" and contained a video, fact sheets and rules for a simulation game concerning negotiations for a protocol to the UNFCCC.

Within the framework of the local Agenda 21 work, several municipalities have prepared "climate plans" describing strategies for emissions reductions. An example is Växjö Municipality in southern Sweden, where a decision was made in 1996 to gradually phase out fossil fuels from the municipality's energy and heat production.

2. Introduction

The United Nations Framework Convention on Climate Change was signed in Rio de Janeiro in June 1992. The convention entered into force on the 21st of September 1994. As of February 1997, approximately 90 nations had ratified the convention.

The UN Framework Convention on Climate Change (FCCC) comprises the basis for continued international cooperation within the field of climate change. The objective of the Convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The Parties to the Convention should take precautionary measures to anticipate, prevent or minimize the causes of climate change. They should adopt national programmes containing measures to mitigate climate change in all relevant socio-economic contexts covering all greenhouse gases and cooperate to facilitate adaptation to a changed climate. The developed countries have set as their objective to have stabilized carbon dioxide emissions at 1990 levels by the end of this decade. The OECD states shall provide new and additional financial resources needed in order for the developing countries to meet their commitments.

According to Article 12 of the UN Framework Convention on Climate Change, the developed countries shall submit a report (”communication”) containing a detailed account of the Policies and measures they have adopted to mitigate the effects of a climate change. The report shall also include an emissions inventory of greenhouse gases. The report shall be submitted to the Conventions secretariat.

In accordance with Article 12 of the Climate Convention, Sweden has prepared the present report. The Swedish Environmental Protection Agency, the Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Institute for Transport and Communications Analysis have participated in the preparation of the report.

3. National data

3.1 Introduction

This section contains a description of Swedish conditions within several sectors of society. Some of these facts may also shed light on what factors may be of importance for the levels of emission and sequestration of climate gases. The greenhouse gas that is of most importance for the climate is carbon dioxide. Anthropogenic emissions in 1990 amounted to 55.4 million tonnes (tonne = metric ton = 1,000 kg). The forecast, which is described in chapter 6.6, suggests an increase of 12% in Swedish emissions by 2010, Table 6.21.

There are large land and water areas in Sweden that are heavily affected by anthropogenic emissions of greenhouse gases in other ways than through their greenhouse effect. One of the most serious problems is acidification of soil and bodies of water, which is caused by, among other things, NO_x emissions originating in both Sweden and other countries. Nitrogen emissions also affect the concentrations of nitrogen accessible for eutrophication of the ecosystems both in inland waters and in the seas off the east (Baltic Sea) and west (Skagerrak and Kattegat) coasts of Sweden.

Sweden joined the European Union on the 1st of January 1995.

3.2 Retrospect

Among the greenhouse gases, carbon dioxide has received most attention to date. The reason is that emissions of carbon dioxide have been increasing ever since the start of industrialization in the 18th century. The rate of increase in these emissions accelerated after the Second World War. Most of today’s carbon dioxide emissions, 80%, derive from combustion of fossil fuels.

The global net flux of carbon dioxide to the atmosphere is also influenced by the cultivation methods practised within agriculture and forestry. In previous centuries, it was above all in the temperate regions of the world that the forested areas were shrinking, contributing to the increase of carbon dioxide concentrations in the atmosphere. Nowadays it is the deforestation of the tropical rainforests that is of greatest importance.

The use of fossil fuels in Sweden started to increase at the end of the 19th century as industrialization progressed. From a level of about 10 million tonnes per year in 1900, CO_2 emissions increased to about 100 million tonnes per year by the end of the 1970s. Since then a decrease in fossil fuel usage has taken place. It can also be noted that the rising trend was temporarily interrupted during the period of the two world wars, when the use of fossil fuels declined markedly.

Carbon dioxide emissions declined in Sweden between 1980 and 1990 from about 82 to about 55 million tonnes per year. This reduction was made possible by a shift in energy consumption from fossil fuels to other energy sources. Fuel oil has been replaced by nuclear power, and to a smaller extent by biofuels and gas. Some of the decline can also be attributed to energy-saving measures. Motor vehicle emissions increased sharply during the same ten-year period.

Sweden imposed a tax on emissions of carbon dioxide in 1991. It takes the form of a fuel tax on fossil fuels. The tax is intended to reduce the economic advantage which fossil fuels enjoy in relation to renewable fuels.

In the case of other climate gases that are not covered by the Montreal Protocol, it is mainly other reasons than climate change that have motivated efforts to reduce emissions. One example is the measures taken to mitigate both occupational hygiene and environmental problems associated with the use of solvent-based paints in industry. These measures have led to reduced emissions of VOCs (volatile organic compounds).

3.3 Geography and climate

Sweden has a temperate climate, due to the fact that the Gulf Stream in the Atlantic Ocean carries huge quantities of warm water on its way north from the Gulf of Mexico. The surface area of the country is 450,000 km². Its shape is long and narrow, stretching 1,572 kilometres north to south. The northernmost part lies north of the Arctic Circle, which means that, in spite of the temperate climate, winters in the northern part are severely cold with large heating requirements for housing and industry as a consequence.

The mean temperatures in southern, central and northern Sweden during the period 1961-1990 were 7.2°C (Sturup), 6.6°C (Stockholm) and -1.6°C (Kiruna), respectively. The annual mean precipitation figures at the same locations during the same period were 677, 539 and 488 mm, respectively. The southwestern part of the country has annual precipitations in excess of 1,000 mm.

The vegetational zones vary from hardwood (broad-leaved) forests in the south to tundra in the north. A vast boreal belt of softwood (coniferous) forest covers most of central Sweden. The land boundary in the west with Norway (1,619 km) runs through a mountain range. There is also a land boundary with Finland (586 km) in the northeast. In the east and south the country borders on the Baltic Sea and in the southwest on the Sound (Öresund) and the Kattegat. Sweden is rich in lakes with some 29,400 km² of lakes and watercourses. The country has several large archipelago areas with tens of thousands of islands.

Administratively Sweden is divided into 23 regions, called counties, and 288 municipalities.

3.4 Demographics

The population of Sweden was 8.84 million inhabitants as of 31 December 1996. The rate of increase was low up to about 1820, when the population was 1.4 million. With the onset of the Industrial Age, the population increased more rapidly. In 1995, the birth rate was 11.7 persons born per 1,000 inhabitants, while the death rate was 10.6 deaths per 1,000 inhabitants per year.

The population is concentrated in the central and southern parts of the country. Most of the people (85%) live in urban areas. Stockholm is the largest metropolitan area. Greater Stockholm, including its suburbs, is home to about 1.6 million people. Only three cities – Stockholm, Göteborg and Malmö – have a population in excess of 200,000 people. The population density in the two northernmost counties is very low, 3 and 5 inhabitants per km², respectively. The average population density in the country is 19 inhabitants per km², which makes Sweden as a whole a sparsely populated country.

3.5 Economy

The Swedish economy is open and the country is highly dependent on foreign trade. The current economic situation can be illustrated by a few key figures from 1994:

Gross domestic product per capita (current SEK):	171,500
National debt per capita (SEK):	155,700
Export share of GDP:	31.1%
Manufacturing share of GDP:	19.4%
Number of cars per capita:	0.41

In 1994, exports of goods from Sweden accounted for 78% of total export revenues. Half of the country's exports go to the EU region. Approximately 15% of the exports of goods go to Norway and Denmark. Compared with other industrial countries, basic industries account for a relatively large share of total exports.

GDP growth averaged 1.8% per year during the period 1975-1990. If an index of 100 is assigned to the year 1985, the GDP has increased from 75.6 in 1970 to 113.2 in 1992.

Different industrial sectors' shares of GDP (1994) are:

Chemical industry	2.5%
Iron and steel industry	0.9%
Engineering industry	8.7%
Pulp and paper industry	3.1%
Construction industry	5.1%

After a deep recession, the Swedish economy has picked up during the last three years. GDP increased by 3% in 1995 and is expected to increase by 1.6% this year. Sweden currently has virtually no inflation. Exports continue to grow strongly, despite a considerable rise in the value of the krona since the summer of 1995. Sweden has large and growing surpluses in foreign trade and barter.

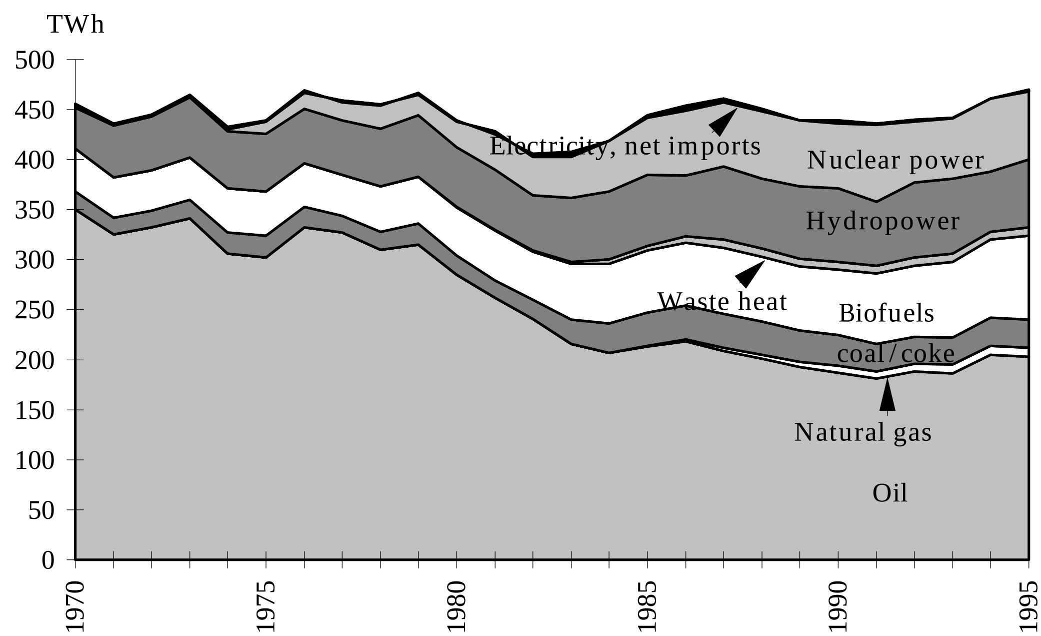
Unemployment, however, is still very high by Swedish standards at 13%.

In 1993, Sweden has a budget deficit in its public finances equivalent to 12.3% of GDP. The deficit this year is expected to amount to 4.0% of GDP. Forecasts suggest that the deficit will be eliminated entirely by 1998. The improvement in the country's public finances has contributed to lower interest rate levels.

3.6 Energy structure

The total energy supply has remained at an even level over the past 25 years at around 450 TWh. During the first half of the 1980s, however, the energy supply was significantly lower, with a record low of 407 TWh. The total supply in 1990 amounted to 437 TWh. At the same time as the volume of the supply has been virtually constant, the composition of energy sources has changed considerably. The oil portion in particular has declined sharply, from 77% in 1970 to 43% in 1995.

Figure 3.1 Sweden's energy supply 1970-1995, TWh



Note: In international contexts, nuclear-generated electricity is often converted to the equivalent heat generated by the reactors. Sweden will gradually implement this model.
Source: Energy situation 1996, NUTEK

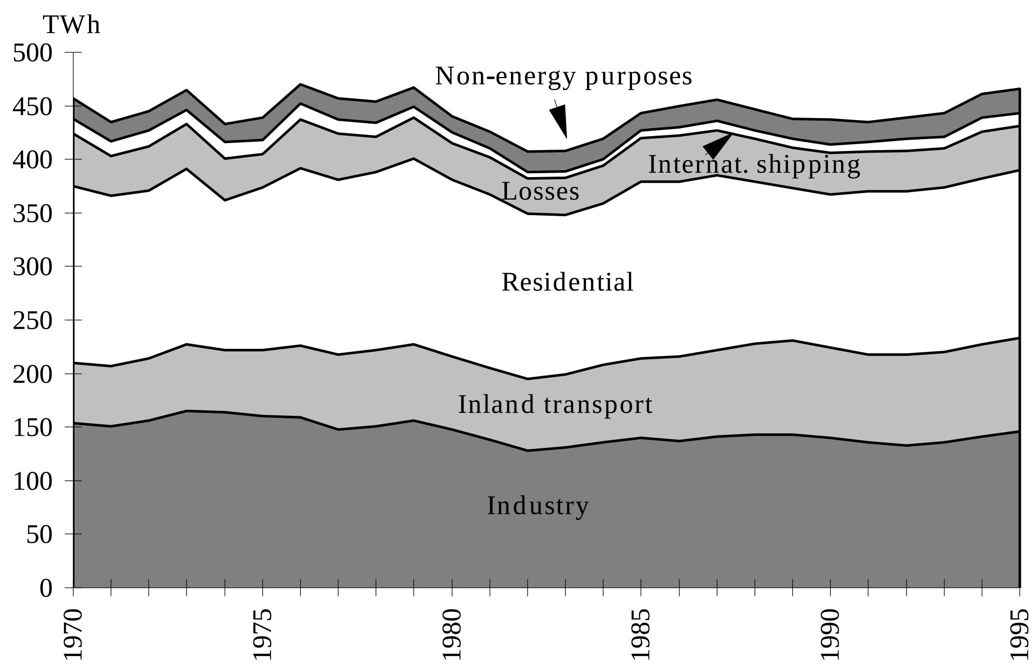
Electricity production more than doubled during the period 1970-1995. The composition of energy sources has also undergone a great change, and production today is based almost exclusively on hydropower and nuclear power. More than 93% of Sweden's electricity production in 1995 was based on hydro or nuclear power, and electricity's share of the total supply was more than 30%, to be compared with 13% in 1970. The use of biofuels and peat has also increased at the cost of petroleum products, from 9% of the total supply in 1970 to 18% in 1995.

Breakdown between the different energy carriers in 1990 and 1995[3]:

oil	187 TWh	203 TWh
coal	31 TWh	28 TWh
natural gas	7 TWh	9 TWh
hydropower	73 TWh	68 TWh
nuclear power	68 TWh	70 TWh
biofuels, peat, etc.	65 TWh	84 TWh
waste heat etc.	8 TWh	8 TWh
net imports of electricity	- 3 TWh	- 2 TWh
Total	437 TWh	468 TWh

Total energy use has declined in industry and in the residential sector, while it has increased in the transport sector. Certain shifts have occurred in proportions between energy sources and sectors. The use of oil as an energy carrier has declined in industry and the residential sector but increased in the transport sector. Electricity use has increased considerably in industry and the residential sector, less so in the transport sector. Electricity use increased by an average of 4.9% per annum during the period 1970-1995, while oil use declined by 1.6% per annum during the same period.

Figure 3.2 Sweden’s energy use 1970-1995, TWh



Source: Energy situation 1996, NUTEK

[3] Energy situation in figures 1996, NUTEK

Biofuels, peat etc.[4] are used within three main areas: the forest products industry, house heating and district heating plants. The biofuel portion of the total energy supply in Sweden in 1995 was 18%, which represents nearly a doubling since 1970. The district heating sector accounts for the largest increase, followed by industry, particularly the forest products industry. The forest products industry traditionally uses its by-products for process heating and electricity generation. The increased use of biofuels in the forest products industry is due to a more efficient use of the by-products. The use of biofuels in the district heating sector increased from 2 TWh in 1980 to more than 20 TWh in 1995. There is a relatively great potential for an increased use of biofuels for district heating production.

The use of biofuels in the residential sector has remained at a relatively constant level, around 10 TWh. In 1995, 3.3 TWh of biofuels was used for electricity production, which corresponds to 2.3% of the total production of electricity. The largest portion of biofuel-based electricity production takes place within the industrial sector.

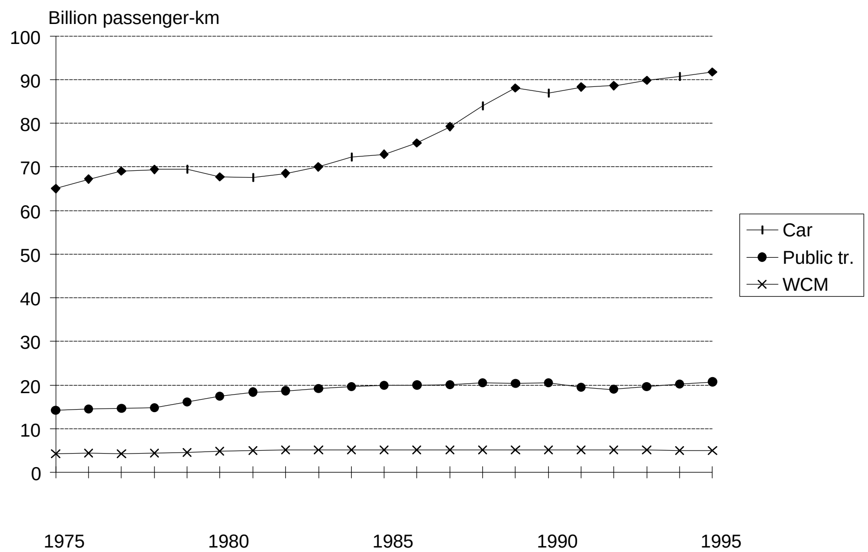
3.7 Transportation structure

Passenger transport

The average distance travelled per day in Sweden has increased steadily during the 1990s. In 1995 the average distance travelled per day was 43 kilometres. The increase of passenger travel in Sweden during the 20th century has followed economic growth. Transportation is also influenced by the economic development in different sectors and regions, the age composition of the population, and changing social patterns, such as the increase in gainful employment among women.

[4] In 1995 the use of peat amounted to 3 TWh, the use of waste to more than 4 TWh. The remaining portion, approximately 77 TWh, consisted of biofuels.

Figure 3.3 Breakdown of passenger transport activity among travel modes, billion passenger-km



In 1995, *passenger cars* accounted for about 75% of the total passenger transport volume. The above graph shows that car transport has accounted for by far the largest increase in transport activity since the mid-70s. Travel by public transport has increased slightly, while the level for walking, cycling and moped riding is unchanged. During the period 1975-1995, the number of cars on the road has increased from 2.8 million to 3.6 million. In 1994 there were 410 passenger cars per 1,000 inhabitants.

Different forms of leisure activity in the broad sense are the most important reason for these journeys. More than 40% of the passenger transport volume consists of trips to and from leisure activities. Trips to work and school account for about 35% of the transport volume.

Rail transport includes both short commutes and longer trips. In 1995 the average length of a journey with SJ (Swedish National Railways) was 63 km. Shorter trips by rail are mainly made in the big-city regions as a part of the public transport systems. Rail accounts for about 10% of the number of long-distance journeys (more than 100 km).

Air transport, which has been deregulated since 1992, is highly cyclical. Between 1993 and 1995, the number of international air journeys increased by 25%, while the number of domestic journeys by air declined by 6%. Domestic aviation's share of the number of long-distance passenger journeys is about 5%.

Differences between men's and women's travelling

Women make almost as many trips as men, but they are shorter on average. In 1994, women accounted for 48% of the number of journeys, but only 39% of the total distance travelled. Men travel an average of 75 minutes per day, while women only travel 62 minutes per day. Women, and particularly younger and older women, make more trips than men by public means of transport, by bicycle and by foot.

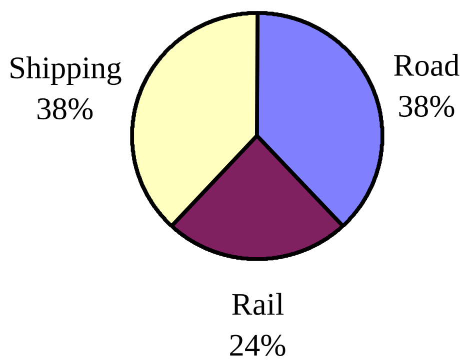
Freight transport

More than 500 million tonnes of goods were transported in Sweden in 1995. Nearly 70% of this amount was transported by road. Trucks dominate, particularly over shorter distances, where they account for more than 90% of the shipments.

Table 3.1 Domestic freight transport in 1995 according to mode of transport.

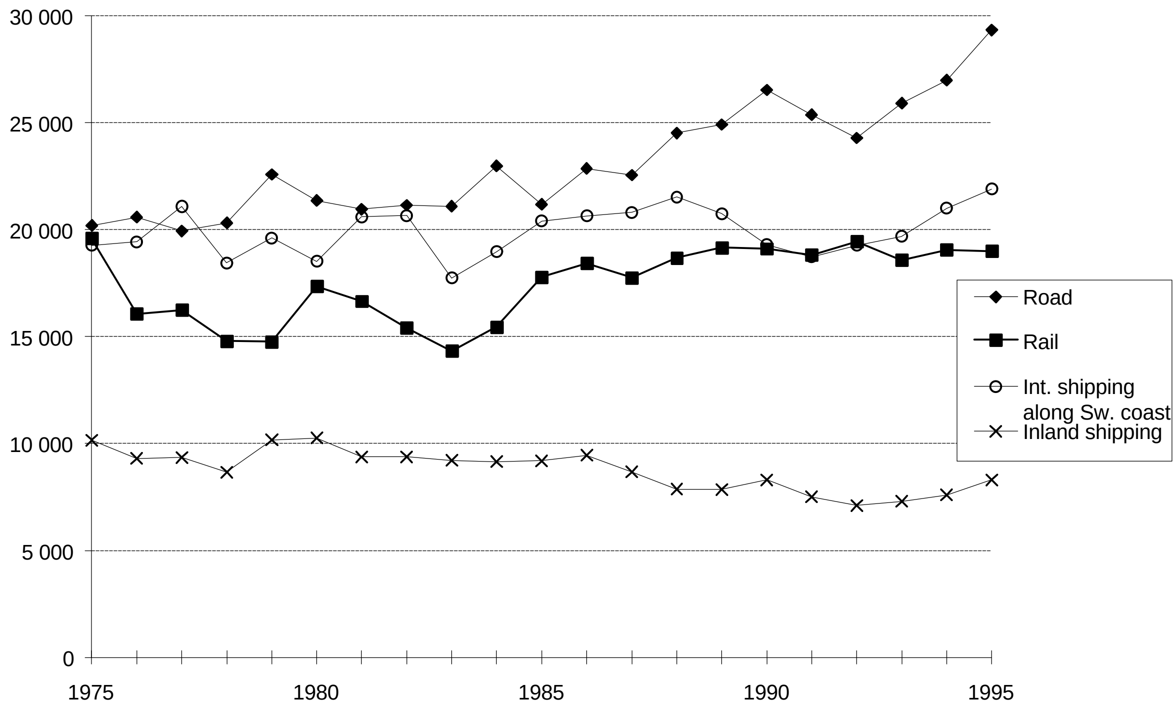
	Million tonnes	**Million tonne-km**
Road	**356**	**29,324**
Rail	**56**	**18,973**
Shipping	**104**	**30,174**
Total	**516**	**78,471**
Of which international shipping	**90**	**21,900**

Figure 3.4 Domestic freight transport volume broken down by transport mode, percent.



Between 1975 and 1995, the volume of goods transport in Sweden increased by more than 9 million tonne-kilometres or about 10%. Freight transport activity by road increased by 45% during the period. Maritime and rail transport in 1995 are roughly on a par with 1975. During the period, the road transport share of domestic freight shipments increased from 29% to 37%, the maritime portion decreased from 43% to 38% and the rail share decreased from 28% to 24%. The rail share has declined in particular during the 1990s, when carriage by road and by sea increased, while they remained more or less unchanged by rail.

Figure 3.5 Freight transport activity 1975–1995 broken down by transport mode, million t-km



The development of freight transport activity has followed business cycle fluctuations, and the traditional basic industries of forest products and steel are important for transport volume. In 1995, the basic industries accounted for 30% of the domestic freight transport volume. The percentage for rail transport was 50%, for maritime transport 30% and for road transport 20%.

The longer the transport, the more even the distribution between transport modes. At distances greater than 300 km, shipping is the dominant transport mode.

Shipping and trucks (lorries) have equal shares of the total transport volume at 38% each. Of the maritime volume, shipments of foreign goods on Swedish waters comprise about 70%.

Of the goods transported by rail, the 25 million tonnes of Laplandian iron ore account for nearly half of the freight quantity and 20% of the transport activity.

The quantities of goods transported by domestic and international aviation in Sweden in 1995 totalled 169,000 tonnes. This was equivalent to 0.03% of Swedish freight carriage. The goods transported by air have a high value added in manufacturing, however. Air freight therefore accounts for 12% of the value of the transported goods and is currently increasing rapidly in importance.

The above account does not include carriage by foreign trucks and trucks with a GVW (gross vehicle weight) of less than 3.5 tonnes. Regarding foreign truck carriage, there is an EU directive requiring member states to furnish particulars on both domestic and international goods transport by road. Certain member states have reported these statistics, but it is not clear at present when a full accounting can be expected.

Light goods vehicles (with a GVW less than two tonnes) accounted for the carriage of about 10 million tonnes of goods in 1991 and a transport activity of approximately 500 million t-km. This is equivalent to about 2% of the quantity of goods transported in Sweden and over 0.5% of the freight transport activity (in t-km).

3.8 Industrial structure

Sweden is an industrialized country with both exploitation of natural resources (mining, forestry, hydropower) and heavy basic industrial production (iron, steel and non-ferrous metals, petroleum refining, chemical manufacture and pulp and paper manufacture). Furthermore, the country has large engineering and electronic industries with both car manufacture and manufacture of high-tech products.

The number of employees in the manufacturing industry in 1994 was about 660,000, with the engineering industry accounting for about half. The engineering industry is also of great importance in terms of the total value added within the manufacturing industry, accounting for about 43% of the total value of SEK 292 billion, see Table 3.2.

Table 3.2 Value added and share of total value added in 1994, SEK billion (1991 prices).

	Value added	Percent
Engineering industry	126	43%
Chemical industry	31	11%
Food industry	30	10%
Pulp and paper industry	24	8%
Graphic arts industry	20	7%
Wood products industry	16	6%
Iron and steel industry	10	4%
Other industry	32	11%
Total	**292**	**100%**

Source: Statistics Sweden, National Accounts

The capital-intensive industrial sector includes the traditional basic industries, the pulp and most of the paper industry, the mining and steel industries and the heavy chemical industry. This sector’s share of production has remained relatively unchanged Since 1970. Capital-intensive industry is distinguished by modern production technology and high efficiency. The trend is towards products with more and more value added in manufacturing. The knowledge-intensive sector of industry has a better productivity structure and renewal potential than other sectors. It includes most segments of the engineering industry as well as manufacturers of drugs and performance chemicals. The sector’s share of total industrial production has increased since 1970.

The labour-intensive part of Swedish industry includes the greater part of the wood products industry plus a large number of industries that manufacture non-durable consumer goods.

This sector is exposed to keen competition from low-wage countries. For example, the Swedish textile industry has been practically driven out of business over the past 30 years. The protected sector of industry consists of industries whose home market is protected from foreign competition. This includes parts of the food industry, some of the wood and stone industry and the graphic arts industry. The protected and the labour-intensive portion of production has diminished substantially over the past 25 years.

3.9 Agricultural structure

Agriculture in Sweden employed about 90,000 people in 1994, which is equivalent to 1.0% of the population. In 1995 there were approximately 87,300 farming enterprises in the country. The agricultural sector has diminished greatly over the past 50 years, in terms of number of persons engaged, number of agricultural units and area of land under tillage. The arable land area amounted to 27,700 km^2 in 1995. The reason for the decline is a structural transformation with increased demands on efficiency.

Approximately 13,000 farms are devoted primarily to plant husbandry, about 37,000 are devoted primarily to animal husbandry, and about 7,000 have mixed production. Most of the remaining approximately 31,000 units are small family holdings.

Animal husbandry is often mixed, but cattle dominate and are found on every other farm. The number of head of cattle in 1995 was about 1.8 million, of which one-third were kept for milk production. The numbers of other animals in 1995 were 0.2 million sheep, 2.3 million pigs, 12.5 million fowls (including chickens) and 0.2 million horses. Horses are not used within agriculture, but are kept for sport and recreation.

The agricultural sector has an impact on the environment. Traditionally it has been nonpoint-source discharges of nutrients to water that have received attention. Atmospheric emissions come mainly from the handling of manure. Ammonia emissions are not believed to have changed significantly during the past 50 years. Atmospheric emissions have been a topic of discussion recently, especially now that climate issues have come under scrutiny.

3.10 Forestry structure

The forest is one of Sweden's most important natural resources and is the basis of the forest products industry. Approximately 30,000 people are engaged in forestry. Forestland covers about 280,000 km^2, corresponding to 62% of the country's surface area. 229,000 km^2 of this area is productive forestland. The predominant tree species are Norwegian spruce (46%), Scots pine (38%) and birch (10%). Other tree species include oak, beech and aspen.
Swedish forestry policy during the 20th century has been characterized by an insistence on sustainable management of timber resources and by determined efforts to improve silviculture practices. As a consequence of these policies, annual forest growth since the 1920s, when the national forest survey started, has increased from about 60 million forest cubic metres (m^3 sk) to nearly 100 million m^3 sk. During the same period, the total volume of standing timber has

increased from 1.8 billion m^3 sk to 2.8 billion m^3 sk. This increase has occurred at the same time as annual fellings have increased from about 50 million m^3 sk to between 65 and 75 million m^3 sk.

Significant changes in forest policy were adopted by the Swedish Government in 1993. Along with the production goal, there is now an equally important environmental goal. Accordingly, the Forestry Act states that the forest is a national asset that shall be managed in such a manner as to provide a good, sustainable yield while preserving biological diversity.

The size of the forested areas and the density and vitality of the forests are of importance for the cycling of carbon dioxide in the atmosphere, since carbon dioxide is sequestered (accumulated) in the growing forest.

Sweden’s forested area has increased very little in the past few decades, and then mainly due to the planting of trees on cropland withdrawn from farming. There is a risk that continued acidification of the forest soil will lead to substantial damage in the form of timber losses. This may have a major economic impact on the forestry sector and on the importance of the forest as a carbon dioxide sink in the future. The risk is greatest in southern and central Sweden.

4. Emissions inventory

4.1 Introduction

Emissions of anthropogenic climate gases in Sweden for the years 1990-1995 are reported in this chapter. Emission estimates for carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), partially halogenated hydrofluorocarbons (HFCs), fluorocarbons (FCs) and sulphur hexafluoride (SF_6) are presented separately. The emission figures are broken down among nine different sectors: combustion in power and district heating plants, combustion in industry, transport, combustion in the residential and commercial sector, industrial processes, fugitive emissions from fuel handling, emissions from solvent use, agriculture and waste. Furthermore, the carbon dioxide sink is reported, i.e. how much carbon dioxide is estimated to be sequestered in growing forests.

The present emissions inventory follows the IPCC's guidelines for reporting to the Climate Convention. This means, inter alia, that emissions of climate gases from international shipping and aviation are not included in the national inventory, but are reported separately. Nor are emissions of carbon dioxide from combustion of biofuels and decomposition of organic waste included in the national total sum in accordance with the guidelines. On the other hand, emissions of other climate gases from biofuel combustion and waste management are reported. Furthermore, estimated carbon dioxide emissions from solvent use and fuel handling are reported, based on the assumption that the carbon content of the emissions from volatile organic compounds is oxidized to CO_2 in the atmosphere. Finally, it can be mentioned that an estimate of the aggregate impact of different greenhouse gases has been made with the aid of GWPs (Global Warming Potentials). These factors were developed by the IPCC and are used as a unit of measure to permit comparison of the relative importance of different gases for global warming, expressed in carbon dioxide equivalent.

The material is based on official Swedish statistics, where e.g. energy statistics, industrial statistics, agricultural statistics and forestry statistics have been used. Previously collected and processed data from inventories already performed have been utilized wherever possible, e.g. from Sweden's annual reporting to the UN Convention on Long-Range Transboundary Air (LRTAP)Pollution and the Framework Convention on Climate Change (UNFCCC). The statistics on industrial emissions originate from a) emissions figures in the annual environmental reports to the regulatory authorities, and b) calculations based on activity data and emission factors.

However, official Swedish emissions statistics do not include data on emissions of nitrous oxide, methane and carbon monoxide. Estimates of the size of the emissions are therefore uncertain in many cases. A kind of quality classification is therefore given for each climate gas to provide an indication of the reliability of the data: High, Medium or Low. This complies with the IPCC's guidelines for indication of the quality of emissions data, where H(igh) stands for high reliability of emissions data, M(edium) for medium reliability and L(ow) for low reliability. The error estimates made are expert assessments.

Emissions of climate gases in Sweden between 1990 and 1994 are presented below in Tables 4.1-4.7. Emissions of climate gases per capita between 1990 and 1994 are presented in Table 4.8. Aggregate per-capita emissions of greenhouse gases, converted to carbon dioxide equivalent, are presented in Table 4.9.

4.2 Emissions of CO2

Carbon dioxide, CO_2 is the most important greenhouse gas and is formed in connection with all combustion. The major emission sources are therefore sectors such as power and heat generation, transportation and industrial combustion. The calculations of combustion emissions are based on delivery and consumption statistics for fuels and emission factors for different fuels and combustion conditions.

Carbon dioxide accounts for the greater part of greenhouse gas emissions in Sweden. Carbon dioxide contributes about 80% of the total emissions of greenhouse gases, calculated as GWP (Global Warming potential). The transport sector accounts for the largest portion, 33%, of the total carbon dioxide emissions. Whereas emissions from the energy sector and the manufacturing industry have steadily declined, emissions from the transport sector have increased.

The emissions data for carbon dioxide may be regarded as having high reliability. However, it is much more difficult to determine how much carbon dioxide is sequestered in growing forest. These figures are less accurate and can be rated as having medium reliability. The uncertainty in the calculation of transport activity in international shipping and aviation is also greater than the corresponding uncertainty for domestic transport activity.

Off-road machines within industry, agriculture and fishing are reported under the sectors “Combustion industry” and “Combustion heating” (in accordance with the IPCC guidelines).

Since 1990, total emissions of CO_2 in Sweden have increased by about 5%. Emissions of CO_2 in Sweden 1990-1995 are presented in Table 4.1, along with sequestration of CO_2 in growing forest (the sink). Emissions from international shipping and aviation are reported separately in Table 4.2.

The comparability between years is disturbed by the natural climatic variations between drier and wetter as well as warmer and colder years. Sweden also reports normal-year-corrected carbon dioxide emissions to the Climate Convention, which have been purged of the extreme values that are due to the variability of the climate.

A model for calculation of normal-year corrections should include the annual variation in temperature and hydropower supply. Fluctuations in the industrial business cycle and nuclear power plant outages are, on the other hand, not included in these corrections, see Appendix 2.

The normal-year-corrected emission values for CO_2 in Sweden indicate a slight increase in the emission rate, with an increase of about 1.5% between 1990 and 1995.

Table 4.1 Emissions of carbon dioxide 1990-1995 (1,000 000 tonnes)

Sector	1990	1991	1992	1993	1994	1995
Combustion	8.8	10.0	10.4	10.5	11.0	10.5
Combustion industry	13.1	12.2	11.8	12.7	13.9	13.5
Transport	18.8	18.7	19.2	18.4	18.8	19.4
Combustion heating	10.7	10.2	10.2	10.0	10.2	9.9
Industrial processes	3.8	3.7	4.1	4.0	4.2	4.5
Fugitive emissions	0.05	0.05	0.04	0.04	0.02	0.02
Solvents	0.3	0.3	0.3	0.3	0.2	0.2
Agriculture	--	--	--	--	--	--
Waste	--	--	--	--	--	--
Total anthropogenic emission_	**55.4**	**55.2**	**56.0**	**56.0**	**58.5**	**58.1**
Normal-year-corrected	**57.6**	**55.8**	**57.5**	**57.1**	**58.8**	**58.5**
Forestry (net sink)	-34.4	NE	-30.0	NE	NE	NE

Table 4.2 Emissions from international shipping and aviation in 1990 (1,000 tonnes)

Sector	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
International shipping and aviation transport	4207	4331	4816	4855	5400	5367

4.3 Emissions of CH4

The largest sources of methane emissions are agriculture plus waste landfills. Together they account for 90% of the total emissions. During the period 1990-1994, emissions from the agricultural sector have been calculated to remain roughly unchanged, while emissions of methane from landfills have been calculated to have declined, owing to an increased withdrawal of landfill gas for energy purposes, as well as declining quantities of landfilled waste.

Methane emissions from agriculture has been calculated with the aid of national emission factors. A comparison has been made between the emissions factors proposed by the IPCC and those used in Sweden, and the conclusion was that the Swedish calculation model better reflected national conditions. When it comes to the estimates of methane emissions from landfills, uncertainties in existing statistics and a lack of adequate methods for calculation of methane emission lead to difficulties in determining the size of the emissions. On the whole, the data on methane emissions can be regarded as having medium reliability.

Table 4.3 Emissions of methane 1990-1994 (1,000 tonnes)

Sector	1990	1991	1992	1993	1994
Combustion power and district heating plants	1	1	1	2	2
Combustion industry	5	4	4	4	6
Combustion heating	10	10	10	10	11
Transport	23	23	22	22	21
Industrial processes	NE	NE	NE	NE	NE
Fugitive emissions fuels	--	--	--	--	--
Solvents	-	-	-	-	-
Agriculture	200	196	197	197	202
Waste	85	85*	85*	85*	61**
Total	**324**	**320**	**320**	**320**	**303**
International shipping and aviation	0.1	0.1	0.1	0.1	0.1

NE: Not Estimated
Shaded cells indicate no new estimates, last year's value is used.
* value from 1990
** value from 1995

4.4 Emissions of N2O

The largest emissions of nitrous oxide (laughing gas) come from various combustion processes. Manufacture of commercial fertilizer is another source. The emission of nitrous oxide from agricultural land has been calculated with the aid of the IPCC's emission factors. These factors are largely adapted to European conditions, and national emission factors should be developed for future calculations

There are however considerable uncertainties in the emission estimates, and they must therefore be regarded as having low reliability.

Table 4.4 Emissions of nitrous oxide 1990-1994 (1,000 tonnes)

Sector	1990	1991	1992	1993	1994
Combustion power and district heating plants	1.1	1.1	1.1	1.5	1.1
Combustion industry	2.1	2.1	2.1	1.9	2.6
Combustion heating	0.5	0.5	0.5	0.7	0.5
Transport	2.6	2.6	2.6	2.6	2.8
Industrial processes	2.7	2.7	2.3	2.3	2.3
Fugitive emissions fuels	-	-	-	-	-
Solvents	-	-	-	-	-
Agriculture	0.2	0.2	0.2	0.2	0.2
Waste	-	-	-	-	-
Total	**9.2**	**9.2**	**8.8**	**9.2**	**9.5**
International shipping and aviation	NE	NE	NE	NE	NE

NE: Not Estimated
Shaded cells indicate no new estimates, last year's value is used.

4.5 Emissions of HFCs, FCs and SF6

HFC compounds are partially halogenated hydrofluorocarbons, i.e. hydrocarbons in which one or more hydrogen atoms have been replaced by fluorine, but at least one hydrogen atom remains. HFCs have been introduced as substitutes for ozone-depleting CFC and HCFC compounds. Like these, however, HFC compounds are very stable, with a long residence time in the atmosphere, and are feared to be capable of affecting the climate by contributing to global warming.

In 1990 there were no emissions of HFCs in Sweden. The value for 1994 is estimated at 150 tonnes.

FC compounds are highly stable compounds with a long life in the atmosphere and a high GWP. FCs are used within very specific areas of application, such as the electronics industry in plasma etching and vapour phase soldering, and in the textile industry in the manufacture of modern outdoor wear. FC compounds are also formed unintentionally during aluminium manufacture.

Emissions of FC gases in 1994 were estimated to be 60 tonnes.

SF_6 also has a high GWP, 24,900. SF_6 is mainly used as an insulating gas in electrical equipment. Emissions of SF_6 were estimated to be about 40 tonnes in 1990. The estimate for 1994 is 52 tonnes.

4.6 Indirect greenhouse gases

Nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs) are categorized as indirect greenhouse gases, i.e. they have an indirect effect on the climate by contributing to the formation of other greenhouse gases, mainly ozone.

4.6.1 Emissions of NOx

Nitrogen oxides are formed primarily during the combustion of fossil fuels, and motor vehicle traffic is responsible for the largest emissions. Emissions of nitrogen oxides have declined by 20% over the past 15 years. This decline has been achieved primarily by the introduction of catalytic converters and improved combustion technologies within the energy sector.

Emissions from combustion have been calculated as the product of fuel consumption and national emission factors. Data on emissions from industrial processes are based primarily on environmental reports from companies. Road traffic emissions have been determined by means of a newly-developed calculation model which includes particulars on quantity of fuel consumed, transport activity and emission factors for different vehicle types and kinds of fuel. Emissions from other mobile sources, besides off-road machines, have been estimated with the aid of data from the national transport authorities. Calculations of emissions from off-road machines have been made by the Swedish Environmental Protection Agency. As a whole, the figures are considered to have high reliability.

Table 4.5 Emissions of NOx 1990-1994 (1,000 tonnes)

Sector	1990	1991	1992	1993	1994
Combustion power and district heating plants	16	16	14	14	14
Combustion industry	23	23	18	19	18
Combustion heating	13	13	12	11	10
Transport	261	261	261	253	249
Industrial processes	23	24	24	26	27
Fugitive emissions fuels	-	-	-	-	-
Solvents	-	-	-	-	-
Agriculture	-	-	-	-	-
Waste	-	-	-	-	-
Total	**336**	**337**	**329**	**323**	**318**
International shipping and aviation	52	52	54	54	54

Shaded cells indicate no new estimates, last year’s value is used.

4.6.2 Emissions of CO

Emissions of carbon monoxide occur primarily in connection with combustion of fossil fuels as well as biofuels. Road traffic is the predominant source, accounting for about 80% of the emissions. Road traffic emissions of carbon monoxide have been estimated with the aid of the aforementioned calculation model (see 4.6.1). Emissions from other mobile sources, besides off-road machines, have been estimated by the national transport authorities. The statistics on carbon monoxide are inadequate and the data on emissions of carbon monoxide may be considered to have medium reliability.

Table 4.6 Emissions of carbon monoxide 1990-1994 (1,000 tonnes)

Sector	1990	1991	1992	1993	1994
Combustion power and district heating plants	6	6	6	11	10
Combustion industry	28	28	28	26	31
Combustion heating	123	123	123	142	136
Transport	1046	1046	985	985	911
Industrial processes	6	6	40	40	54
Fugitive emissions fuels	-	-	-	-	-
Solvents	-	-	-	-	-
Agriculture	-	-	-	-	-
Waste	-	-	-	-	-
Total	**1204**	**1209**	**1182**	**1204**	**1142**
International shipping and aviation	6.2	6.2	6.2	6.2	6.2

Shaded cells indicate no new estimates, last year's value is used.

4.6.3 Emissions of Non-Methane Volatile Organic Compounds (NMVOCs)

Volatile organic compounds are released during combustion of various fuels. The largest contributions to emissions of NMVOCs come from motor vehicle traffic and wood-burning for space heating of single-family homes. Solvent use and evaporation during fuel handling (fugitive emissions) are other sources of NMVOC emissions.

Road traffic emissions of NMVOCs have been estimated in the previously mentioned calculation model (4.6.1). Emissions from other mobile sources, mainly off-road machine, have been calculated by the national transport authorities. Considerable difficulties exist in determining the emissions of NMVOCs from other sources, and the data must be regarded on the whole as having low reliability.

Table 4.7 Emissions of NMVOCs 1990-1994 (1,000 tonnes)

Sector	1990	1991	1992	1993	1994
Combustion power and district heating plants	2	2	3	3	4
Combustion industry	6	6	6	6	6
Combustion heating	142	142	137	137	146
Transport	216	216	209	209	188
Industrial processes	42	42	39	39	36
Fugitive emissions fuels	26	26	21	21	15
Solvents	92	92	86	86	83
Agriculture	NE	NE	NE	NE	NE
Waste	-	-	-	-	-
Total	**526**	**526**	**502**	**502**	**478**
International shipping and aviation	1.5	1.5	1.4	1.4	1.6

NE: Not Estimated
Shaded cells indicate no new estimates, last year's value is used.

Table 4.8 Anthropogenic emissions, kg per capita 1990-1994

Emissions per inhabitant	**CO_2 tonnes**	**CH_4 kg**	**N_2O kg**	**NO_x kg**	**CO kg**	**NMVOCs kg**
1990	6.5	37	1.1	39	141	61
1991	6.4	37	1.1	39	141	61
1992	6.4	37	1.1	38	138	58
1993	6.4	37	1.1	37	138	57
1994	6.6	34	1.1	36	130	54

4.7 Aggregate emissions of greenhouse gases

The aggregate impact of different greenhouse gases can be calculated with the aid of GWPs (GWP = Global Warming Potential). Greenhouse gases can have a direct and an indirect effect. In the IPCC's evaluation, it is said to be difficult to assign exact values to the indirect component, so only a value for the direct component is given. An IPCC report published in 1994 contains weighted and updated values. Nitrogen oxides, carbon monoxide and NMVOCs have only an indirect effect.

Table 4.9 GWP values (100 years) for greenhouse gases

Gas	GWP
Carbon dioxide, CO_2	1
Methane, CH_4	21
Nitrous oxide, N_2O	310
HFC 134a	1300
CF_4	6500
SF_6	23900

Aggregate emissions of greenhouse gases expressed as carbon dioxide equivalent (in million tonnes of carbon dioxide) converted using the IPCC's GWP values are given in Table 4.10.

Table 4.10 Total emissions of greenhouse gases in million tonnes of carbon dioxide equivalent

	1990	**1992**	**1994**
Carbon dioxide, CO_2	55.4[3]	56.0[3]	58.5[3]
Methane, CH_4	6.7	6.7	6.4[1]
Nitrous oxide, N_2O	3.0	2.9	2.9
HFC 134a	0	0,1[2]	0.2
CF_4	0.4	0.4	0.5
SF_6	1.0	1.1[2]	1.2
Total	**66.5**	**67.2**	**69.7**

[1] Value from 1995
[2] Interpolated value
[3] Normal-year corrected values are 57.6 (1990), 57.5 (1992) and 58.8 (1994)

4.8 Calculation of forest sink

Background
The state of the Swedish forests has been inventoried and reported regularly since 1923 by the National Forest Survey. Forest production conditions on all land with growing forest and for all landowner categories are inventoried annually in a ten-year cycle, which means that the same area is resurveyed at ten-year intervals. At present we are in the midst of the seventh nationwide survey, which began in 1993 and will end in 2002.

Permanent sample plots were introduced in 1983 as a complement to previous line surveys and randomly chosen sample plots. This change reflects a gradual transition from only describing the state of the forest to also shedding light on changes and gathering data for future impact assessments of various silvicultural measures. Since then, forest site surveying is also carried out on the permanent sample plots with collection of data concerning soil, vegetation and hydrology as a complement to pure tree data. For example, soil and vegetation type are determined and humus thickness is measured. In this manner, the National Forest Survey has become increasingly important within environmental monitoring. An annual report on the state of the forests in Sweden is made in the publication “Forest data”, which is published by the Swedish University of Agriculture in Umeå.

Supplementary forest statistics are published by the National Board of Forestry in Jönköping through the publication “Forest Statistical Yearbook”, whose statistics are based on data from the National Forest Survey, forest statistics which the National Board of Forestry collects from the forest-owners via the regional forestry boards, and other national statistics pertaining to forest conservation, the forest products industry and trade in forest products.

Calculation of the forest sink above the ground surface
Available and published forest statistics are used in the calculations of emissions and sequestration of greenhouse gases from Swedish forests that are performed in accordance with the IPCC’s methodology.

Sweden’s cultivated forests are distributed within the temperate and boreal forest regions. The temperate forests cover just under 80,000 hectares in the far south. The rest, or nearly 23 million hectares, consist principally of boreal coniferous forest. The growth of biomass above the ground is converted to quantity of stored carbon. Biomass that is harvested and removed from the forest is subtracted from this gross value. The remaining quantity of biomass, converted to carbon quantity, provides a measure of carbon storage during the inventory year. The above-ground biomass in 1992 is estimated to have amounted to about 30 Mt (million tonnes) CO_2. (Table 4.1).

Calculation of forest sink below the ground surface
Carbon changes below the ground surface are currently not included in the IPCC’s calculation methodology. This is mainly due to the fact that available data are very scanty. The carbon reservoir below the ground surface in boreal forests is, however, large as a rule, providing the forest has not recently been ravaged by fire. Estimates of the carbon reservoir in boreal forest soil have previously been made in Canada and Finland. By using the various data on soil conditions obtained from the forest site survey, Sweden has now carried out a calculation of the carbon reservoir in forest soil. By comparing data from the 1983-1986 Forest Site Survey with data from the ongoing survey cycle during the 1990s, we have also obtained data on changes in the carbon reservoir. The result of these preliminary assessments is that the carbon reservoir in Swedish forest soil is currently increasing rapidly, at a rate estimated to be about 18 Mt of CO_2/year.

5. Measures to Limit Emissions of Greenhouse Gases

5.1 Swedish energy policy - an historical retrospect

The energy policy applied has led to a reduction of carbon dioxide emissions from the Swedish energy system. The fact that Sweden already modified its energy system back in the 1970s and 1980s in the direction towards lower carbon dioxide emissions greatly limits the options available today for further mitigating emissions. With this in mind, let us examine more closely the energy policy that was pursued during the 1970s and 1980s.

After the oil crisis in the early 1970s, the primary goal was to reduce Sweden's dependence on oil. As a consequence of the oil crisis, the price of oil rose sharply and a large national effort was begun to ease adjustment to the new price situation. Information campaigns for energy conservation were given great attention, subsidies for energy-saving investments within the commercial, institutional, residential and industrial sectors were introduced, and a comprehensive energy research programme was begun. Economic instruments, such as a tax on energy, were used widely. Different rule systems were also introduced during this period.

In 1973, a new rule system within the planning and building sector began to be applied as a part of Sweden's national physical planning. The new rule system enabled the authorities to control establishments of industrial activity in view of the environmental impact of the activity. The Act on Municipal Energy Planning was enacted in 1977. The purpose of the law is to enable the municipalities to influence the structure of the energy system and to enable the state to follow the municipalities' planning.

Moreover, a big investment programme in nuclear power reactors began in the early 1970s. The first reactor, in Oskarshamn, was commissioned in 1972. The risks of nuclear power began to be discussed in the mid-1970s. After the accident at the Three Mile Island nuclear power station in 1979, a national referendum on nuclear power was held in Sweden in 1980. The Riksdag (Swedish Parliament) decided that the nuclear power reactors that were under construction should be taken into service, but that no additional construction should take place and that nuclear power should be phased out by not later than 2010.

At that time, in 1979/80, prices on the international oil market once again rose sharply. In further defining the nation's energy policy, the Riksdag introduced the concept of oil substitution. With this decision, Swedish energy policy adopted a more price- and market-oriented approach. A new energy tax system was introduced, resulting in the introduction of several policy taxes on energy. National energy policy in the early 1980s was also characterized by quantitative goals such as that the oil share of total energy use should decrease to 40%, and coal use should be limited to 3–4 million tonnes per year. Support to investments in energy-saving measures within industry and the residential sector continued.

The premises for Swedish energy policy were changed in the mid-1980s when oil prices fell. To prevent the trend towards lower oil consumption from being broken, the state tried to keep the price of oil up by raising the tax. However, the tax increases were unable to keep up with the fall in price on the world market. The state gradually cut back on the investment subsidies in favour of more basic research and development activities. The energy research programme focused on supporting research institutions instead of developing special technologies for oil substitution.

The nuclear reactor accident in Chernobyl occurred in 1986, once again raising doubts about nuclear power. Since then, Swedish energy policy has focused on creating the necessary conditions for a transformation of the energy system to enable nuclear power to be phased out. Funds were allocated to support energy conservation, research and the introduction of new technology to replace nuclear power.

Over the years, environmental problems have come to play an increasingly important role in guiding national energy policy. The big unharnessed rivers have been protected from exploitation. Measures have been adopted against the harmful effects of combustion, acidification and eutrophication. Economic instruments which are supposed to ensure that the environmental costs of different activities are taken into account in decision-making have begun to be applied on a wider scale. In order for the economic instrument approach to be successful, however, well-functioning energy markets are needed. National energy policy has therefore been increasingly aimed at creating the prerequisites for efficient energy markets. The need for international solutions to environmental problems, along with Sweden’s EU membership, has also led to the increasingly international orientation of Swedish energy policy. EU membership entails, for example, active participation in the work of the Union to present proposals for measures that reduce the environmental impact of the energy sector.

5.2 Energy policy during the 1990s

The current energy policy was formulated in an agreement between the Social Democrats, the Centre Party and the Liberal Party. The agreement resulted in the 1991 Energy Policy Bill[5]. The purpose of the agreement was to create the conditions for long-term sustainable political decisions on energy policy, whose goal was defined to be to secure the availability of electricity and other energy in the long and short term at prices that are competitive on the world market. Furthermore, national energy policy shall be based on what nature and the environment can bear.

It was observed in the decision that the time for the start of the nuclear power phase-out, and the pace at which the phase-out can proceed, are to be determined by the results of electricity conservation efforts, the availability of electricity from environmentally acceptable power production, and the ability to maintain internationally competitive prices.

From a climate viewpoint, it was considered urgent to avoid burning fossil fuels wherever possible. According to the Government Bill, this was to be done by means of active energy conservation and by utilizing renewable energy sources. The Bill further stipulated that taxes and price mechanisms ought to be accorded great importance in the nation’s energy policy. Sweden is a small country with an open economy, and its integration with the rest of the

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[5] Gov. Bill 1990/91:88

world means that Sweden cannot have energy prices that deviate significantly from those in our competing countries without undesirable effects.

A more concrete strategy for Swedish climate policy was defined in the Climate Policy Bill of 1993[6]. This means that a national strategy ought to be that carbon dioxide emissions from fossil fuels should be stabilized in accordance with the FNCCC at the 1990 level by the year 2000, after which they should decrease. The strategy applies to all greenhouse gases, but pending the acquisition of new knowledge, targets have not been set for any other greenhouse gases besides carbon dioxide. The exception is leaching of methane from waste landfills, for which the goal is a reduction of emissions by 30% by the year 2000. Developing sinks, for example by means of continued good silvicultural practices, is regarded as a complement to the limitation of carbon dioxide emissions. Later the Riksdag decided on goals for emissions of HFCs and FCs and other closely-related gases. Emissons of these gases may not exceed 2% of Sweden's carbon dioxide emissions in the year 2000, counted as carbon dioxide equivalent[7].

Swedish climate policy is placing increasing emphasis on the cost-effectiveness of measures, and it is stressed that Sweden should adopt actions both nationally and internationally. It is emphasized that Sweden should be a driving force in the international work of restricting emissions of climate gases.

The guidelines established in the 1991 Energy Policy Bill are subject to revaluation. A parliamentary Energy Commission was appointed in the spring of 1994 to examine the ongoing programmes for transformation of the energy system and analyze the need for changes and additional measures.

The work of the Energy Commission was presented in December 1995, and the energy policy negotiations between the parties in the Riksdag were commenced during the autumn of 1996. They were concluded on the 3rd of February 1997 and resulted in an agreement between the Social Democrats, the Centre Party and the Left Party which contains the following wordings:

> A proposal for an act on the shutdown of nuclear power reactors will be submitted to the Riksdag during 1997 in such good time that the act can enter into force on 1 January 1988. The act will provide that the right to operate nuclear power reactors to generate nuclear energy can be rescinded by the Government.
>
> Negotiations will be opened with the owner of the Barsebäck Nuclear Power Station to close one reactor prior to 1 July 1998 and a second reactor prior to 1 July 2001. Immediately after the act has entered into force, the Government intends to pass a resolution regarding the shutdown of Barsebäck 1 and Barsebäck 2. A condition for the shutdown of the second reactor is that the loss of electricity production can be offset by new electricity production and reduced electricity usage.
>
> Measures will be adopted during the next few years to compensate for the loss of electricity from the two reactors by means of more efficient energy use, conversion and conservation, and supply of electricity from other energy sources.
>
> Conditions will be created for more efficient utilization of the existing natural gas network.
>
> Special measures will be adopted to reduce the use of electricity and to increase the construction of electricity and heat production capacity based on renewable energy sources. The overall result is expected to be equal to the annual production of electricity in the Barsebäck Station.

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[6] Gov. Bill 1992/93:179, JoU19, rskr 361

[7] Gov. Bill 1994/95:119

> The measures include reduced use of so-called interruptible electric boilers in the district heating system, conversion and power-reducing measures in houses with direct-acting electric heating, increased connection to district heating and creation of new electricity production from renewable energy sources through e.g. investment support and technology procurement.
>
> International measures to date under the UNFCCC have proved inadequate in fulfilling the purpose of the Convention. Negotiations concerning further commitments and measures are now being held with a view beyond the turn of the century. Successful international cooperation is predicated upon an equitable sharing of commitments and costs. The different present-day situations and circumstances in the different countries should be taken into account when assigning commitments within the framework of the convention, as should the principle of a cost-effective allocation of measures. Consideration should be given to measures already adopted and current climate-affecting emissions per inhabitant.
>
> Sweden should institute cost-effective actions both internationally and nationally. The requirement of an equitable distribution of the cost responsibility and cost-effective measures must be met. The Swedish climate strategy should be formulated so that carbon dioxide emissions in Sweden are restricted as much as possible without unduly compromising competitiveness, employment and welfare. Production and use of alternative fuels shall be supported as a means of reducing polluting emissions from traffic.
>
> The trend towards an increasingly international electricity market necessitates that measures against emissions from electricity generation be coordinated within Europe as far as possible. Sweden shall work actively for emissions reductions even from activities exposed to competition, such as energy-intensive industry.

The political process will be continued with the presentation of the Energy Bill in the middle of March 1997[8].

5.2.1 Energy and environmental taxation

The use of energy in Sweden has long been subject to excise taxes such as general energy tax, special tax on petroleum products and coal, and production taxes on hydropower and nuclear power. The energy taxes have been motivated by both energy-political and purely fiscal reasons. Since 1989 the energy taxation has undergone several major and minor changes. An account is given below of the main aspects of the changes, followed by an description of the present-day structure of the taxation.

Changes in energy and environmental taxes since 1989

In conjunction with the reform of corporate and income taxation in Sweden in 1990, VAT was imposed on energy. The VAT was levied on the energy price, including excise taxes. In order to obtain a price structure consistent with the national political goals, supplementary environmental taxes and environmental charges were introduced

In 1991 a tax was introduced on emissions of carbon dioxide equal to SEK 250 per tonne of carbon dioxide. Fuels for electricity production were exempted from the carbon dioxide tax. Fuels for electricity production were exempted from the carbon dioxide tax, as they were from the general energy tax. At the same time as the carbon dioxide tax was introduced, the energy taxes were reduced by 50%. That same year a sulphur tax was also introduced equal to SEK

[8] Gov. Bill 1996/97:84 ”A Sustainable Energy Supply”

30 per kg of sulphur emissions on coal and peat, and SEK 27 per cubic metre for every tenth of a percent by weight of sulphur content in oil.

A nitrogen oxide charge was introduced in 1992 for certain plants. The charge is SEK 40/kg emitted No_x (calculated as NO_2). Boilers or gas turbines larger than 10 MW or with an energy production larger than 50 GWh annually was originally covered by the system. Today the capacity limit is abolished and the charges applies to boilers with an energy production larger than 25 GWh per annum.

Further changes were made in the energy tax system in 1993. The changes mainly apply to industry. In the former system, energy-intensive industry was able to obtain a tax abatement.[9] In the new system, the general energy tax on fuels and electricity was now instead abolished for the entire industrial sector, and the carbon dioxide tax was reduced to one quarter of the general level of the carbon dioxide tax. The tax reform led to a general lowering of prices of fossil fuels for industry. For other users, the energy tax remained at the same level and the carbon dioxide tax was raised from SEK 250 to SEK 320 per tonnes of carbon dioxide to finance the reform.

To prevent them from being undermined by inflation, it has been decided that the energy and carbon dioxide taxes are to be index-adjusted, which means that the taxes are written up annually by the consumer price index.

As from 1 January 1995, a new act is in effect, the “Act on Energy Tax”. The new act includes a modified taxation procedure in accordance with the EC’s mineral oil directive.

To help finance Sweden’s membership fee to the EU, energy taxation was changed as per 1 January 1996. The carbon dioxide tax was raised to SEK 360 per tonne of carbon dioxide. The electricity tax was raised by SEK 5 per MWh and the time limit for index-adjustment of the energy and carbon dioxide taxes was abolished. Furthermore, the production tax on hydropower plants commissioned prior to 1973 was raised by SEK 20 to SEK 40 per MWh. For hydropower plants commissioned during the period 1978–1977, the tax was raised from SEK 10 per MWh to SEK 20 per MWh. The production tax on nuclear power plants was also raised from SEK 2 to SEK 12 per MWh.

On 1 September 1996 the energy tax on all fuels, plus the special tax on nuclear power, were raised. The raise varied. For the fossil fuels oil, coal, natural gas and LP gas the energy tax was raised by about 11%. For petrol and diesel the equivalent rise was about 3% and for electricity between 15 and 35%, depending on the customer category. The special tax on nuclear power was raised from SEK 12/MWh to SEK 22/MWh. Another increase in the energy tax was effected on 1 July 1997. In addition, on 22 November 1996 the Riksdag passed a resolution to change the taxation of hydropower by abolishing the current taxation of hydropower and replacing it with a special property tax. The planned increase in the special nuclear power tax from SEK 22 to 32/MWh as of 1 July 1997 was rescinded at the same time.

Besides the above-mentioned changes in energy taxation, the Government has put forth a proposal to raise the carbon dioxide tax for industry and simultaneously introduce abatement rules for the energy-intensive sector of industry. The matter was tabled pending a ruling by

[9] The tax abatement entailed that the companies did not have to pay energy tax (nor CO2 tax after 1991) in excess of a certain proportion of the sales value of their production. This has varied over the years between 1.3 and 1.7%.

the EU on whether the Swedish decision is compatible with the rules of competition, the mineral oil directive and the coal and steel treaty. The EC institutions' review of tax relief for energy-intensive activities is concluded, with a positive result for Sweden. Sweden has been given a time-limited approval for three years.

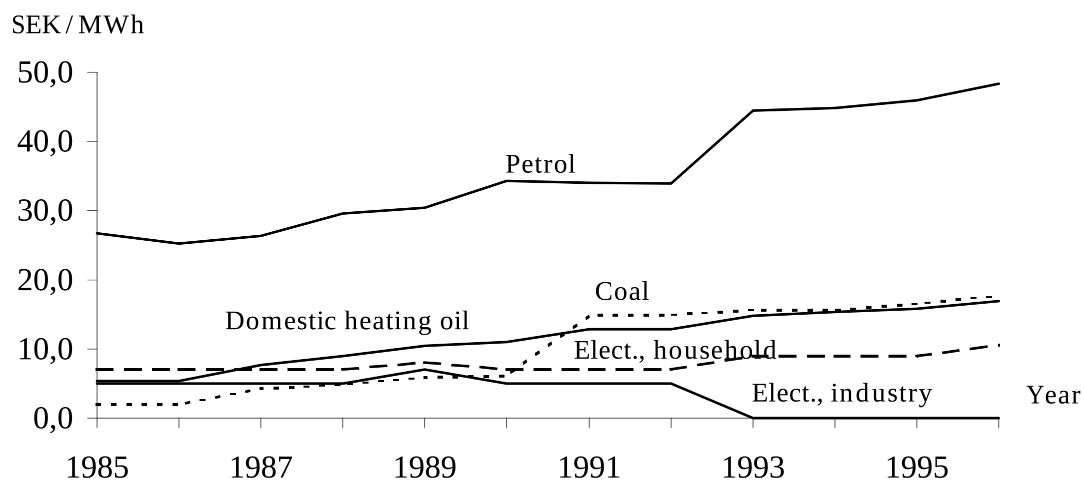
Table 5.1 Energy and environmental taxes on different fuels 1985-1996, not including VAT, current prices

Year	Petrol SEK/litre	Domestic fuel SEK/m^3	Coal SEK/tonne	Natural gas SEK/1,000 m^3	Electricity, household SEK/MWh	Electricity, industry SEK/MWh
1985	2.33	533	150	308	70	50
1986	2.20	533	150	308	70	50
1987	2.30	758	318	308	70	50
1988	2.58	883	366	308	70	50
1989	2.65	1033	438	329	80	70
1990	2.99	1083	463	350	70	50
1991	2.97	1267	1124	710	70	50
1992	2.96	1267	1124	855	70	50
1993	3.88	(230) 1460	(350) 1180	(170) 855	90	0
1994	3.91	(239) 1519	(358) 1180	(177) 889	90	0
1995	4.01	(246) 1559	(364) 1249	(181) 912	90	0
1996	4.22	(264) 1676	(379) 1331	(197) 990	1050	0

Note: In cases where the taxes have been changed in the middle of a calendar year, an unweighted average is given. Figures in parentheses after 1993 pertain to industry. The electricity tax for households applies to southern and central Sweden. As from 1990, VAT is payable on the indicated taxes. In 1990 the VAT rate was 23.46%, in 1996 it is 25%.

Source: National Tax Office, special tax office in Ludvika

Figure 5.1 Energy and environmental taxes 1985-1996, SEK/MWh, not including VAT, current prices



Note: As from 1993, industry's tax on coal and oil is one quarter of the level reported in the figure.

Source: National Tax Board, special tax office in Ludvika.

Current energy and environmental taxes

Table 5.2 shows current Swedish energy and environmental taxes. In addition to the taxes presented in the table, VAT is payable at a rate of 25%, and where applicable an environmental charge for emissions of nitrogen oxides[10]. The energy and environmental taxes differ between industry and other users. Industry pays no energy tax and only one quarter of the carbon dioxide tax paid by other users.

Biofuels are untaxed for all users. For all fuels used for electricity production, including in CHP plants, deduction of energy and carbon dioxide taxes is allowed. On the other hand, electricity is taxed at the consumer level, i.e. when electricity is used. Moreover, all fuels used for electricity production are subject to sulphur tax, and the energy production plants are subject to nitrogen oxide charges. On top of this, a special tax is levied on electrical power from nuclear power plants, and a special property tax is paid for hydropower.

Fuel used for healing purposes only e.g. not heat produced in CHP-plants pays full energy, carbon and sulphur taxes. Final consumers do not pay any energy or environmental taxes but VAT. For deliveries of district-heat to industry, repayment of the energy tax and three quarters of the carbon dioxide tax is allowed on fuels that were consumed in the production of the heat. The rules for the taxation of CHP plants have been changed several times in recent years. At present, fossil fuels for heat production are subject to half of the energy tax plus full carbon dioxide and sulphur taxes.

[10] The charge applies to energy production with boilers, gas turbines and stationary combustion engines with a minimum annual energy production of 25 GWh. The charge is repaid in proportion to the plant's energy production.

Table 5.2a Energy and environmental taxes as from 1 January 1997, not including VAT[1)]

	Energy tax	CO_2 tax	Sulphur tax	Total tax	Tax SEK/MWh
Fuels[2)]					
Light fuel oil, SEK/m^3, environmental class 3 (< 0.1% sulphur)	654	1 050	-	1 704	172
Heavy fuel oil, SEK/m^3 (0.4%sulphur)	654	1 050	108	1 812	168
Coal, SEK/tonne (0.5% sulphur)	278	913	150	1 341	177
LP gas, SEK/tonne	127	1 101	-	1 228	96
Natural gas, SEK/1,000 m^3	212	785	-	997	92
Peat, SEK/tonne 45% moisture (0.2% sulphur)	-	-	40	40	15
Fuels[3)]					
Petrol, leaded, SEK/l	4.03	0.86	-	4.89	561
Petrol, unleaded, SEK/l					
environmental class 2	3.41	0.86	-	4.27	490
environmental class 3	3.47	0.86	-	4.33	496
Diesel, SEK/l					
environmental class 1	1.52	1.05	-	2.57	260
environmental class 2	1.74	1.05	-	2.79	282
environmental class 3	2.02	1.05	-	3.07	311
Natural gas, SEK/1,000 m^3	584[5)]	785	-	2369	219
Electricity, consumer tax					
Electricity, northern Sweden, SEK/MWh	58	-	-	58	58
Electricity, rest of Sweden, SEK/MWh	113	-	-	113	113
Electricity, district heat producers northern Sweden, SEK/MWh	58	-	-	58	58
Electricity, district heat producers others, SEK/MWh	91	-	-	91	91
Electricity, production tax[4)]					
Nuclear power, SEK/MWh				22	22

1) VAT of 25% is payable on the taxes.
2) for fuels used for electricity production, deduction is allowed for energy and carbon dioxide tax. Fossil fuels for heat production in CHP plants are subject to half energy tax and full carbon dioxide and sulphur taxes. Biofuels are untaxed for all users.
3) Aviation fuel is not directly taxed. Domestic aviation is however taxed via the Civil Aviation Administration's environmentally related take-off and landing fees.
4) A special property tax is payable for hydropower instead of the former tax on hydropower.
5) Via pilot project dispensations, however, energy tax is charged for motor vehicle fuel users in amounts corresponding to the level that applies to heating.

Table 5.2b Industry's energy and environmental taxes as per 1 January 1997, not including VAT

	Energy tax	CO_2 tax	Sulphur tax	Total tax	Tax SEK/MWh
Light fuel oil, SEK/m^3	0	263	-	263	27
Heavy fuel oil, SEK/m^3	0	263	108	371	34
Coal, SEK/tonne	0	228	150	378	50
LP gas, SEK/tonne	0	275	-	275	21
Natural gas, SEK/1,000 m^3	0	196	-	196	18

Source: National Tax Board, Tax Administration and own calculations.

5.2.2 National energy programmes

Through the 1991 Energy Policy Bill, Sweden's energy policy was allocated additional resources to facilitate the transformation of the energy system to nuclear power phase-out and an improved environment. The additional programmes were investment support to biofuel-based CHP production, investment support to wind power and solar heating, additional funds to the Energy Technology Fund, support programme for biofuel-based electricity production, the programme for more efficient use of energy and support to ethanol production.

The 1993 Climate Policy Bill added support for construction of district heating systems. Furthermore, funds were allocated for investments in substitution of biofuels for fossil fuels and energy efficiency improvements in the Baltic states and Eastern Europe[11]. Table 5.3 presents the most important programmes, their budgets in SEK million and their timetables.

Table 5.3 Energy programmes, SEK million

	Budget	Programme period
Investment support		
CHP, bio	1,000	1991-1996
Wind power	340	1991-1996
Solar power	138	1991-1996
District heating	150	1993-1996
Development and demonstration	approx. 72 per year	1988-1991
Energy Technology Fund (incl. transportation)[1)]	approx. 170-200 per year	1991-1996
	approx. 72 per year	1996-1997
FABEL - electricity from biofuels	625	1992-1997
Ethanol from cellulose raw materials		
More efficient use of energy	1,000	1991-1998

1) The Swedish Transport and Communications Research Board's investment for demonstration in fleets for ethanol and biogas is included in the Energy Technology Fund.

Investment support

[11] See section 5.3.3 regarding the investments in the Baltic states and Eastern Europe.

Investment support to CHP production with biofuels has been paid at a rate of:

- SEK 4,000 per kW of installed electrical output to investments in *new* plants for CHP production with biofuels.
- 25% of the investment cost for *rebuilding of existing heating plants* to CHP production with biofuels. The subsidy may not exceed SEK 4,000/kW of installed electrical output.
- 25% of the investment cost for *conversion of fossil-fuelled CHP plants* to plants for CHP production with biofuels. The subsidy may not exceed SEK 4,000/kW of installed electrical output.

The actual use of biofuels on an annual basis in both new and rebuilt or converted plants has amounted to at least 85% of the total fuel consumption in the biofuel-fired boiler during a period of 5 years.

Support to investments in wind power plants was originally given at 25% of the investment cost, which was later changed to 35%. To obtain support, the plant had to have an output of at least 60 kW.

Support to investments in solar heating plants was given at up to 25% of the investment cost.

The purpose of the support to district heating system construction has been to enable emissions of carbon dioxide to be reduced by increasing the use of district heating. Subsidies of 15% of the investment cost were given for the portion of the distribution system located between the district heating plant and the subscriber's system. Subsidies could also be given to investments in pipelines to interconnect the district heating network.

Production subsidies

Since 1 July 1994, wind power production receives a production subsidy (environmental bonus) equal to the excise tax on electricity. In southern and central Sweden, this amounts to SEK 113/MWh as from 1 September 1996 and will be raised to SEK 138/MWh. In northern Sweden the bonus is SEK 58/MWh and will be raised to SEK 82/MWh.

Support to development and demonstration

The Energy Technology Fund was established in 1988. The purpose of the fund was originally to develop, or prepare for the commercial introduction of, new energy technology or new pollution control technology. The rules for the fund were changed by the passage of the Energy Bill in 1991 so that funding in accordance with current guidelines can also be given to programme-oriented research and joint sectoral research. The possibility of funding new pollution control technology via the fund was abolished in 1994.As a result of the change of rules made in 1991, the Energy Technology Fund complements state-funded energy research. In this way, increased scope has been given to collective research programmes with a greater emphasis on application, while support to experimental facilities has declined.

During 1995 and 1996 some 20 or so such programmes have been active, with a total budget of SEK 166 million. Examples of programmes include research on forest-based bioenergy, ash recycling, straw fuels, energy forest, biogas, alternative refrigerants, district heating, hydropower and black liquor gasification. Through the programme, companies participate actively in both funding and management of the activities. This has resulted in an emphasis on applied research and development which is prioritized by both the state and the concerned sectors and companies. A close interaction between universities and the business community in cross-sectoral R&D programmes contributes simultaneously to effective knowledge transfer and good mobility of competence between different actors. At the same time, support to pilot and demonstration plants comprises a complement and is an important part of an overall research strategy.

Altogether some 580 projects have been granted support[12], normally in the form of grants of between 25 and 40% of the project cost. This is equivalent to between SEK 170 and 200 million per year in allocated funds.

A programme for the promotion of biofuel for electricity generation – FABEL – was established in 1992 as a result of the 1991 Energy Policy Bill. The purpose of the programme is to increase the efficiency and improve the environmental performance of biofuel-based electricity production. Its main thrust is support to development and demonstration of technology for electricity production based on biofuels. Technology for fuel production can also obtain support. However, the technology must be particularly suited for fuel production in conjunction with a large-scale expansion of biofuel-based electricity generation. The programme comprises a complement to other programmes and has, for example, been combined with the investment support to CHP. It was decided in 1993 to allow these funds to be used also for demonstration plants for production of ethanol from cellulose-rich raw materials

Within the framework of the energy research programme, support is given to research and development of new technology for ethanol production in the amount of SEK 4 million per year. The research programme for alternative fuels was supplemented in 1993 with a development programme of SEK 15 million per year for three years to support the development of new technologies. These funds are mainly intended to support research and laboratories for the production of ethanol from cellulose.

Programme for more efficient energy use

The programme for more efficient energy use and replacement of electricity begun in 1988 was strengthened and broadened by the 1991 Energy Policy Bill. The technology procurement programme was given additional resources and broadened to encompass the entire field of energy use. The emphasis in the programme lies on the efficiency-improvement programme being conducted by NUTEK (the National Board for Industrial and Technical Development)[13]. The programme is based on technology procurement, framework agreements and programme requirements. It is hoped that by augmenting technology procurement with demand-boosting measures (framework agreements and programme requirements), a wider use of the procured technology will be achieved. The programme also includes support for

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[12] Not including projects within the framework of the programme for more efficient energy use on commercial/institutional and residential premises.

[13] Several authorities are involved in the programme for more efficient energy use (NUTEK, the National Board of Housing, Building and Planning, the Swedish Transport and Communications Research Board, the Council for Building Research, the National Board for Consumer Policies and the Swedish Environmental Protection Agency).

demonstration of energy-efficient technology in the residential, commercial and industrial sectors plus backing of the work with energy labelling, product testing and information. Altogether, the programme for more efficient energy use has at its disposal funds of nearly SEK 1 billion during a seven-year period.

National energy and climate programmes – transport sector

Programmes for research, development and demonstration (RD&D) concerning the climatic impact of the transport sector are planned and funded by the Swedish Transport and Communications Research Board, KFB, and the National Board for Industrial and Technical Development, NUTEK.

Climate issues are of central importance in both the regular research programmes on planning, decision processes etc. and the special interdisciplinary programmes on environmentally related transport research conducted by KFB. KFB is also in charge of RD&D programmes on biobased fuels and on electric and hybrid vehicles which are funded outside of the usual appropriations and require a high degree of co-funding with parties in the business community. In 1990 the Riksdag allocated SEK 190 million to the programme for biobased fuels, which will be concluded at the end of 1997. In 1993, the Riksdag allocated SEK 115 million to the RD&D programme with electric and hybrid vehicles for a four-year project.

A number of RD&D programmes and competence centres for closer collaboration with the business community are being run by NUTEK, in the area of Transport Means and Energy Systems. The RD&D programmes of which NUTEK is in charge are concerned with engines, combustion technology and production of alternative fuels. The activities also encompass technology procurement of electrical vehicles, information technology for transportation and logistics for commerce and industry. NUTEK's programme for transportation technology, which is concerned with energy systems and climate questions, comprises activities for about SEK 70 million during 1996.

5.2.3 Activities Implemented Jointly, AIJ

At the first Conference of the Parties in 1995, it was decided to introduce a pilot phase for joint implementation. Activities Implemented Jointly (AIJ) are be undertaken during a pilot phase lasting until the year 2000 at the latest. During this pilot phase, the countries may not accrue credits for the emissions reductions that are achieved by the activities. Another prerequisite for a project to be included in the pilot phase is that the financing of this project is additional, i.e. not included in the normal foreign aid commitments of the developed countries. No rules have been established for the period after the pilot phase.

The Swedish programme - Baltic/East programme at NUTEK

Sweden ratified the UN Framework Convention on Climate Change (UNFCCC) in 1993 in conjunction with the Riksdag's approval of the Climate Bill[14]. Besides a national Swedish

[14] Gov. Bill 1992/93:179

programme, a proposal was simultaneously approved for pilot programmes aimed at the execution of projects in Sweden's "near region", the Baltics and Eastern Europe. The projects are supposed to lead to increased energy efficiency and an increased use of renewable fuels in the district heating sector in this region[15]. The fact that the forms for so-called joint implementation had not been finalized at this point should not, in the Government's opinion, constitute an obstacle to climate-related initiatives in the Baltic States and Eastern Europe.

The purpose of the programme is to investigate the possibilities of contributing to reduction of carbon dioxide emissions via joint implementation in accordance with the UNFCCC. The programme has been granted SEK 277.5 million through budget year 1995/96. The Government Bill further provides that most of the funds are to be used for loans on commercial terms to plant-owners to finance the projects, and that a smaller portion is to be used for subsidies to support the execution of the projects. The projects are to be implemented taking into account both Swedish technical and industrial know-how and Swedish experience, and the recipient countries' corresponding technical and administrative capacities. It has further been decided that repaid interest and principal should be returned to NUTEK's appropriation for funding future projects within the programme. The Government further prescribes that the projects are to be continuously evaluated and followed up, and reported on in accordance with the guidelines adopted for the pilot phase for JI/AIJ.

Results and experiences from executed projects[16]

The projects in the Baltic/East programme are primarily aimed at the district heating sector and encompass production, distribution and end use of district heating in buildings.

Since the start in April 1993, a total of about 60 projects have been approved, of which about 40 have been completed and 20 are in progress, 10 of which were approved during 1996. The projects are being carried out in the district heating sector in the Baltic countries and in the St. Petersburg and Kaliningrad areas in Russia. In addition there is a biogas project in Gdansk in Poland. Some of the projects involve funding of twin city projects.

The production projects mainly involve the conversion of 3–10 MW boilers in heating plants from use of fossil fuels such as heavy fuel oil and coal to biofuels, i.e. wood chips, forest waste and waste from the wood-processing industry. Within the framework of a special small-boiler project in Latvia, based on the technology procurement model used by NUTEK in Sweden to promote the development of energy-efficient products, four projects of around 1.5 MW have so far been carried out.

The distribution projects concern renovation of the district heating networks by replacement or reinsulation of the piping systems, water treatment to extend the life of the entire system, and installation of subcentres and control equipment etc.

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[15] Funds for the programme were appropriated by the Ministry of Industry and Commerce and NUTEK was commissioned to execute the programme. NUTEK had previously been allocated a lump sum of SEK 45 million for such projects in the Baltic Sea Bill 1992/93:99 from the Environmental Ministry's appropriation.

[16] In connection with the second Conference of the Parties (COP2) to the UN Climate Convention in July 1996, Sweden presented a first preliminary report of the results of the Swedish programme, which is administered by NUTEK. The report is currently subject to review and comment by the cooperating countries so that Sweden and the country in question will be able to submit joint reports to the Climate Convention's secretariat.

The efficiency improvement projects in buildings comprise measures such as rebuilding or reinsulation of roofs, installation of subcentres, heat exchangers, measurement and control equipment, balancing of systems and weatherproofing of windows and doors etc. Other building renovation measures than those that are of vital importance and are cost-effective from an energy efficiency viewpoint are not included, for example insulation of exterior walls is not included other than in exceptional cases.

The projects are being executed in cooperation with the appropriate ministries and authorities in the country in question, either in response to direct proposals from them or by their approval of project proposals submitted directly by e.g. municipalities or plant-owners.

Loans to plant-owners or similar persons are generally given for ten years and with two amortization-free years. The interest on the loans consists of STIBOR[17], occasionally with a surcharge of 0.5%. The ambition in the projects is that they should have a payback time that is shorter than the loan period. The payback time in the boiler conversion projects is estimated to average about 5 years, in the distribution projects the payback time varies between about 2 and 12 years depending on to what extent new pre-insulated pipes are required. In the building projects, the pure energy efficiency improvement measures have a payback time of 7–9 years, while those building renovation measures that are deemed necessary from an energy efficiency viewpoint have a payback time of 16–20 years.

Table 5.4 shows the results of completed projects. The projects are divided into boiler conversions, renovation of district heating networks and energy efficiency improvements in buildings. The table shows the emission reductions yielded by the projects in each project and country, and the specific cost in Swedish kronor per reduced kilogram of emissions, counted as an average of all concerned countries' results in each group of projects[18].

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[17] Stockholm Interbank Offered Rates, which are established by a group of Swedish commercial banks for financing costs within the Swedish banking system for loans of between 1 month and 1 year.
[18] The account is based on the data furnished in the above-mentioned report to the COP2 meeting in Geneva.

Table 5.4 Results of completed projects

						Emission reduct. in tonnes		
Boiler conversion	No. of projects	Inv. MSEK	Cap. MW	MSEK/ MW	Prod. MWh/y	SO_2	CO_2	NOx
Estonia	7	36.9	41.0	0.90	208 000	1 033	67 700	26.2
Latvia	10	32.2	32.9	0.89	171 500	587	78 400	33.6
Lithuania	5	23.5	26.2	0.95	157 000	798	60 200	33.2
Russia	1	2.4	2.0	0.91	10 000	30	3 900	2.6
Total	**23**	**94.2**	**103.1**	**0.91**	**556 500**	**2 504**	**213 900**	**97.8**

Renovation of district heating network	No. of projects	Inv. MSEK	Reduc. loss MWh/y *heat*[1]	Reduc. loss MWh/y *water*	Connected capacity MW	SO_2	CO_2	NOx
Estonia	3	9.7	12 100	2 600	52.5	82.7	4 900	8.6
Latvia	2	5.9	3 400	100	138.0	20.8	4 412	4.2
Total	**5**	**15.6**	**15 500**	**2 700**	**200.5**	**103.5**	**9312**	**12.8**

Energy efficiency in buildings	No. of projects	Inv. MSEK	Energy use MWh/y	Estimated energy saving MWh/y	SO_2	CO_2	NOx
Estonia	2	7.50	8 850	2 300-2 700	5.35	612	0.40
Latvia	2	1.83	4 500	950-1 150	2.5	290	0.19
Lithuania	1	2.70	10 800	3 350	34.0	2 200	1.40
Total	**5**	**12.03**	**24 150**	**6 600-7 200**	**41.9**	**3 102**	**1.99**

1) In addition, better utilization of converted heating boilers in one project each in Estonia and Latvia has made it possible to produce an additional 15,500 MWh/y of biofuel-based heat and to retire fossil-fired boilers.

In addition to the project reported above, support has also been given to five twin city projects, two of which have involved support for installation of biofuel-fired boilers donated by Swedish twin city municipalities, and three projects involving energy efficiency improvement measures in school, day-care centres, etc.

The total emission reductions can thus be estimated to be:

CO_2	approx.	220,000 t/y
SO_2	approx.	2,500 t/y
No_x	approx.	120 t/y

At the same time, heavy fuel oil and coal in the amount of about 61,500 t/y and 18,500 t/y, respectively, has been replaced by biofuels. Improvements in distribution networks have enabled oil- and coal-fired boiler plants to be closed in some cases, equivalent to an annual use/combustion of an additional 2,000 tonnes of oil and 1,000 tonnes of coal. Boiler conversions and renovation of distribution networks have thus enabled about 63,500 tonnes of oil and about 19,500 tonnes of coal to be replaced by biofuel.

Most of the projects have been implemented in the Baltic countries.

In *Russia*, a boiler conversion project has been completed near St. Petersburg. Another ten or so projects in the St. Petersburg and Kaliningrad areas are in the process of being implemented. The reason why more projects are not being conducted in Russia is that the decision-making process there is more drawn-out. Besides loan agreements and guarantees from the plant-owners or municipal authorities, the borrower must also obtain a permit from the Central Bank to take loans from abroad. The first permit took more than 6 months to obtain. Nowadays permits are issued within just over a month. Aside from boiler conversions, the projects in Russia include renovation of the distribution systems and energy efficiency improvements in buildings, including three hospitals in Kaliningrad and one in St. Petersburg.

Other activities, evaluations, follow-up measures, spin-off effects

Knowledge transfer

Besides executing projects, NUTEK has also held a number of seminars based on manuals in local languages produced in connection with the programme. Aside from technical matters, economic aspects including rates and contracts between producers and distributors and between distributors and consumers are also dealt with. In addition, a number of seminars and workshops have been held on different topics in the heating sector and e.g. biofuel extraction and biofuel handling.

The economic topics include procurement of equipment and fuel, maintenance and rates. These are included as integral parts of the projects. New schedules of rates are intended to be introduced at a couple of the towns where projects have been carried out.

Evaluations, international work, etc.

Local experts make continuous evaluations of the projects. Within the framework of a cooperative project between the Chalmers University of Technology and the Tallinn University of Technology, a number of Swedish and Estonian students have carried out degree projects based on studies of different technical and economic aspects of projects in Estonia. The projects were also included in the evaluations that served as a basis for the Bill on future cooperation with the countries of Central and Eastern Europe that was passed by the Riksdag in the spring of 1995. A hearing with workshops was held in October 1995 attended by representatives of the energy and environmental ministries in the cooperating countries and by Swedish and international experts. Different parts of the programme have also been the subject of studies by a special Nordic panel of experts and other international experts. Among other things, cost-effectiveness has been evaluated in the light of the criteria that apply for the UN Global Environment Facility (GEF)[19].

A special function and measurement programme regarding environmental effects was executed in February 1995 at a number of completed projects in Estonia and Latvia. A new similar programme is being prepared for the upcoming heating season.

The Baltic/East programme has been given positive judgements in evaluations, and there is great interest in all the cooperating countries that the programme should continue. International and local funding bodies have also expressed interest in cooperation based on the experience gained in the programme. An important indication of the success of the projects is that the repayment discipline for the loans is good, in several cases it has been found possible to start the repayments earlier than stipulated in the loan agreements.

Spin-off effects

All procurement of equipment and services in the projects takes place in open competition in which Swedish, Nordic, international and local companies can all compete with tenders. A review of some 25 or so completed boiler conversion and distribution projects in the Baltic states shows that about 65% of the orders have gone to Swedish companies and 30-35% to local companies. Several Swedish companies have, after participating in one project, continued participating in other projects in the region, both inside and outside the framework of the programme.

5.3 Transport policy during the 1990s

The activity trend in the transport sector is closely associated with economic growth, but is also dependent on the development of the social structure and investments in transportation infrastructure. Current trends suggest, among other things, a continued thinning-out and functional fragmentation of urban areas. For example, peripheral siting of commercial centres has become increasingly common. At the same time, the increase in transport activity as a consequence of this trend is counteracted by a certain densification of development in urban areas. An increased utilization of information technology can also lead to new transport patterns and more efficient transportation.

The development of transport activity is of great importance for the impact of transport on climate and environment. There is a close connection between increasing traffic and increasing carbon dioxide emissions. Emissions of carbon dioxide from road traffic increased slightly during the period 1990–1992, but decreased in 1993 to just below the 1990 level. Emissions once again increased during the years 1994 and 1995. In 1995, emissions of carbon dioxide from road traffic were 1.7% higher than in 1990. Carbon dioxide emissions have

[19] Evaluations will also be made at some plants within the framework of an EU-funded project entitled “Joint Implementation: - accounting and accreditation of joint implementation projects under the Framework Convention on Climate Change and the Second Sulphur Protocol” for which the University of Surrey in England is the coordinator and in which NUTEK and the Stockholm Environment Institute are participating.

increased steadily since 1990 for the entire transport sector, including international air and sea transport, but not including off-road vehicles, work implements and construction equipment, and it is estimated that these emissions were 8% higher in 1995 than in 1990. Emissions from domestic transport, not including off-road vehicles, work implements and construction equipment, increased by just under 4% during the same period.

Of other climate-affecting gases, some quantities of methane and nitrous oxide also come from the transport sector. Emissions of carbon monoxide, other volatile hydrocarbons and nitrogen oxides from traffic also contribute indirectly to the greenhouse effect. Emissions of nitrogen oxides, hydrocarbons and methane have declined as a result of the installation of catalytic converters and the tougher emissions standards that were introduced for passenger cars from the 1989 models. On the other hand, the increased use of catalytic converters in cars has led to increased emissions of nitrous oxide.

Principles and overall goals for the current national transport policy were established in the 1988 Traffic Policy Bill. It was determined that a socioeconomic approach would be adopted, and guiding principles that were established concerned the consumer's free choice, the social responsibility of transport facilities, the conditions for competition and interaction, and cost responsibility of transport.

The Government decided in December 1996 to propose in Gov. Bill 1996/97:53, "Infrastructure strategy for future transport", a revised strategy for the long-term infrastructure plans. The proposal was based on the proposal put forth by the parliamentary Transport and Communications Committee and entails a continuation of the previously decided investment in expansion of the railway network. Besides creating a good infrastructure for passenger train transport, the investment programme will also improve conditions for freight train transport. For the road network, the strategy entails a reorientation from big investments in the national trunk roads to increased efforts to improve the existing road network as regards accessibility, environment and traffic safety. The Riksdag passed the Government Bill in March 1997. The new plans for the period 1998 - 2007 will now immediately be prepared by regional and central authorities. However, the forecast that has been used for carbon dioxide emissions from transportation in the national report does not include the consequences of the Riksdag's decision regarding new investments in roads and railways after 1997.

In 1991, appropriations for investments in roads and railways were doubled in conjunction with the Government Bill on Commerce and Industry for Growth. This decision emphasized the importance of the infrastructure investments for the competitiveness of commerce and industry. At the same time, an environmental policy bill was passed which established overall goals for Swedish national environmental policy and the principle that the transport sector should contribute towards the fulfilment of these goals. The decision called for increased sectoral responsibility and decentralization as a main line for the future environmental policy.

With the support of material from the various transport authorities proposing alternative strategies for action within the various transport modes, the Government and the Parliament passed a new transport policy bill in 1993 outlining strategies for investments in roads and railways. On the basis of the strategy decisions, the concerned authorities were instructed to draw up plans for the period 1994–2003.

In 1992, the Government instructed the transport authorities to submit annual environmental reports. That same year, the Swedish Environmental Protection Agency proposed sectoral goals to the transport authorities. On the eve of the budget year 1994/95, the Government instructed the National Road Administration and the National Rail Administration to quantify the environmental goals. The National Road Administration's instruction included quantifying the goals for emissions of, among other things, carbon dioxide, nitrogen oxides etc. In response to the instruction, the National Road Administration proposed that no increase in carbon dioxide emissions should occur between 1990 and 2000. This goal coincides with the national goal for total emissions in Sweden decided on by the Riksdag.

The commenced investment programme in roads and railways is expected to lead to a small increase in emissions of carbon dioxide from road and rail traffic due to the higher speeds that will be allowed on the road networks. A small increase in carbon dioxide emissions is also believed to have resulted from the raising of the speed limit on motorways to 110 km/h in 1992 on motorways that had had a top speed of 90 km/h since 1989.

Taxation of road traffic is an important element of transport policy, providing an instrument to influence the composition and turnover of the motor vehicle fleet, the environmental and safety characteristics of the vehicles, and transport activity. For example, the tax level is differentiated between different fuel grades in order to promote the development of cleaner fuels and less polluting vehicles. The summary of energy and environmental taxes shown in Table 5.1 shows how the tax on petrol has eveloved since 1985. Since 1991, this tax includes a carbon dioxide tax which is estimated to have generated about 11% of the state's revenues from road traffic-related taxes in 1996. A VAT of 23.46% was imposed on petrol in 1990, and has subsequently been raised to 25%.

Up until October 1993, a tax was paid on diesel-powered trucks, cars and buses which was based on distance driven (kilometre tax). This tax was abolished and replaced by a diesel oil tax for administrative reasons and because Sweden could not have a system that required border controls, which the kilometre tax did, after joining the EU. The vehicle tax for diesel-fuelled passenger cars was also raised sharply in 1993, and lowered slightly for heavy vehicles.

The environmental and carbon dioxide charges that were introduced in 1990 for aviation have been abolished as of 1 January 1997. A defect in the design of these charges was that they did not co-vary with the actual emissions. The intention is, however, to create a new environmentally related charge system for aviation.

A system for environmental classification of cars was introduced in 1992 via provisions in the Motor Vehicle Emissions Act. The purpose was to accelerate the development of better emissions control technology and, together with tax rebates, create a demand for cars with lower emissions. The environmental classes include requirements on emissions of carbon dioxide, hydrocarbons, nitrogen oxides and particulates for the three groups passenger cars, light goods vehicles and heavy goods vehicles. The proportion of environmentally classified passenger cars increased rapidly from 11% in 1992 to 32% in 1994, and nearly 60% of the 1996 models were environmentally classified. There are no requirements on emissions of carbon dioxide or on fuel consumption. There are, however, guidelines supported by the Marketing Act regarding information on passenger car fuel consumption which also apply to information on environmental class as from 1993. Carbon dioxide emissions will also be specified as from 1997.

Within the maritime sector, a voluntary agreement was reached 1996 between the National Maritime Administration, the Swedish Shipowners' Association and the Swedish Port and Stevedoring Association on the installation of catalytic converters on ships for limitation primarily of nitrogen oxides, and on the use of low-sulphur oil for propulsion of the ships.

In 1996 the Riksdag decided to change the taxation of the company car benefit. The new system entails that people with company cars are supposed to pay the variable costs to a greater extent, giving them an incentive to drive less. It is, however, difficult to predict how fuel consumption and thereby carbon dioxide emissions will be affected, since it can be assumed that the company cars will lower the age of the car fleet and that people with company cars have higher incomes and can therefore be assumed to drive farther than average.

5.4 Measures within agriculture

As yet, no measures have been taken within agriculture for the express purpose of reducing the production of climate gases. Some of the measures that have been adopted for other purposes have had an effect against climate gases as well, however. Examples are measures against nitrogen leaching.

Carbon dioxide
Oxidation of organic matter in arable soil results in carbon dioxide formation. It is primarily in connection with drainage and tillage of organogenic soils that a net loss of carbon dioxide from the cropland is obtained. In mineral soils, an equilibrium has normally been established between the accumulation of carbon in the soil via plants and the loss of carbon via oxidation.

Possible and partially adopted measures:
- Intensively tilled organogenic soils are turned over to extensive grazing or afforestation. This results in a slower loss of CO_2.
- Restoration of wetlands on organogenic soils means that carbon dioxide loss is reduced, but methane emission increases at the same time.
- Increased cultivation of energy crops such as Salix reduces the amount of carbon dioxide emitted compared with the use of fossil fuels. Salix also increases soil carbon content. Salix is grown on approximately 16,000 ha in Sweden today.

Methane
Methane is formed by microorganisms in the gastrointenstinal tracts of ruminants when they digest their fodder (enteric fermentation). The lower the quality of the fodder, the more methane is formed. Formation of methane is reduced when cattle are raised mainly on grain. Adopted measures:
- Constant efforts to increase the yield from animal husbandry are reducing the amount of methane emitted per quantity of meat and milk produced.
- Measures adopted to reduce ammonia emission from manure storage result in a higher ammonia content of the manure, which may inhibit methane formation in it.

Nitrous oxide

Nitrous oxide is formed by denitrification in the soil. A small quantity of easily soluble nitrogen in the soil reduces the risk of increased emission of nitrous oxide. The action programme that has been adopted to reduce the leaching of plant nutrients from agriculture therefore also affects the emission of nitrous oxide.
Adopted measures via Section 6b of the Animal Husbandry Act and the Animal Husbandry Ordinance:

- Limitation of the number of animals per hectare in the whole country.
- 8-10 months' storage capacity for manure in K, LM, N and I counties as well as a coastal zone from the Norwegian border up to and including the Stockholm archipelago.
- Increased proportion of autumn- and winter-planted land. 60% in K, LM, N counties and 50% in the rest of southern Sweden.
- Ban on manure spreading during December-February in the whole country and restrictions on spreading in southern Sweden and in the coastal zone from the Norwegian border up to and including the Stockholm archipelago during August-November.

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With today's knowledge it is difficult to say how much the measures adopted in agriculture to reduce nutrient leaching will affect the emissions of climate gases from Swedish agriculture.

5.5 Measures within forestry

Measures in forestry affect the emission of greenhouse gases. The predominant flux in the Swedish forest is carbon dioxide, but emissions of methane and nitrous oxide also have a certain influence on the balance of greenhouse gases from the forest. Annual emissions of other non-methane volatile organic compounds (NMVOCs) from the trees in the forest are considerable but mainly constitute a natural source.

Carbon dioxide
Forest felling in the form of final felling, thinning and clearing amounted in 1992/93 to more than 67 Mm^3 sk (forest cubic metres, i.e. whole trees with bark) on the forest-productive area (22.9 Mha). The annual increment that year was 96 Mm^3 sk, which gives an annual average of 4.2 m^3 per hectare. The gross increase in the total volume of standing timber, including branches and stumps, corresponds to about 30 Mt CO_2, which is the carbon sink for the above-ground parts of the forest. Official felling statistics are not yet available for 1994 and 1995, but it is known that felling has been higher, especially during the boom year 1994, which would mean a correspondingly lower carbon sink for the forest in these years.

The timber balance for the Swedish forest is very positive, as is evident from Table 5.5.

***Table 5.5 Sweden's timber balance 1992/93*(not including tops and branches)**

	Total million m^3sk	Per hectare forestland m^3sk
Timber volume	2797	116

Increment	96	4.2
Felling (incl. clearing, thinning and final felling)	67	2.9

Whole-tree utilization mainly in the form of felling residues such as tree tops and branches leads in the long run to a marginal impact on the net flux of carbon from soil to atmosphere. Calculations show that removal of this waste from 300,000 hectare of forestland, which corresponds to 70% of the area which is finally felled and thinned annually, would reduce the carbon sink by 0.5 Mt C/y.

Fertilization of forest soil with nitrogen fertilizer leads to considerable accumulation of carbon in the soil and trees. Since the fertilized area is currently only 25,000 hectares/year, this has little effect on Sweden's carbon balance.

Liming of forest soil is currently being conducted on an experimental basis in southern Sweden (1995 about 5,000 hectares). Experimental results show that liming of nitrogen-rich soil can give rise to carbon losses (0.5 t C/ha,y). Liming of forest soil is therefore only recommended on soil where the advantages in terms of production are deemed to be of greater importance than the disadvantages of increased nitrogen cycling and carbon dioxide loss as a result of the measures.

Planting of forest on cropland generally leads to a relatively great increase in the carbon reservoir, (5,000 ha/y), Sweden's carbon balance is not significantly affected.

Soil scarification increases the net flux of carbon from the soil to the atmosphere. Methods which disturb the soil's surface layer as little as possible are preferable to more radical measures. In recent years, soil scarification has been site-adapted in such a way that the scarification methods are gentler and only affect the area to be planted/sown . Aside from various kinds of felling measures, soil scarification causes the greatest emission of greenhouse gases off all of the forestry methods. The potential for reducing the carbon loss by ceasing scarification entirely is estimated to be 0.6-2.5 Mt C/y for Sweden as a whole. Inadequate or no soil scarification can on certain soils lead to lower forest production and thereby a lower carbon sink. This factor should be taken into account in a holistic appraisal of the effects of soil scarification on carbon cycling.

Transition to sustainable silviculture methods and increased life of forest products
Changes in forestry practices which affect emissions of greenhouse gases:

- forest fuel as a substitute for fossil fuels.
- reduced size of clear-cut areas, reduced pre-regeneration cleaning, increased use of shelterwood all lead to improved soil husbandry, which sustains the soil carbon better than before.
- soil scarification is done using gentler methods.
- afforestation of arable land is contributing to an increase in the size of the carbon dioxide sink. The scope of this measure, which has been conducted since 1990 within the framework of the agricultural realignment programme, has so far been limited, however. According to the Agricultural Register, more than 14,000 hectares of cropland were

afforested between 1990 and 1993, and the contribution made by this to the carbon dioxide sink is insignificant.

- a transition to wood products with a longer life and increased recycling of paper products can reduce carbon dioxide emissions in the short term. The recycled fibre is an important raw material for the pulp industry today, covering about 10% of the annual requirement. At the same time as this leads to an increase in the carbon dioxide sink in the forest, the replacement of fossil fuel by old paper in heat production can also contribute to reducing carbon dioxide emissions.

Methane and nitrous oxide

The emissions of nitrous oxide affected by forestry have probably declined since 1990. The large uncertainties inherent in previous estimates make it impossible at present to specify values for this reduction. Ongoing acidification and future liming of forest soil may lead to an increase in these emissions.

5.6 Measures in the waste sector to limit methane emissions

The overall waste strategy should be to minimize the quantity of waste that needs to be disposed of on sanitary landfills. Environmentally good solutions for energy and material recovery should be chosen. Measures should be adopted to limit landfilling of readily degradable organic materials. Towards this end, the Government will consider proposals for a tax on landfilled waste. Programmes for collecting and using methane from existing landfills should be supported.

Of the waste that is produced in society today, it is the organic content of household refuse, sludge from sewage treatment plants, garden waste, agricultural residues and organic industrial waste that can generate methane in landfills.

The total potential for methane gas production is over 500 million m^3/year from the waste that is generated today, while the potential for landfilled waste is about 190 million m^3/year. Of this, sludge from the forest products industry generates about 28 million m^3 of methane per year. Of remaining waste, household refuse accounts for 80% of the methane production potential, i.e. about 135 million m^3 of methane per year. The organic waste that is not landfilled is treated by by incineration, composting or digestion.

An estimate of the total quantity of methane that escapes from the Swedish landfills is associated with great uncertainty. Methane is formed by anaerobic decomposition of organic matter. However, some of the material in the landfill is broken down aerobically or leached out with the leachate. Estimates of how much of the organic matter is degraded anaerobically differ, but 80% may be a reasonable assumption. Furthermore, a certain quantity of methane is oxidized in the landfill’s cover layer. Here again, estimates of what quantities are involved differ, but 10% might be a reasonable guess. With these assumptions, methane gas emissions from all landfilling would amount to 145 million m^3/year and from landfilling of household refuse to about 100 million m^3/year, if nothing were done to collect the methane.

In the Climate Bill 1992/93:179, the Government stated as a goal that methane gas emissions from landfilling should be reduced by 30% by the year 2000.

The principal measures that have been adopted to reduce methane emissions from landfills are installation of landfill gas recovery systems. As far as alternative treatment methods are concerned, a large-scale facility for digestion was taken into service in early 1995, and more facilities are planned.

1994 there were at least 56 sanitary landfills with landfill gas recovery.
In 1994, at least 90 million m^3 of landfill gas was withdrawn, which is equivalent to about 43 million m^3 of methane gas. The reduction of methane gas emissions entailed by digestion plants built to date has not been calculated, but is not estimated to amount to any large volume. This means that methane gas emissions today can be estimated to be about 90 million m^3/y.

In summery we expect that:

- The theoretically calculated reduction of methane gas emissions by means of landfill gas recovery up to 1995 comprises approximately 35-40% of the quantity of gas that would have been released without any measures, i.e. a reduction of emissions from 145 million m^3 to 90 million m^3.

- The theoretically calculated reduction of methane emissions by means of landfill gas recovery from 1990 up to today is about 28% of 1990 emissions, i.e. a reduction of methane emissions from 125 million m^3 to 90 million m^3 per year.

6. Forecasts and effects of measures

Future energy use will be highly dependent on how the Swedish economy develops. Up to now, increased economic activity has led to increased energy needs. Whether this will continue to be true in the future depends above all on how successful our efforts to improve efficiency in energy use are and what structural changes occur in the economy as it develops. Energy use is also affected by changes in the price of energy. A higher price normally results in lower use. The price relationships between different energy carriers affects the composition of energy use.

Conditions on the energy market are determined to a great extent by political decisions. Such decisions will influence energy use and energy production in the future. The present forecasts are based on the decisions that have already been made within the framework of Sweden's current energy and environmental policy.

A political process is currently under way in Sweden which is expected to lead to the energy policy guidelines that will govern future development in the energy sector. One of the important questions is at what pace Sweden's nuclear power plants are to be phased out, and how nuclear power is to be replaced, particularly with reference to the climate goals that have been set. One phase in the political negotiation work has recently been concluded, ending in an agreement between the Social Democrats, the Centre Party and the Left Party. The contents of this agreement are described in section 5.2. In March of 1997 the Government presented the new Energy Policy Bill.

The forecasts presented in this chapter were arrived at while the energy-political discussions were still in progress, in other words before the agreement was announced. Under the directives that govern this reporting, only measures based on political decisions actually taken are to be taken into account in the forecasts. This principle notwithstanding, we have, on the basis of available information, assumed that one nuclear power reactor will be shut down prior to the year 2000. For the calculations of the capacity and production volume of the electricity production system, we have assumed that the decommissioned reactor has an average capacity of 835 MW and an annual output of 5 TWh. It is further assumed that the other reactors will be used for their technical life, which is assumed to be 40 years. The present-day system of taxes and charges is assumed[20].

6.1 Forecast premises

6.1.1 Economic growth

Predictions regarding Sweden's future economic performance are necessarily associated with uncertainty. Sweden's total production of goods and services (GDP) grew considerably more slowly during the first half of the 1990s than during the 1970s and 1980s. However, following

[20] See Chapter 5.2.1, Table 5.2, for a presentation of current energy and environmental taxes.

a severe recession between 1990 and 1993, when the GDP fell each year, the economy has recovered. GDP growth was 2.6% in 1994 and 3.0% in 1995. Table 6.1 shows the historic and forecast GDP in Sweden.

Table 6.1 Historic and forecast GDP, annual percentage change

Period	Average annual percentage change
Historic GDP	
1960-1970	4.6
1970-1980	2.0
1980-1990	2.0
1990-1995	0.2
Whole period 1960-1995	2.5
Forecast GDP	
1995-2000	1.6
2000-2005	2.2
2005-2010	2.0
Whole period 1995-2010	1.9

Source: SCB and NUTEK, "Industrial structural model ISMOD".

For the entire forecast period 1995-2010 it is assumed that the economy, in terms of GDP, will grow by an average of 1.9% per annum. This growth rate is in line with growth in Sweden during the 1970s and 1980s.

6.1.2 Industrial production

When it comes to the development of industry, we have based our forecasts on calculations done using NUTEK's industrial structural model ISMOD. The results of the model show that average production will increase by 2.1% during the forecast period 1995-2010, which is slightly higher than growth during the 1980s, which was around 2% per annum. Production will increase slightly more slowly at the beginning of the period, increasing more rapidly towards the end.

Table 6.2 Historic and forecast industrial production, annual percentage change.

Period	Average annual percentage change
Historic industrial production	
1960-1970	5.8
1970-1980	1.1
1980-1990	2.0
1990-1995[1)]	2.2
Whole period 1960-1995	2.9
Forecast industrial production	
1995-2000	1.4
2000-2005	2.6
2005-2010	2.8
Whole period 1995-2010	2.2

1) 1990-93: 1.0 %, 1993-95: 11.6 %
Source: SCB and NUTEK, "Industrial structural model ISMOD".

The calculations also show that the structure of industry will change towards being more knowledge-intensive. In terms of energy demand in industry, this means that the less energy-intensive sectors industry are expected to grow more than the more energy-intensive sectors. See further section 6.2.

6.1.3 Private and public consumption

Private consumption is assumed to grow by an average of 2.2% per annum during the entire forecast period 1995-2010. Consumption will grow slightly more slowly up to the year 2000 and at a faster rate during the rest of the period. A comparison with historic values shows that the forecast growth rate is higher than the corresponding level during the 1970s and 1980s, when private consumption grew at a rate of approximately 1.5% annually. If we consider the entire period 1960-1995, private consumption grew at a rate of just under 2% annually, while it grew by 1.0% per annum during the first half of this decade.

It is assumed that public consumption will grow very weakly during the period, which means it will decline as a percentage of GDP. A transfer of certain services from the public to the private sector is therefore assumed.

6.1.4 Exports

Exports are assumed to grow by an average rate of 4% per annum during the period 1995-2010, which is in line with the growth rate of exports during the 1970s and 1980s. Sweden’s GDP growth is thus expected to continue to be dependent on relatively strong growth for the export industry.

6.1.5 Prices of fossil fuels

Our assumptions regarding fuel prices and the exchange rate of the dollar are shown in Table 6.3. The prices are real (inflation-adjusted) and do not include taxes. Further on, fuel prices are shown for different customer categories. The prices are then reported including energy and environmental taxes. Prices for households are given without VAT.

In the forecasts we assume that 1996 year’s energy and environmental taxes will remain in effect throughout the forecast period. They can be found in section 5.2.1, Table 5.2.

Table 6.3 Prices of crude oil and coal, and dollar exchange rate, for 1995, 2000, 2005 and 2010

	1995	2000	2005	2010
Crude oil, USD/barrel	17	19	21	23
Coal, USD/tonne	43	46	50	53
Exchange rate SEK/USD	7.5	7	7	7

The crude oil price is estimated to be around 23 dollars/barrel in 2010, which is on a par with the estimate made by the Energy Commission in their final report[21].

Domestic prices can differ sharply between different users depending on the volume used and whether the user imports directly or buys via a distributor. On top of this, taxes vary between different customer categories.

The energy prices shown below are expressed in 1995 prices and have been calculated based on the assumed dollar exchange rate. The prices are calculated as deliveries at gate and have been converted to SEK/MWh.

Table 6.4 Fuel prices for large heating plants, large and small industries, SEK/MWh, including energy and environmental taxes but excluding VAT

	1995	Of which tax '95	2010	Of which tax '97 1)
Central heating plants				
Light fuel oil	257	158	304	172
Heavy fuel oil	230	154	262	168
Coal	219	165	238	177
Local heating plants				
Light fuel oil	280	158	336	172
Heavy fuel oil	242	154	283	168
Coal	229	165	248	177
Large industry				
Light fuel oil	124	25	157	25
Heavy fuel oil	109	33	128	34
Coal	99	48	109	50
Small industry				
Light fuel oil	148	25	189	25
Heavy fuel oil	121	33	149	34
Coal	109	48	118	50

1) The forecast price includes the most recent tax, i.e. from 1 January 1997.

Table 6.5 Fuel prices for residential buildings and single-family homes, SEK/MWh, including taxes and VAT

	1995	Of which tax '95	2010	Of which tax '97 1)
Residential buildings				
Light fuel oil	351	228	420	256
Heavy fuel oil	303	215	355	239
Coal	286	222	310	239
Single-family homes				
Light fuel oil	380	234	445	261

1) VAT is imposed on the forecast price for the year 2010 including the most recent tax rate, i.e. from 1 January 1997.

[21] Transformation of the energy system, SOU 1995:139.

6.1.6 Prices of forest fuel

The prices of forest fuel, which is the market-leading biofuel, have fallen substantially in recent years. Table 6.6 shows the price trend for forest fuel wood chips, which are a mixture of wood chips from the forest and the by-products of the forest products industry.

Table 6.6 Prices of forest fuel wood chips 1985-1995, current and constant prices, SEK/MWh

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Current prices	98	111	114	111	110	115	116	118	108	100	99
1995 prices[1)]	162	169	174	160	149	141	130	129	113	102	99

1) Deflated with the consumer price index, CPI

Source: Competition Authority and NUTEK

In our judgement, the price of forest fuels will continue to decline in the short term. However, increased demand, mainly due to the construction and conversion of biofuel-fired heating or CHP plants, will push up prices in certain regions. Imports of biofuels have increased during the past year and are expected to increase further in coming years. Since the prices of imported biofuels of all types are lower than domestically produced ones, imports may have a dampening effect on price increases.

The prices of unprocessed forest fuels will remain stable in real terms up to 2010, which means a price of about SEK 100/MWh in 1995 prices. In the longer term, demand will increase further and more expensive grades will be utilized. This can be expected to lead to rising prices due to increasing production costs[22].

6.1.7 Electricity prices

The electricity market in Sweden has changed considerably in the past few years, in terms of both structure and organization, making the future price of electricity more difficult to predict than before. Furthermore, the Swedish electricity market is influenced by price trends on the electricity markets in neighbouring countries in the Nordic region and in the Baltic Sea region[23]. Continuous change is occurring in these countries as well. Another factor that affects the Swedish electricity market is the EU directive concerning an internal electricity market[24].

New laws have entered into force in the area of electricity in Norway, Sweden and Finland. The regulations open the market to competition in the production and sale of electricity. A new electricity supply act that will allow limited competition will enter into force during 1997 in Denmark. These changes on the national markets will be accompanied by changes in the conditions for international trade with electricity as well. More and more customers will be

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[22] NUTEK R 1996:37: Effects of increased biofuel use - A summary of the state of knowledge.
[23] “The electricity market around the Baltic Sea 1996”, NUTEK, R 1996:83.
[24] EU 3638/1/96, “European Parliament and Council Directive 96/92/EC on common rules for the internal market for electricity”.

able to buy electric power in competition from foreign other countries as well. The trend in the Nordic countries is leading us ever closer to a Nordic electricity market. Rapid changes are taking place on the electricity markets in the other Baltic Sea countries as well, in terms of both organizational and structural frameworks. In practice, these changes are bringing a northern European electricity market ever closer. When in the future such a market will come into being is dependent on the region's economic development, development of legal structures, political decisions and how fast price mechanisms have effect.

Thus, there are many different uncertainty factors which make it very difficult to predict the future price of electricity. Another uncertainty factor is when the phase-out of Swedish nuclear power will begin and at what pace it will proceed[25]. In the calculations we assume that nuclear power capacity will decrease from the year 2000 by the capacity of an average reactor, i.e. by 835 MW[26]. Otherwise it is assumed that the capacity of nuclear power will remain unchanged during the forecast period.

In the projections of the future electricity market, we assume that competition in the production and sale of electricity will increase further. On a well-functioning electricity market, the price of electricity will be determined by the marginal cost of electricity production. The *short-term marginal cost* of electrical energy at a given time is determined by the variable cost of the most expensive energy type used at the time plus a so-called shortage cost component which reflects the capability of the production system to deliver electrical energy. The *long-term marginal cost* is determined by the total production costs, i.e. both the fixed and the variable costs of new production plants. In the future, when increasing electricity consumption necessitates a higher degree of utilization of more expensive existing sources of energy, the short-term marginal costs will rise. When the short-term marginal cost in the system is on a level with the long-term marginal cost, new electricity production capacity will be built.

On an electricity market that is open to competition, the electricity producers will adapt production capacity to demand. It is likely that the power companies will be more restrictive in building high-capacity plants, since the risks for individual producers with large plants is greater on a free electricity market than on a regulated one. According to the forecasts, electricity use will increase at such a pace that additional power will be needed beyond the CHP that is assumed to be added in the district heating systems. This additional power requirement is expected to amount to 0.7 TWh in the year 2000 and 2.7 TWh in 2005 and 2010.

When it comes to CHP in the district heating network, it is assumed that the plants that are added have an electricity capacity of 50 MW, since this plant size is in most cases adapted to the heating demand. In some district heating systems, however, this plant size is too large.

It is difficult to say how the additional power need will be satisfied, since the electricity markets in the Nordic countries and Northern Europe will eventually become increasingly integrated. The integrated market offers greater potential for increased utilization of existing electricity generation capacity and construction of new capacity. Estimates of the cost trend for a hypothetical expansion of production capacity in other countries suggest that these costs will be on a par with the long-range marginal cost in Sweden. It is thereby conceivable that

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[25] According to the energy policy agreement from February 1997 (see Chapter 5.2), one reactor will be shut down in Barsebäck prior to 1 July 1998.
[26] The total installed capacity in the Swedish nuclear power stations divided by the number of reactors, i.e. 12.

Swedish power companies will choose to build production capacity in some other country. Natural gas combined-cycle technology is the most advantageous alternative, based on the fuel price assumptions that have been made. Since some of the countries in the Baltic Sea Region have access to natural gas, it is assumed that the marginal costs will, in the long run, be equal to those for natural gas combined-cycle plants.

It is further assumed that natural gas-fired condensing power plants, natural gas combined-cycle power plants, will be built with a maximum capacity of 600 MW, due to the greater risks on a re-regulated and more open electricity market in the Baltic Sea Region.

As far as fuel prices are concerned, the assumptions reported in Chapter 6.1 are followed.

The calculations of the variable and marginal costs in the electricity system have been carried out with the aid of the power balance model ELFIN, where the operation of an electricity production system at a given electrical load is simulated. The marginal costs rise when more expensive existing or new production capacity is taken into service in conjunction with the forecast increased electricity use.

On the new electricity market, the *electricity price* paid by the customers is composed of three different components: the price of electrical energy, the price of the network service, and any charges and taxes. By "electrical energy price" is meant the average price of electricity[27]. Future electricity prices are determined by means of ELFIN[28]. To this is added the price of the network service, which is considerably higher for low-voltage than for high-voltage customers. This means that the cost of the network service is much lower for customers who take their electricity directly at the trunk-line system level than for household customers. For the forecast years it is assumed that the price of the network service remains unchanged in real terms, since we assume that efficiency improvements in the network service with resultant reduced costs will be counteracted by increased costs in connection with reinforcement and expansion of the electricity networks. Certain customer categories also pay charges, taxes and VAT. Today's taxes and charges also apply during the forecast period. Table 6.7 shows electricity prices for 1995 and estimates of changes in electricity prices for different customer categories during the period 2000-2010.

Table 6.7 Electricity prices for different customer categories, including excise taxes and VAT for 1995 and forecasts for 2000, 2005 and 2010, SEK/MWh.

	Elect.-intensive industry[1)]	Medium-sized industry	Electric heating[3)]	Household electricity[4)]
1995				
Electricity price	240	290	410	600
Excise tax	0	0	90	90
Electricity price incl. excise tax and VAT[5)]	240	290	620	890
2000				
Electricity price	250	300	420	610
Excise tax	0	0	113	113

27 This price can in principle by definition be compared with the average spot price on the electricity exchange.
28 The power balance model ELFIN is described in appendix 3

Electricity price incl. excise tax and VAT[5)]	250	300	670	900
2005				
Electricity price	280	330	450	640
Excise tax	0	0	113	113
Electricity price incl. excise tax and VAT[5)]	280	330	700	940
2010				
Electricity price	300	350	470	660
Excise tax	0	0	113	113
Electricity price incl. excise tax and VAT[5)]	300	350	730	970

1) Annual consumption 140 GWh and subscribed demand 20 MW. 2) Annual consumption 50 GWh and subscribed demand 10 MW. 3) Annual consumption 25 MWh. 4) Annual consumption 2 MWh. 5) VAT applies to other energy users.

Sources: The prices for electricity-intensive industry are calculated on the basis of Vattenfall’s data for medium-sized industry. The prices for electric heating are taken from SCB and the prices for household electricity are calculated from these data. The electricity prices for the forecast years are based on own calculations.

6.1.8 District heating prices

The price of district heating varies between different locations, due to the fact that production conditions differ. The average price of district heating in 1995 was just over SEK 410/MWh, including taxes. In general, industrial customers pay a lower price than households. The price of district heating to industry is estimated to lie within the range SEK 200-300/MWh, excluding VAT for 1995.

The future district heating price will depend above all on future fuel prices and the costs of new capacity. With the assumptions we are making concerning the future fuel price and the cost of additional production capacity, it follows that the average price for households will be around SEK 450/MWh in 2000, SEK 500/MWh in 2005 and SEK 550/MWh in 2010.

6.2 Future energy use in industry

6.2.1 Background

Annual energy use in industry amounts to 147 TWh and represents about 31% of Sweden's total energy use today. In 1970 this share was just over 34%, and annual energy use was 154 TWh. The largest part of energy use consists of electricity, biofuels, oils, and coal and coke. Energy use, and above all oil use, has declined since 1970, despite an increase in industrial production, which has been made possible by increased electricity use and energy efficiency improvements. This trend began with the oil crises during the 1970s, which led to intensive efforts on the part of both government and industry to reduce oil consumption. Since then, energy use has declined by 5% while industrial production has increased by 50%. Oil consumption decreased by 75% between 1970 and 1993, when oil use in industry increased slightly.

In the short term, production volume is decisive for energy use in industry. This is particularly true within the energy-intensive sectors. In the longer term, total energy use in industry is affected by several factors, for example the composition of production, advances in technology, energy prices and structural changes.

Growth in industrial production in the early 1990s has been weak, which has resulted in a moderate increase in energy use. During the period 1990-1995, energy use increased by an average of 0.7% annually.

A few energy-intensive sectors in Sweden account for more than two-thirds of industry's total energy use. They are the pulp and paper industry, the iron, steel and nonferrous metals industry, and the chemical industry. These sectors' share of industry's total production value is much lower, however, amounting to less than one quarter, as is evident from table 6.8. The engineering industry is not counted as an energy-intensive sector, but uses a great deal of energy in absolute terms due to the industry's size and production volume.

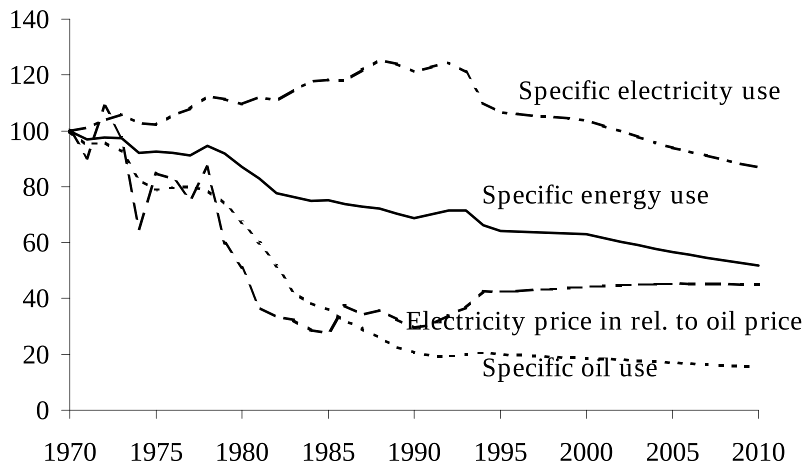
Table 6.8 Production value, energy use and electricity use for different industrial sectors, in percent, 1995

	Percentage of total production value	Percentage of total energy use	Percentage of electricity use
Pulp and paper industry	8	45	37
Iron, steel and nonferrous metals	6	17	15
Chemical industry etc.	8	6	11
Engineering industry	45	8	13
Other industry	32	25	24
Total	**100**	**100**	**100**

Different energy carriers vary in importance between the individual sectors. Coal and coke are used mainly in the iron and steel industry and account for over half of the sector's energy use. Biofuels, mostly internal derived by-products, play an important role within the wood products, pulp and paper industry. Oil is used in most sectors, but has the largest share of total energy use in the textile and food industries. Electricity is used to a large extent in all sectors. Those sectors which have the highest electricity share of their total energy use are the nonferrous metals, chemical and engineering industries. The pulp and paper industry uses most electricity compared with other sectors, counted both in absolute terms and in relation to production (specific electricity use).

Figure 6.1 shows how the relative price of electricity and industry's specific electricity, oil and energy consumption have changed during the period 1970-1995, plus forecasts up to 2010[29].

Figure 6.1 Energy prices and electricity and energy intensity in industry, 1970-1993, forecast up to 2010. Index 1970 = 100.



Note: The prices include excise tax, and from 1990 exclude VAT.
Sources: SCB, Vattenfall and SPI plus own calculations[30].

As is evident from Figure 6.1, the price of electricity in relation to oil declined sharply from 1970 up to the mid-80s. Since then it increased up to 1995 due to falling real oil prices. Forecasts of the relative price of electricity show a weak increase up to 2010. Specific electricity use increased up to 1987, after which it decreased up to 1995. Between 1995 and 2010, specific electricity use is expected to decline further owing to a changed sectoral structure, but also to rising electricity prices and more efficient electricity use. Specific oil use fell sharply between 1970 and 1995, which can be explained by the conscious effort to reduce oil dependence within industry. Specific oil consumption is expected to continue to decline up to 2010, but at a much slower pace.

The figure also shows that industry's specific energy use has declined between 1970 and today by a total of 37%, which is equivalent to a decrease of 1.8% per year. For industry as a whole, this is a result of a trend towards less energy-demanding products and manufacturing processes, plus a changed sectoral structure. This long-term trend is expected to continue up to 2010.

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[29] Specific energy use is defined as energy consumption per krona of production value, kWh[energy]/SEK, kWh[elec]/SEK and kWh [oil]/SEK.
[30] Electricity price for medium-sized industry 10 MW and 50 GWh/year. The price is based on a forecast electricity price with a standard surcharge for distribution costs. The oil price is based on the 1995 price for heavy fuel oil, excluding volume discounts.

6.2.2 Forecast results

For the entire forecast period 1995-2010, energy use is expected to increase by 12.5%, i.e. from 147 to 165 TWh. The average annual increase in energy use is thus expected to be about 0.8%. At the same time, industrial production[31] is predicted to increase by a total of 39.6%. Specific energy use is projected to decline by 19% for the entire period, or about 1.4% per annum, and specific electricity use by 18%, i.e. 1.3% per annum.

For the period 1995-2000, energy use in industry is expected to increase by 1.0% per annum. The sectors expected to have the highest growth are the chemical industry, the wood product industry and the graphic arts industry. The use of electricity and biofuels will therefore increase most, in absolute terms. Coal and coke use are also expected to increase, due to growth in the iron and steel industry. The production value in the food, mining, textile, and soil and stone industries is expected to decrease. For this reason, a weak increase is projected in the use of steam coal, while the use of LP gas is expected to decrease.

Between the years 2000 and 2005, industry's total energy use is projected to increase by 0.4% annually. High growth rates are expected in the food, engineering, graphic arts and chemical industries during the period. Production in the food industry and the soil and stone industry is expected to recover. The use of district heating, natural gas and heavy fuel oils is therefore expected to increase most in relative terms. In absolute terms, electricity use is projected to increase most. As a consequence of the production decline in the pulp and paper industry, biofuel use is expected to decline slightly.

For the period 2005-2010, total energy use in the industry is expected to grow with 1% per annum. An increased production in the engineering and chemical industries is expected, leading to an increasing demand for district heating, electricity and light fuel oils, while a recovery will occur in the pulp and paper industry, leading to increasing demand for electricity and bio-fuels. Owing to the growth in the iron and steel industries coal, coke and LPG will increase. The use of natural gas is expected to grow because of increasing demand in the chemical and foodindustry.

[31] The growth in the different industry sectors are based on measurements from NUTEK's industrial sector model ISMOD

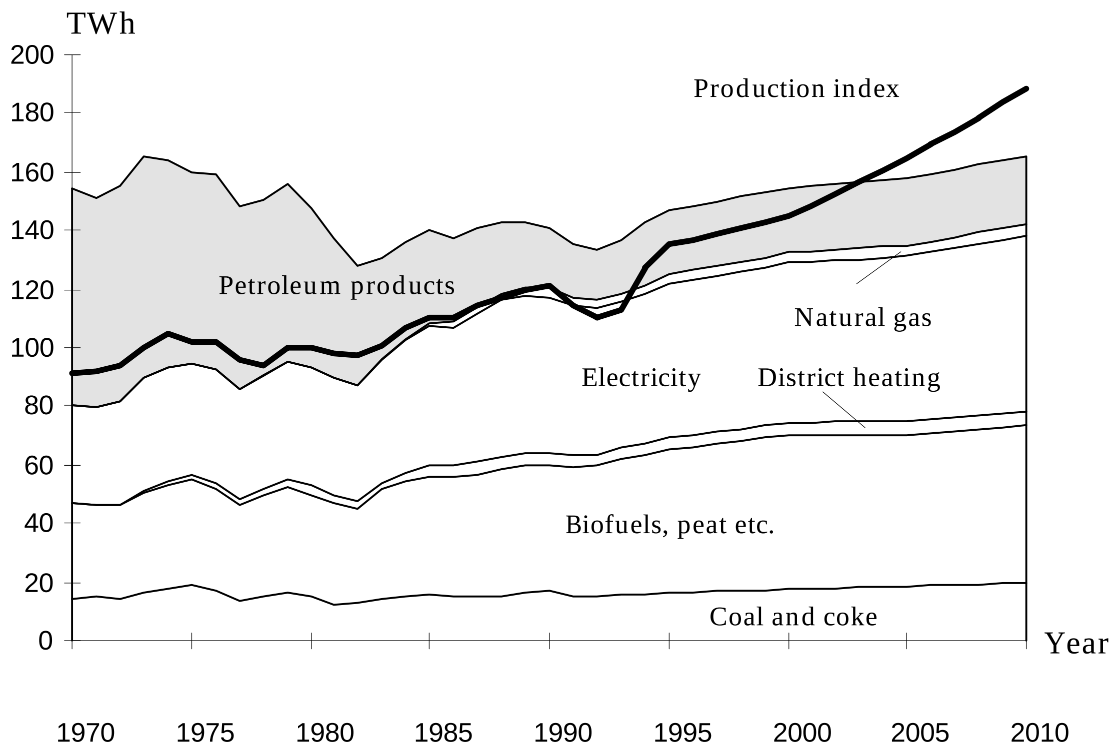
Table 6.9 Industry's energy use 1990, 1995 and forecast for the years 2000, 2005 and 2010, TWh

Energy carrier	1990	Percent p.a.	1995	Percent p.a.	2000	Percent p.a.	2005	Percent p.a.	2010
Steam coal	7.1	-5.0	5.5	0.6	5.7	0.9	6.0	1.3	6.3
Coke[1)]	9.8	1.6	0.7	2.0	11.8	1.2	12.5	1.5	13.5
Biofuel, peat etc.[2)]	42.8	2.8	49.1	1.5	52.8	-0.4	51.8	0.6	53.3
Natural gas	3.1	1.5	3.4	0.0	3.4	2.4	3.8	2.0	4.2
Diesel oil	1.9	-2.0	1.7	-0.4	1.7	0.6	1.7	0.6	1.8
Light fuel oil	3.8	-2.7	3.3	0.4	3.4	2.8	3.9	0.9	4.1
Heavy fuel oil	11.6	1.2	12.3	0.0	12.3	0.0	12.3	0.1	12.3
LP gas	4.1	3.5	4.8	-0.7	4.7	1.4	5.0	1.1	5.3
Town gas[3)]	0.1	-9.3	0.0	-100.0	0.0		0.0		0.0
District heating	3.6	1.6	3.9	1.1	4.1	2.2	4.6	2.1	5.1
Electricity[4)]	50.4	0.0	50.4	1.4	54.0	0.6	55.6	1.2	58.8
Interruptible electric boilers	2.6	-11.8	1.4						
Total	**140.9**	**0.8**	**146.5**	**1.0**	**153.8**	**0.4**	**157.1**	**1.0**	**164.7**
Production value, SEK bn, 1991 prices	828.5	2.2	924.8	1.4	989.9	2.6	1126.6	2.8	1290.8
Specific energy use, kWh per SEK of production value	0.170	-1.4	0.158	-0.4	0.155	-2.1	0.139	-1.8	0.128
Specific electricity use, kWh per SEK	0.064	-2.6	0.056	-0.5	0.055	-2.0	0.049	-1.6	0.046

1) Coke also includes coke gas and blast-furnace gas. 2) Biofuels also include waste liquors in the pulp and paper industry. 3) Town gas is reported together with natural gas for the forecast years.
4) Excluding petroleum refineries. For the years 1990 and 1995, prime electricity and electricity to electric boilers are reported separately. For the forecast years, electricity to electric boilers is included in electricity.
Note: The figures may contain rounding-off errors.

Source: SCB and own calculations.

Figure 6.2 Industry's energy use, 1970-1995, forecast up to 2010, TWh, production index 1980 = 100



Source: SCB and own calculations

The relative proportions of the different energy carriers are expected to remain more or less unchanged up to 2010. Electricity use is expected to increase by 7.3 TWh and the use of biofuels, peat etc. by 4.3 TWh. The fossil fuels oil, coal and coke, natural gas and LP gas are expected to increase by 5.7 TWh. District heating use is projected to increase relatively strongly, by an average of 1.8% per annum. This increase is mainly due to an increased need for heating of new industrial premises in the chemical and engineering industries, where production is expected to increase sharply.

Table 6.10 Industry's energy use per sector, 1990, 1995 and forecasts for the years 2000, 2005 and 2010, TWh

Sector	1990	1995	2000	2005	2010
Mining industry	4.1	4.5	4.3	3.8	3.5
Food industry	7.3	6.9	6.0	6.6	7.4
Textile industry	1.1	1.0	1.0	1.0	1.0
Wood products industry	9.6	11.4	13.1	14.1	15.4
Pulp and paper industry	62.2	65.9	69.7	67.0	67.1
Graphic arts industry	0.7	0.8	0.9	1.0	1.0
Rubber goods industry	0.4	0.5	0.5	0.6	0.6
Chemical industry etc.	9.7	8.6	9.9	10.9	12.0
Petroleum and coal industry	1.0	1.1	1.1	1.2	1.3
Soil and stone industry	7.5	5.8	5.7	6.3	6.8
Iron and steel works	18.9	21.1	22.9	24.5	26.3
Nonferrous metals works	3.9	3.5	3.6	3.8	3.9
Engineering industry	11.8	11.4	12.0	13.1	14.8
Other industry	0.1	1.1	1.1	1.1	1.1
Non-sectoral industry	3.4	3.6	2.5	2.8	3.3
Industry total	**141.9**	**147.0**	**154.4**	**157.8**	**165.5**

Note: The figures may contain rounding-off errors.

Source: SCB and own calculations.

The change in energy use in industry can be largely explained by changes in production volume and sectoral structure, plus efficiency improvements or technological advances measured in specific energy use. Table 6.11 shows how growth and structure effects plus changes in specific energy use have affected energy and electricity use in industry since 1980, as well as the results of the calculations according to the forecast up to 2010.

The growth effect indicates how great the change in industry's energy use would have been due to the increase in production if energy use per unit produced had been the same in the base year as in the end year. The structure effect indicates the change in industry's energy use due to the fact that the growth of the individual sectors has deviated from the average between the base year and the end year. The change in specific use indicates the efficiency improvement effect due to the fact that energy use per unit produced has changed in the sectors between the base year and the end year. The sum of the three effects gives the total change in energy and electricity use.

Table 6.11 Growth and structure effects plus effect of the change in specific energy use for 1980-1995 and for the forecast up to 2010, TWh

	1980	1980-90	1990	1990-95	1995	1995-2010	2010
Energy							
Growth effect		+30.0		+16.5		+58.2	
Structure effect		-4.1		-5.3		-28.1	
Specific use		-32.6		-6.1		-11.5	
Total effect		-6.7		+5.1		+18.6	
Total energy use	148.5		141.9		147.0		165.5
Electricity							
Growth effect		+8.1		+6.2		+20.7	
Structure effect		-2.0		-0.8		-7.6	
Specific use		+7.4		-6.8		-5.8	
Total effect		+13.5		-1.4		+7.3	
Total electricity use	40.1		53.7		52.3		59.6

Note: The figures may contain rounding-off errors.

The assumptions regarding the development of production indicate a structural transformation within industry, which is expected to be of importance for total energy and electricity use in 2010. The increase in energy use that is due to growth in production will be dampened by a structural transformation towards less energy-intensive sectors and products. Energy efficiency improvements will also have a restraining effect on energy demand via their influence on specific use.

In conclusion, it should be pointed out that the projections of energy use in industry are based on a number of implicit assumptions and environmental factors which are more or less uncertain. Changes in both economic premises for individual sectors and energy and environmental policy decisions have a great influence on the outcome developments we have described above. The results should be interpreted with this in mind.

6.3 Future energy use in the residential, commercial and institutional sector

6.3.1 Background

Energy use in the residential, commercial and institutional sector in 1995 amounted to 158.3 TWh, which is equivalent to more than 34% of Sweden’s total energy use. The corresponding percentage in 1970 was 36%, with a total energy use of 164.8 TWh. 1970 was a cold year, which meant that energy use in the sector was high. Temperature-corrected use amounted to 157.8 TWh, which means that energy use has been stable. Reduced oil consumption has been offset by increased use of electricity and district heating.

Oil crises, increased energy prices and changes in energy taxation have affected the transition from oil to other energy carriers. Today, oil consumption in the residential, commercial and institutional sector amounts to just under 20% of Sweden's total energy consumption, compared to just over one-third in 1970. The decline is largely attributable to a shift from oil to electric and district heating for space heating purposes, so that district heating meets most of the heating requirement in residential, commercial and institutional premises today.

Energy use in the residential, commercial and institutional sector increased by 5.7% during the period 1990–1995, which is equivalent to an increase of 1.1% per annum. This increase is mainly due to an increase in energy consumption for space heating and hot water. The use of electricity also increased sharply during the period: household electricity by 3.1% and operating electricity by 6.6% compared with 1990.

A large portion of the energy consumption in the residential, commercial and institutional sector is influenced by temperature conditions, which can lead to considerable random variations in energy demand from year to year. Temperature-corrected energy use declined by 1.8% between 1990 and 1995. The nominal increase in electricity use of 8.6 TWh is thus due to the fact that 1995 was colder than 1990.

As a consequence of changed taxation, energy prices for consumers in the residential, commercial and institutional sector have increased sharply during the 1990s. The imposition of VAT on energy in 1990 sharply increased space heating costs for households. To some extent, a rising crude oil price has also contributed to this price increase. In all, the electricity price rose by more than 10% in real terms for household customers with electric heating in 1990. At the same time, the price of domestic heating oil rose by more than 40%.

In the long term, sharply increased energy prices lead to more widespread adoption of energy-saving measures such as supplementary insulation, installation of triple- and quadruple-glazed windows and heat pumps. Higher energy prices can thereby have a moderating effect on energy use in the residential, commercial and institutional sector as well.

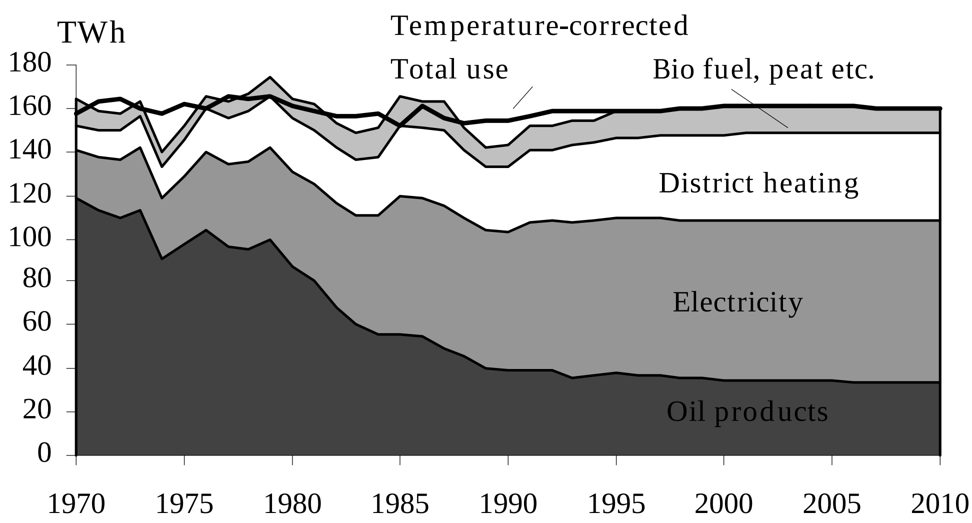
In the shorter term, energy use is less sensitive to price changes, due to the fact that households are slow to alter their energy-related behaviour. In the short term, changed prices for electricity and oil mainly have an effect on those who have the option of switching between different types of fuels and electricity for heating in flexible systems. Combi-boilers, and thereby the option of rapid fuel switching, are mainly found in single-family homes. An estimated 10–20% of the total energy use for space heating of about 100 TWh in the sector alternates between electricity and oil.

6.3.2 Forecast results

The estimates up to the year 2010 indicate a continued stable trend in energy use in the residential sector. Up to 2005, a very weak increase in energy use is expected, averaging about 0.1% per annum. Energy use is expected to decline slightly during the period 2005–2010.

Figure 6.3 shows the projections of future energy use within the sector. The large changes in energy use in the residential, commercial and institutional sector which have taken place since 1970 are also shown by the figure.

Figure 6.3 Energy use in the residential, commercial and institutional sector 1970–1995, forecast up to 2010, TWh



According to the forecast, the relative proportions of the different energy carriers will continue to change. Electricity use is projected to increase in relation to oil use. This is largely due to conversions from oil to combi-boilers in the single-family home sector. Electricity use is expected to increase by 3 TWh between 1995 and 2010, while oil use is expected to decrease by 5.4 TWh during the same period. Besides conversion to electricity, the reduced oil use is also due to some conversion to district heating. District heating is expected to increase by 3.1 TWh during the period, which is equivalent to approximately 0.5% per annum. The use of natural gas is also expected to increase by 0.7 TWh for the whole period, which is equivalent to an increase of about 1.5% per annum.

Table 6.12 Energy use in the residential, commercial and institutional sector broken down by different user categories, 1990, 1995, forecasts up to 2010, TWh

	1990 corrected	1995 corrected	2000	2005	2010
Space heating and hot water	110.1	104.6	104.2	103.6	102.9
Single-family homes	51.6	47	46.9	46.3	45.9
Apartment buildings	31.0	30.6	30.1	29.8	29.4
Commercial and institutional premises	27.5	27.1	27.3	27.5	27.6
Household electricity	16.3	16.8	17.1	17.3	17.3
Single-family homes	8.6	8.6	8.8	8.9	8.9
Apartment buildings	7.7	8.2	8.3	8.4	8.3
Operating electricity on commercial and institutional premises	15.2	16.2	16.7	17.4	17.8
Second homes	3.3	3.6	3.7	3.8	3.8
Agriculture, forestry, rangelands, fishing, etc.	8.3	7.4	7.3	7.3	7.2
Other use	9.0	10.6	12.3	12.2	12.0
Total	**162.2**	**159.2**	**160.5**	**160.6**	**160.1**

Energy use for space heating and hot water is predicted to decrease by 1.7 TWh, while use of household electricity is expected to increase by about 0.5 TWh. Household electricity is expected to increase during the period up to 2005 and then decline slightly. Operating electricity is expected to increase by 1.6 TWh during the entire period, which is equivalent to an increase of 0.5% per annum.

It should be pointed out that the results of the forecast are dependent on the assumptions that are made. Three important assumptions are: the size of the heated areas, the specific net use (defined here as energy use per square metre) and the assumption of improved efficiencies. Table 6.13 shows what effects these three variables have on the results of the forecast.

Table 6.13 Effects of improved efficiencies, reduced specific use and growth in heated areas, TWh

	1995	2000	2005	2010
Effects of				
improved efficiencies[1)]	0	-0.5	-2.2	-4.0
reduced specific use	0	-1.3	-3.1	-5.1
heating	0	-1.2	-2.8	-4.1
household electricity	0	-0.1	-0.1	-0.4
operating electricity	0	0.0	-0.2	-0.6
growth in heated areas	0	3.0	6.7	10.1
Total energy use	**159.2**	**160.5**	**160.6**	**160.1**

1) Technological development in the space heating system

The total effect for 2010 is an increase of energy use by 10.1 TWh due to the assumption of increased areas and a reduction of energy use by 9.1 TWh due to technological development and efficiency improvements. The net result is an increase of energy use by 0.9 TWh.

The uncertainty inherent in assumptions regarding the future, which is not taken into consideration in the predictions made here, must be borne in mind when interpreting the results.

6.4 Future energy use in transportation

6.4.1 Background

The transport sector uses nearly 100 TWh of energy today, which accounts for over 21% of Sweden's total energy use. Of this total, 12 TWh consists of bunker oil for international shipping. Most of the use consists of petrol and diesel oil. The growth of traffic during the 1970s and '80s has led to a sharp increase in the transport share of total energy use. In 1970, the transport sector accounted for approximately 15% of Sweden's total energy use.

The sector's energy use has increased by more than 8% during the period 1990–1995. Besides withdrawals of bunker oils, which increased by over 50%, diesel oil consumption accounted for the greatest increase. This is a direct consequence of the strong growth in industry, above all export-oriented industry, during 1994 and 1995. Petrol consumption also increased, despite several counteracting factors such as relatively heavy tax increases at the beginning of the period, low private consumption as a consequence of the recession, and relatively large cutbacks in Sweden's public consumption.

The use of aviation fuel remained at an unchanged level during the period 1990–1995. The weak growth of air traffic during the past five years is largely attributable to the recession and the weak consumption associated with it. Domestic air traffic has declined during the period, while international traffic has increased slightly[32].

In Sweden, *alternative fuels* are used above all in public transport. In relation to total fuel consumption, however, their use is marginal. The primary reason is higher fuel and vehicle costs in relation to petrol- and diesel-engined vehicles, but also the lack of the requisite infrastructure consisting of distribution systems, fuelling and service stations for alternative fuels. The number of vehicles driven by alternative fuels is reported below.

[32] Air traffic is measured in number of landings at Swedish airports, the Civil Aviation Administration.

Table 6.15 Use of alternative fuels in Sweden, 1995

Fuel	No. of vehicles
Ethanol	Approx. 280 buses 4 trucks 50-100 FFVs (Flexible Fuel Vehicle)
Mixed fuel 15% ethanol	24 buses 20 trucks
Natural gas	Approx. 180 buses 17 trucks Approx. 100 passenger cars
LPG (Liquefied Petroleum Gas)	2
Biogas	46 buses
Electricity	100 electric cars 11 electric hybrid buses

Source: Data for assessment of introduction of alternative fuels, KFB, SIKA, NUTEK

With today's policy instruments, we do not believe alternative fuels will be used on any major scale in 2010. This assessment does not, however, rule out the possibility that alternative fuels will be used on a larger scale in certain limited areas. Examples are the use of petrol with small amounts of alcohols, increased use of alternative fuels in urban public transport, and an increased use of electric cars in urban areas. Such use of alternative fuels will not appreciably affect the transport sector's total demand for fuels and will probably lie within the scope of a normal range of uncertainty.

6.4.2 Traffic forecasts

Passenger transport activity has increased five-fold since 1950. During the same period the population has grown by 24%. This means that we are travelling four times more per person and year than we were in 1950. The increase has mainly consisted of an increase in car travel. The car dominates passenger travel, approximately 80% of the traffic activity in Sweden is performed by car and 60% of the number of journeys take place in cars. Car ownership in the population is projected to increase from 415 cars per 1,000 inhabitants in 1992 to 481 cars per 1,000 inhabitants in 2010, which is a slower rate of growth than the historical rate. The number of cars on the road is expected to increase by 24% during the same period.

In the traffic forecast, transport activity is projected to increase by an average of 1.6% per annum between 1990 and 2910. The largest absolute portion of the increase is passenger car traffic, while air traffic represents the largest relative increase.

The car occupancy rate is assumed to be constant, i.e. the number of vehicle-kilometres is assumed to increase at the same rate as the number of passenger-kilometres. The occupancy rate in buses, on the other hand, is assumed to increase. Thus, bus traffic activity will increase only marginally from 0.75 billion vehicle-kilometres per year in 1990 to 0.76 billion in 2010.

The forecast of future passenger traffic is based on the assumption that no new investments in infrastructure will be made, nor other measures adopted besides those already taken or commenced as of the beginning of 1998. It is further assumed that operation and upkeep can be carried out so that the capital invested in the road and rail networks can be sustained[33].

Freight transport (goods transport) grew during the 1950s and 1960s at roughly the same pace as GDP. In recent decades growth has been lower in absolute terms, and also lower than GDP growth. The slowdown in the growth rate of freight transport activity is due to a diminished growth rate for the physical freight volumes, in the case of certain categories of goods even a decrease, and an increase in the goods value per unit weight.

No transport mode plays as dominant a role for goods transport as the car does for passenger transport. The goods transport modes both compete with and complement each other. In most freight transport, a combination of several transport modes has to be used from consignor to consignee. We believe that the relationship between the transport modes will be relatively constant in the future. Truck traffic's share of total freight transport activity will increase in relative terms due to the fact that the sales volume in those sectors whose goods are preferably carried by truck, i.e. highly manufactured goods, are increasing more than the average.

Freight transport activity, expressed in tonne-kilometres, is expected to grow by more than 19% between 1995 and 2010, provided that transport policies remain unchanged and no additional infrastructure measures are taken beyond those already planned. As the already planned measures in the infrastructure entail considerable improvements for the land-based transport modes, these modes will increase relatively more than maritime transport.

Table 6.16 shows the traffic forecast for passenger and freight transport.

Table 6.16 Transport activity, passenger and freight transport

	1990	1995	2000	2005	2010
Passenger transport activity					
Car, bn vehicle-km	57.2	61.1	64.6	71.7	77.0
Car, bn passenger-km	86.9	92.9	98.2	108.9	117.0
Bus, bn vehicle-km	0.75	0.79	0.78	0.77	0.76
Bus, bn passenger-km	9.0	9.4	9.5	9.5	9.6
Rail, bn passenger-km	6.2	6.1	6.8	8.1	9.1
Air domestic, bn passenger-km	3.4	2.7	3.0	3.5	3.9
Air international, bn passenger-km	7.9	9.7	11.4	13.2	14.9
Freight transport activity					
Heavy trucks, bn vehicle-km >3.5 tonnes (diesel-engined)	2.4	2.5	2.6	2.7	2.9
Light trucks, bn vehicle-km < 3.5 tonnes (petrol-engined)	2.1	2.1	2.3	2.6	2.9
Truck, bn t-km	29.0	32.8	34.0	35.9	37.8
Rail, bn t-km	19.1	20.0	21.5	23.7	26.0
Shipping, bn t-km		26.3	27.4	29.0	30.7

Source: SIKA

[33] Transport authorities' framework planning 1996 "The comparison alternative".

6.4.3 Forecast of fuel use

Energy use in domestic transportation is expected to increase by an average of 0.9% per annum during the forecast period 1995–2010. The rate of increase is thereby expected to slow down compared to the historical trend between 1970 and 1995, when domestic energy use increased by approximately 1.8% per annum. Factors which influence the results of the forecast include an assumed development of the industrial/commercial structure towards sectors with less heavy freight shipments, efficiency improvements in fuel consumption and a slower growth of the population's car ownership[34].

Fuels for international shipping are expected to increase by an average of 1.4% per annum between 1995 and 2010. This growth rate is higher than between 1970 and 1995. The use of fuels for international shipping was roughly the same in 1995 as in 1970. There was considerable fluctuation between these years, however.

An important reason why fuel use is predicted to increase lies in the anticipated development of the energy system in relation to its historical development. After the oil crises during the 1970s and '80s, Sweden's oil use declined. In the forecast for the period, however, oil use is assumed to increase. Energy fuels in particular are transported via international shipping. More than 90% of the imported goods weight and approximately half of the exported goods weight consists of oil and coal.

Table 6.17 shows energy use in the transport sector today and in 2010. Figure 6.4 shows the historical trend from 1970 and the forecast up to 2010.

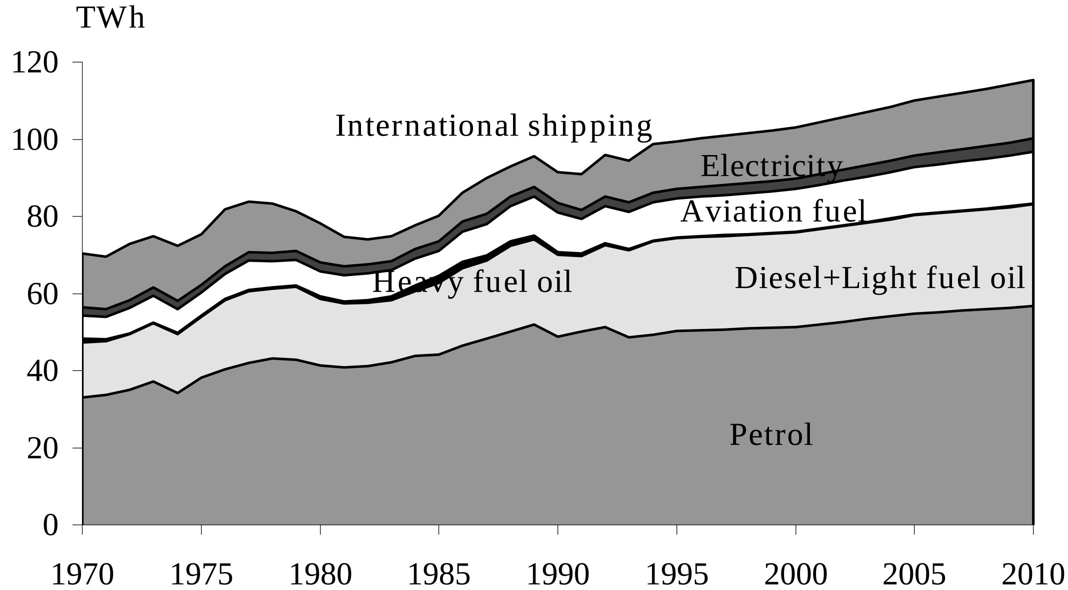
Table 6.17 Transport sector's energy use 1990–2010, TWh

	1990	1995	2000	2005	2010
Petrol	48.8	50.3	51.3	54.8	56.7
Diesel oil	20.3	23.5	23.9	24.8	25.7
Light fuel oil	0.9	0.6	0.6	0.7	0.7
Heavy fuel oil	0.7	0.2	0.2	0.2	0.2
Aviation fuel - domestic		6.2	6.6	7.2	7.8
Electricity	2.5	2.5	2.7	3.1	3.5
Total	**83.5**	**83.3**	**85,3**	**90.8**	**94.6**
Annual change in %		0.8	0.7	1.3	0.9
International aviation		3,8	4,6	5,1	5,6
International shipping					
Diesel oil	0.07	0.4	0.5	0.6	0.7
Light fuel oil	1.7	1.7	1.8	1.9	2.0
Heavy fuel oil	6.1	10.3	11.0	11.7	12.5
Total	**7.9**	**12.4**	**13.3**	**14.2**	**15.2**
Annual change in %		9.4	1.4	1.4	1.4

Note: Approximately half of the civilian aviation fuel use goes to domestic aviation and half to international aviation. Domestic aviation fuel also includes fuel for the Swedish Air Force.
Source: SCB and SIKA

[34] Approximately half as high as during the past 20 years.

Figure 6.4 Transport sector's energy use 1970-1995, forecast up to 2010, TWh



6.5 The future energy system

6.5.1 The electricity market

Figure 6.5 shows electricity use and electricity supply between 1970 and 1995 plus the anticipated trend between 1995 and 2010. Table 6.18 shows this information in figures for the period 1990-2010.

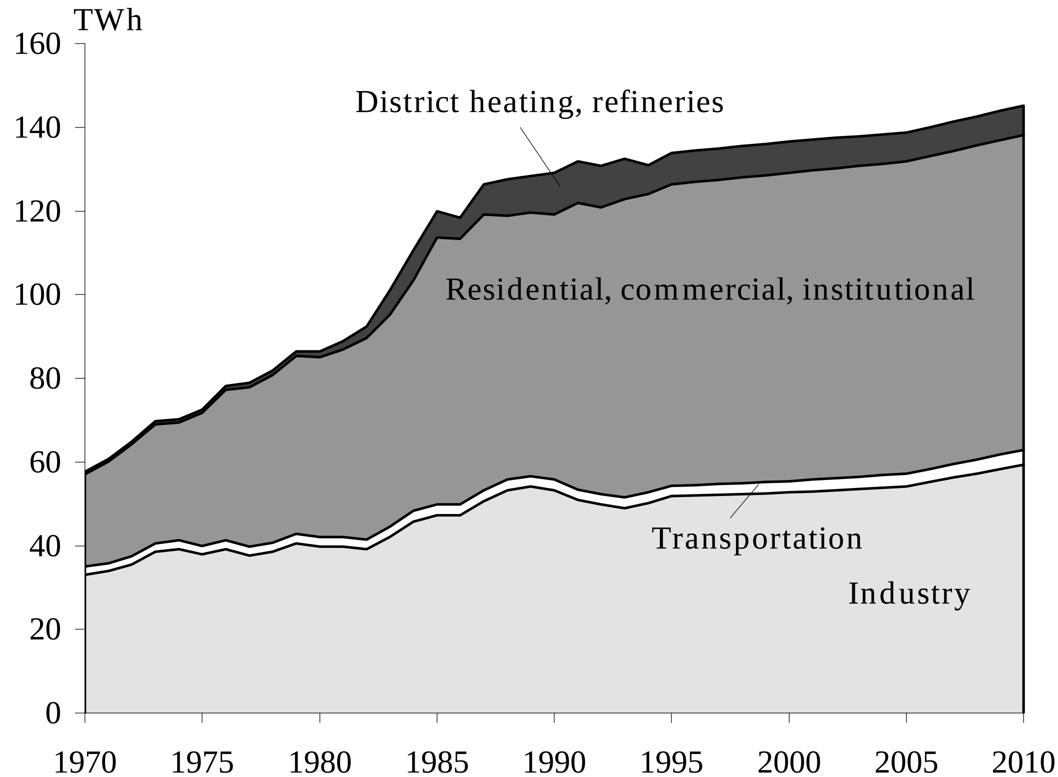
Electricity use is projected to increase during the whole forecast period: between 1995 and 2000 by 4 TWh, between 2000 and 2005 by 2 TWh, and between 2005 and 2010 by 5 TWh, i.e. a total increase of 11 TWh. For both the period 1990-2005 and the period 1990-2010, this corresponds to an increase in use of 0.4% per annum. Historically, this is a relatively slow rate of growth. During the 1970s and '80s, electricity use increased by around 2% per annum. This can be explained by the conscious efforts that were made to find substitutes for oil and the fact that the availability of inexpensive electricity increased with the expansion of nuclear power. The economic downswing in around 1990 has since led to a stagnation of electricity use, and even a decline in certain years, so that it only increased by 0.2% per annum between 1990 and 1995.

Industry's energy use is projected to increase from 52 to 59 TWh, i.e. by 7 TWh between 1995 and 2010, which is equivalent to an increase of 0.9% per annum. This increase is a consequence of the fact that industrial production is expected to increase during the forecast period.

In the *residential sector*, electricity use is projected to increase by about 0.4% per annum during the period 1995-2000 and by about 0.1% per annum during the periods 1995-2005 and 1995-2010. These relatively low growth rates are explained by the fact that heated areas in homes and commercial/institutional premises are expected to grow moderately and that the use which this increase represents is offset by efficiency improvements in the sector.

Relatively little electrical energy is used in the *transport sector*. Nevertheless, growth in the sector's electricity use is expected to be relatively substantial. For the period 1995-2000, growth is projected to be about 1.6% per annum, for the period 1995-2005 about 1.4% per annum and for the period 1995-2010 about 0.7% per annum. This is due to an expected increase in traffic as a result of the infrastructure investments that are currently being carried out or are planned to be carried out in the rail sector.

Figure 6.5 Use of electrical energy per sector for the years 1970-1995 and forecast up to 2010, TWh



Electricity supply. In a normal year, *hydropower* generates 63.5 TWh, which is equivalent to approximately 45% of the total electricity supply today. Hydropower production can vary widely, since precipitation varies during the year and between years. In a dry year, hydropower production may be 10-15 TWh lower than in a normal year, and in a wet year about 10 TWh higher. Hydropower production has varied greatly in recent years. In 1990 it was 71 TWh, and in 1995 67 TWh. According to preliminary figures, it was 52 TWh in 1996.

In the forecast we assume that precipitation will be normal in 2000 and 2005. The production capacity of hydropower is assumed to be 64 TWh, as a consequence of efficiency improvements and minor expansions. For 2010 as well we assume a normal water year and further efficiency improvements and expansions. Altogether, this results in a production capacity of around 66 TWh in 2010.

Production capacity in the Swedish *nuclear power plants* amounts to about 72 TWh, providing that no production losses occur in the form of e.g. unplanned outages[35]. Nuclear power plants are run at reduced capacity (power reductions) for economic reasons mainly in the spring, when the supply of hydropower is good and the demand for electricity is low. In 1995, power reduction accounted for a production loss of 0.8 TWh. Production capacity is further limited today by coast-down or burnup-associated power reduction, whereby the degree of enrichment of the fuel is adjusted so that fuel costs are minimized. To be more exact, the size of the fuel charge is adjusted so that the reactor’s production capacity gradually

[35] Production loss is subdivided into availability-dependent versus non-availability-dependent loss. Availability-dependent production loss is due to e.g. periodic tests, faults and refuelling outages.

declines during the weeks prior to each refuelling outage. In all, production was reduced in 1995 by 2.7 TWh by coast-down. The Oskarshamn 1 reactor was also shut down during the whole of 1995, entailing a production loss of about 3.7 TWh. Other availability-dependent factors contributed to a production loss of about 4 TWh[36]. For these reasons, nuclear power production was limited to about 67 TWh in 1995.

From the year 2000, we assume that the production capacity of nuclear power has been reduced by the capacity of an average reactor, which is equivalent to 835 MW[37] or a reduction of the annual output by 5 TWh. The installed capacity of the twelve Swedish reactors varies considerably. The smallest reactor, Oskarshamn 1, is rated at 445 MW and the biggest, Oskarshamn 3, at 1,160 MW. The production capacity of nuclear power with an average reactor decommissioned amounts to about 67 TWh, provided that no operational disturbances or unplanned outages occur. We have not taken into account any improvements or upward adjustments of the outputs of the nuclear power plants that may be done during the forecast period.

When the demand for electricity rises, more expensive energy sources in the existing system must be utilized, and finally new power plants must be built. This leads to higher electricity prices. In the forecasts we assume that the utilization of existing *CHP* will increase, and that new production capacity will be added in the district heating networks and within industry.

When and how new CHP can enter the system depends on a number of factors, including the level of electricity use and electricity prices, the design of the tax system and the development of heating demand. The life of existing heat production plants also influences when new combined heat and power plants can come into the system. The profitability of CHP is greatest in those cases where the choice stands between investing in new heat production or in CHP, since the heating capacity which is then added to the system does not compete with existing capacity, but replaces old capacity. In the district heating networks, electricity production has been expanded via the investment support given up to 1997 to biofuel-fired CHP plants. The production of CHP in industry is limited by the need for steam in the processes. We predict that electricity production capacity in industry will be utilized to a slightly higher degree during the forecast period than heretofore. Conventional oil condensing power will also be used to a greater extent in our judgement.

We expect a fairly large expansion of *wind power* capacity in Sweden. At NUTEK's initiative, a consortium has been formed called the Swedish Wind Turbine Buyer Consortium for the purpose of coordinating the procurement of cost-effective wind turbines. The procurement has been carried out and Bonus Energy AS has been contracted to deliver 15 plants with an output of 600 kW each. Through this procurement, it is estimated that the total electricity production cost will decrease from SEK 300-400 per MWh to SEK 250-300 per MWh. The production subsidy of SEK 113/MWh which wind turbines receive today will increase as from July 1997 to SEK 138/MWh. The total production costs, including subsidies, will thus be considerably lower than for e.g. new natural gas combined-cycle. The potential of land-based wind power is estimated to be about 4 TWh. Production is expected to amount to 0.4 TWh in 2000, 0.5 TWh in 2005 and 1.5 TWh in 2010.

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[36] These calculations contain rounding-off errors. Non-availability-dependent production loss is associated with coast-down, power reduction, coolant disturbance and off-site faults.

[37] The total installed capacity in the Swedish nuclear power stations of 10,055 MW divided by the number of reactors.

According to our projections, electricity demand will increase at such a rate that the production capacity of the energy system must increase. This means that *new power plants* must be built and net imports of electricity must increase. This new or additional power requirement is expected to amount to 0.7 TWh in 2000 and 2.7 TWh in 2005 and 2010.

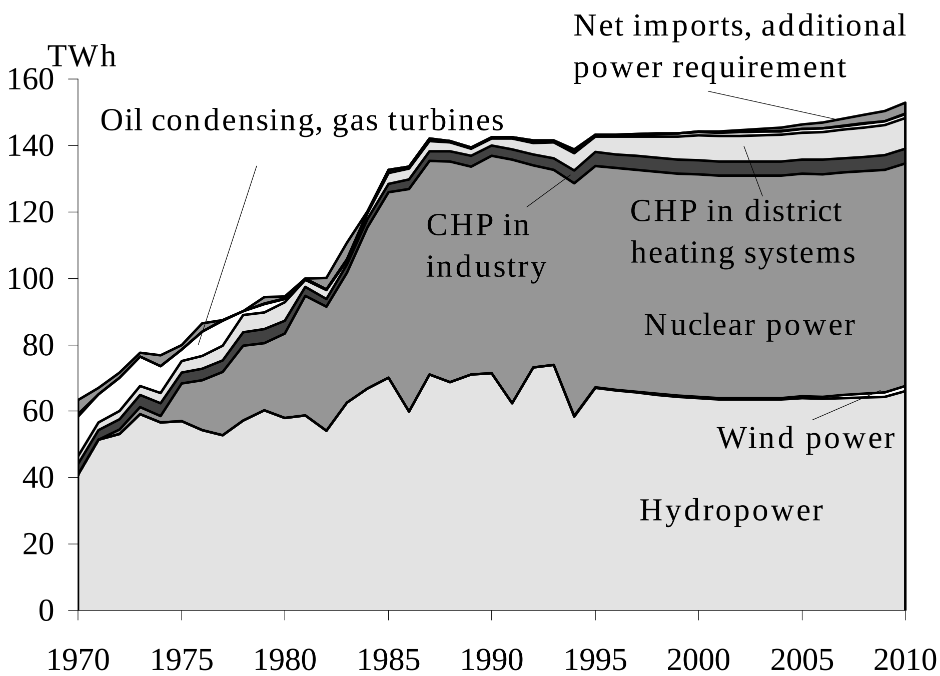
By means of the re-regulation of the Swedish electricity market and the ongoing integration of the Nordic electricity market, new possibilities are being created to satisfy a growing demand for electricity in Sweden. One alternative to building new power plants in Sweden can be to import the power from countries where transmission links exist or will be built. The Swedish power companies may also choose to build capacity in another country for export to Sweden. In the electricity balance we have chosen to express this as net trade or additional power requirement.

Based on the forecast results which indicate growing demand for electricity, the use of *fuels in power production* is expected to increase. The use of oils is projected to increase from 4.9 TWh in 1995 to 9 TWh in 2005 and 2010. This is mainly due to an increase in oil condensing power production, but also to increased production in the combined heat and power stations. The use of biofuels, peat etc. is expected to increase slightly through increased utilization and expansions of CHP, and fuel changes in existing CHP plants.

Due to the construction of the tax system, fossil fuels will continue to be reported principally for use within electricity production and biofuels for use in heat production. We have taken this allocation principle into account in the electricity and district heating balances.

The use of biofuels etc. for electricity production in the pulp and paper industry is predicted to rise as well, as a consequence of increased production in the industry. The use of natural gas is expected to increase from 0.8 TWh today to 2.5 TWh in 2010 due to an expansion of natural gas-based CHP in the district heating systems.

Figure 6.6 Supply of electricity for the years 1970-2010, TWh



Note: Between the years 1970 and 1992, the statistical difference between use and supply is included in net imports, additional power requirement. A statistical difference arises when the use and supply statistics do not balance.

Source: SCB and own calculations.

Table 6.18 Electricity balances for the years 1990, 1995 and forecast for the period 2000-2010, TWh

	1990	1995	2000	2005	2010
Use					
Industry	53.3	51.8	54.0	55.6	58.8
Transportation	2.5	2.5	2.7	3.1	3.5
Residential, commercial, institutional	63.3	72.1	73.7	74.6	75.3
District heating, refineries[1)]	10.3	7.5	7.5	6.9	7.0
Distribution losses	10.7	7.5	7.6	7.6	7.7
Total use, net	**139.7**	**141.4**	**145.5**	**147.8**	**152.3**
Supply					
Hydropower	71.4	67.0	64.0	64.0	66.0
Wind power	0.03	0.1	0.4	0.5	1.5
Nuclear power	65.3	66.7	67.0	67.0	67.0
CHP in industry	3.1	4.2	4.2	4.2	4.5
CHP in the district heating systems	2.1	4.7	8.1	8.1	9.3
Oil condensing	0.3	0.4	1.0	1.2	1.2
Gas turbine, other	0.1	0.2	0.1	0.1	0.1
Net production	142.2	143.3	144.8	145.1	149.6
Net trade/additional power requirement	-2.5[1)]	-1.8	0.7	2.7	2.7
Statistical difference		-0.1	0.0	0.0	0.0
Total electricity supply, net	**139.7**	**141.4**	**145.5**	**147.8**	**152.3**

1) Possible statistical difference is included in this item.
Note: The balance for electricity has been revised compared with the 1994 report.

6.5.2 District heating

The forecasts point towards an increase in total district heating use by 6.3 TWh between 1995 and 2010. If 1995 use is temperature-corrected to a normal year, the expected increase decreases to 6.0 TWh.

Table 6.19 Use and supply of district heat in the years 1990, 1995 and forecast for the period 1995-2010, TWh

	1990	1995	2000	2005	2010
Industry	3.9	3.9	4.1	4.6	5.1
Residential, commercial, institutional	30.0	37.2	39.2	39.9	40.6
Distribution and transformation losses	6.8	7.1	7.9	8.3	8.9
Total use	**40.7**	**48.1**	**51.2**	**52.9**	**54.5**
Supply					
Fuel input					
Oil	3.9	5.8	5.7	4.8	4.5
Natural gas incl. LP gas	1.9	4.1	4.0	4.6	5.2
Coal incl. blast-furnace gas	8.8	4.4	4.0	3.7	3.2
Biofuels, peat etc.	10.2	20.4	24.1	27.1	28.8
Total	24.8	34.6	37.8	40.2	41.8
Heat pumps etc.	12.8	10.0	9.9	9.2	9.2
Waste heat etc.[1]	3.1	3.5	3.5	3.5	3.5
Total supply	**40.7**	**48.1**	**51.2**	**52.9**	**54.5**

1) Heat received from industry and the residential, commercial and institutional sector.
Note: Due to rounding-off, the subtotals do not always agree with the grand total. Furthermore, the balance for district heat has been revised compared with the 1994 report.

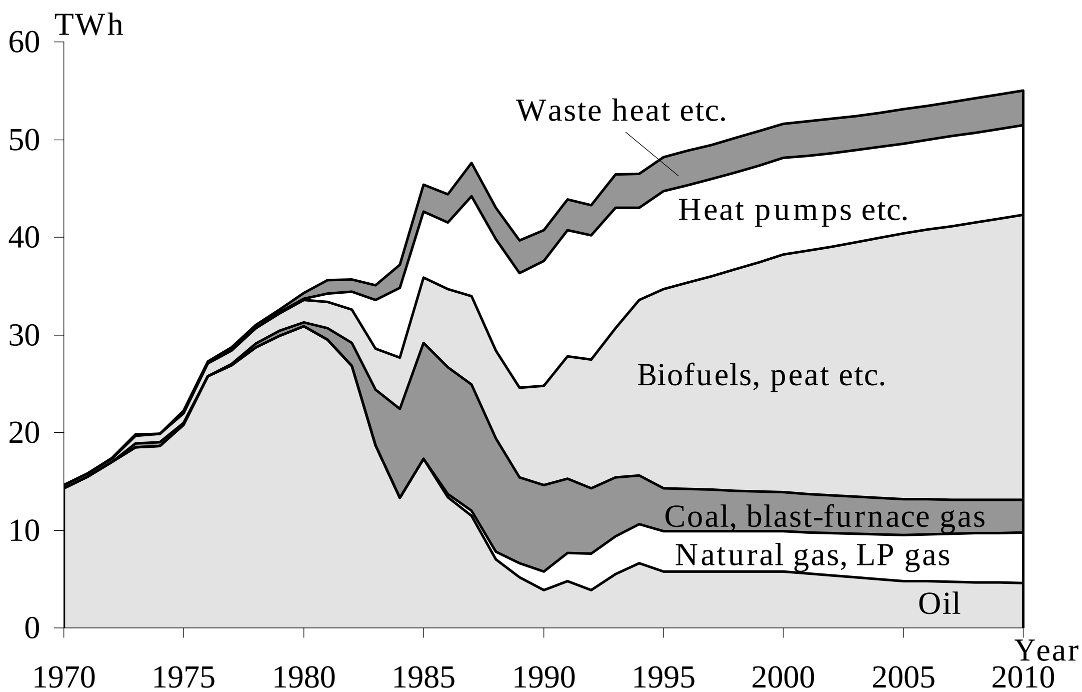
District heat is used for the most part within the residential sector. Use in the sector amounts to around 80% of total use. Most of the remainder is used in industry, while a small portion is lost in the form of transformation and distribution losses.

In 1990, fuels accounted for roughly 60% of the input of energy carriers to district heat production. The rest of the input came from electric boilers, heat pumps and waste heat. To get an historical perspective, it should be mentioned that oil accounted for more than 90% of the input in 1980. Since then it has been diversified to today’s composition of energy carriers, which is shown in Figure 6.7.

The composition of the input of energy carriers to production of district heat is determined to a high degree by their relative prices and taxes. As a consequence of the changes in energy taxation in recent years, biofuel use has increased sharply in the sector. In 1990, biofuels, peat etc. accounted for 25%, oil for 10%, coal including blast-furnace gas for 22% and natural gas including LP gas for 5% of the input of energy carriers. In 1995, biofuels, peat etc. accounted for 42%, oil for 12%, coal including blast-furnace gas for 9% and natural gas including LP gas for 8% of the input.

The apparent reduction in coal use is due in part to the fact that the tax rules make it possible to attribute a large portion of the coal use to electricity production in the CHP stations. This is done to avoid carbon dioxide tax on the fuel, since no tax is payable on fossil fuels for electricity production. Accordingly, a portion of the coal use for heating production is booked on the electricity production side of the balances. Nowadays, the tax system allows an abatement of the carbon dioxide tax and an energy tax exemption for deliveries of district heat to industry, which makes it more advantageous than before to burn fossil fuels in the district heating plants.

Figure 6.7 Total supply of district heat in the years 1970-2010, TWh



Source: SCB and own calculations.

6.5.3 Energy balances

Aggregate domestic final energy use in 1990 amounted to 367 TWh. If energy use for international shipping, transformation and distribution losses, and use for non-energy purposes is included, total energy use is obtained, which amounted to 437 TWh in 1990. Total use in 1995 amounted to 469 TWh.

According to the calculations, domestic final energy use is expected to amount to 404 TWh in 2000, 413 TWh in 2005 and 425 TWh in 2010. As is shown by Table 6.20, this growth is not completely evenly distributed over time. Use is expected to increase slightly faster at the beginning and end of the forecast period. This is associated with the assumed production trend for the different sectors of industry. The transport sector increases relatively much during the later period, 2000-2005 and 2005-2010, which has partly to do with assumptions concerning the development of private consumption.

Altogether, it is mainly energy use in industry and transportation which is expected to grow. Use in the residential, commercial and institutional sector is only expected to increase by 2 TWh by the year 2000 (temperature-corrected), and thereafter remain unchanged until 2005, finally declining by 1 TWh by 2010.

The forecast for the energy supply does not indicate any dramatic changes in the composition of the energy system. The oil share lies around 43% during the entire period. The coal share is also more or less unchanged. Hydropower, nuclear power, waste heat and heat pump heat reduce their shares from 31% in 1995 to 29% in 2010.

Table 6.20 Energy supply in 1990 and 1995 and forecast for the years 2000, 2005 and 2010, TWh

	1990	1995	2000	2005	2010
Industry	140	146	154	157	165
Transportation	84	87	90	96	100
Residential, commercial, institutional	143	158	161	161	160
Domestic final energy use	367	392	404	413	425
Conversion and distribution losses and energy for non-energy purposes	62	65	69	72	75
International shipping	8	12	13	14	15
Total energy use	**437**	**469**	**487**	**500**	**515**
Supply of fuels	290	324	342	353	366
Of which:					
oils[)]	187	203	210	217	223
natural gas[2)]	7	9	9	11	13
coal and coke	31	28	29	30	32
biofuels, peat etc.[3)]	65	84	94	95	98
Hydropower, nuclear power, waste heat and heat pump heat in district heating systems[4)] and net imports of electricity	146	144	144	147	150
Total supply	**437**	**469**	**487**	**500**	**515**

1) Including LP gas. 2) Including town gas. 3) Including private wood use.
4) Not including electricity input
Note: Due to rounding-off, the subtotals do not always agree with the grand total. Furthermore, the balance for district heat has been revised compared with the 1994 report.

Final energy use broken down by energy carriers is presented in Appendix 1, Table B1.10.

6.6 Emissions of carbon dioxide 1995-2010

A forecast of carbon dioxide emissions and sinks is presented in Table 6.21. The forecast is based on the projections presented above. Emissions in 1995 refer to normal year corrected emissions in 1995, since the forecast for other years assumes that these years are normal with respect to e.g. temperature and availability of hydropower.

Total emissions of carbon dioxide (not including international transportation) are projected to increase by about 13% between 1995 and 2010. The sink (removals) in the forest is projected to decrease slowly.

The emissions increase comes largely from plants for the production of electricity and district heating. Here it should be noted that the change in emissions is dependent on how the additional electricity that is projected to be needed is generated. This electric power can be produced from biofuel, natural gas, oil or coal, or be imported, but the probable result is a mix of these production forms.

Table 6.21 Forecast of carbon dioxide emissions and sinks (removals), million tonnes

	1995	2000	2005	2010
Fuel combustion Energy and transformation industries	10.6	12.5	12.9	13.8
Fuel combustion Industry	13.5	13.6	13.7	14.0
Fuel combustion Residential, commercial and institutional sector	10.1	9.2	9.0	8.6
Domestic transportation	19.4	20.0	21.3	22.3
Fugitive fuel emissions	0.02	0.02	0.02	0.02
Industrial processes	4.5	4.6	5.0	5.4
Solvents	0.2	0.2	0.2	0.2
Agriculture	--	--	--	--
Waste disposal	--	--	--	--
Total emissions	**58.5**[1]	**60.1**	**62.1**	**64.3**
Removals in forest	--[2]	29	26	22
International transportation	5.4	5.9	6.3	6.8

[1] Actual value 58.1 [2] Not estimated

Uncertainty

As we have pointed out above, the forecast of future changes in carbon dioxide emissions is contingent upon the assumptions that are made regarding e.g. national energy policy, economic growth and technological development. The most important determining factors for the results of the forecast are the assumptions concerning economic performance (GDP growth, change in industrial production and composition) and the assumption as to when nuclear power will be phased out. Assuming faster economic growth and a structural transformation towards heavier industry would lead to a faster growth in the demand for energy that we have calculated on.

6.7 Emissions of other greenhouse gases 1995 - 2010

Forecasts of emissions of other greenhouse gases are presented in tables 6.22-6.29.

Methane
A forecast for emissions of methane is presented in Table 6.22. The forecast for the energy and transport sectors is based on projections presented above. Values obtained from the Swedish Environmental Protection Agency are presented for agriculture and waste. Emissions in 1995 refer to actual emissions in 1994/95.

Total methane emissions are projected to decrease by about 13% between 1995 and 2010.

Table 6.22 Emissions of methane in 1,000 tonnes

	1995	2000	2005	2010
Fuel combustion Energy and transformation industry	2	2	3	3
Fuel combustion Industry	6	6	6	6
Fuel combustion Residential, commercial and institutional sector	10	11	10	10
Domestic transportation	20	16	12	8
Agriculture	202	206	210	215
Waste	61	42	30	20
Total	**302**	**284**	**271**	**262**
International transportation	0.1	0.1	0.1	0.1

Nitrous oxide
A forecast for emissions of nitrous oxide is presented in Table 6.23. The forecast for the energy, transport and industrial sectors is based on projections presented above. Values obtained from the Swedish Environmental Protection Agency are presented for agriculture. Emissions in 1995 refer to actual emissions in 1994/95.

Total nitrous oxide emissions are projected to increase by about 37% between 1995 and 2010.

Table 6.23 Emissions of nitrous oxide in 1,000 tonnes

	1995	2000	2005	2010
Fuel combustion Power and heating plants	1.1	1.3	1.3	1.4
Fuel combustion Industry	2.3	2.4	2.3	2.4
Fuel combustion Residential, commercial and institutional sector	0.5	0.5	0.5	0.5
Domestic transportation	2.9	3.5	4.1	4.7
Industrial processes	2.3	2.6	3.0	3.4
Agriculture	0.2	0.2	0.3	0.3
Total	**9.3**	**10.5**	**11.5**	**12.7**
International transportation	--	--	--	--

Nitrogen oxides

A forecast for emissions of nitrogen oxides is presented in Table 6.24. The forecast for the energy, transport and industrial sectors is based on projections presented above. Emissions in 1995 refer to actual emissions in 1994/95.

Total nitrogen oxide emissions are projected to decrease by about 21% between 1995 and 2010.

Table 6.24 Emissions of nitrogen oxides in 1,000 tonnes

	1995	2000	2005	2010
Fuel combustion Energy and transformation industry	12	12	11	12
Fuel combustion Industry	20	18	15	16
Fuel combustion Residential, commercial and institutional sector	9	9	8	7
Domestic transportation	239	207	177	165
Industrial processes	28	31	36	42
Total	**308**	**277**	**246**	**242**
International transportation	54	55	40	35

Carbon monoxide
A forecast for emissions of carbon monoxide is presented in Table 6.25. The forecast for the energy, transport and industrial sectors is based on projections presented above. Emissions in 1995 refer to actual emissions in 1994/95.

Total carbon monoxide emissions are projected to decrease by about 59% between 1995 and 2010.

Table 6.25 Emissions of carbon monoxide in 1,000 tonnes

	1995	2000	2005	2010
Fuel combustion Energy and transformation industry	11	13	14	15
Fuel combustion Industry	32	34	34	35
Fuel combustion Residential, commercial and industrial sector	124	112	63	59
Domestic transportation	873	657	426	268
Industrial processes	49	55	63	73
Total	**1089**	**871**	**600**	**450**
International transportation	6.0	6.0	6.6	7.4

Emissions of non-methane volatile organic compounds (NMVOCs)
A forecast for emissions of NMVOCs is presented in Table 6.26. The forecast for the energy, transport and industrial sectors is based on projections presented above. Values obtained from the Swedish Environmental Protection Agency are presented for fugitive solvent emissions. Emissions in 1995 refer to actual emissions in 1994/95.

Total NMVOC emissions are projected to decrease by about 57% between 1995 and 2010.

Table 6.26 Emissions of NMVOCs in 1,000 tonnes

	1995	2000	2005	2010
Fuel combustion Energy and transformation industry	5	6	6	7
Fuel combustion Industry	6	8	7	8
Fuel combustion Residential, commercial and institutional sector	132	128	57	34
Domestic transportation	179	136	92	62
Industrial processes	36	36	36	36
Fugitive emissions, energy	15	12	12	12
Solvents	83	42	42	42
Total	**457**	**368**	**252**	**201**
International transportation	1.5	1.6	1.3	1.3

Emissions of HFCs, FCs and SF_6

Forecasts for emissions of HFCs, FCs and SF_6 are presented in Tables 6.27-6.29. The forecasts were made by the Swedish Environmental Protection Agency.

Aggregate emissions of HFCs are projected to increase by about 450% between 1995 and 2010. The projected increase for FCs is 50%, and stable emissions are projected for SF_6.

Table 6.27 Emissions of HFCs in tonnes

	1995	2000	2005	2010
Refrigerants	120	400	400	400
Plastic foams	10	200	200	200
Aerosols	20	40	60	60
Other	0	10	10	10
Total	**150**	**650**	**670**	**670**

Table 6.28 Emissions of FCs in tonnes

	1995	2000	2005	2010
Products	20	30	30	30
Industrial processes	40	45	52	60
Total	**60**	**75**	**82**	**90**

Table 6.29 Emissions of SF_6 in tonnes

	1995	2000	2005	2010
Total	**52**	**52**	**52**	**52**

6.8 Total emissions of greenhouse gases

The aggregate impact of different greenhouse gases can be calculated with the aid of GWPs (GWP = Global Warming Potential). Greenhouse gases can have a direct and an indirect effect. In the IPCC's evaluation, it is said to be difficult to assign exact values to the indirect component, so only a value for the direct component is given. An IPCC report published in 1994 contains weighted and updated values. They are presented in Chapter 4.7.

Total emissions of greenhouse gases for the period 1995-2010, expressed as carbon dioxide equivalent (in million tonnes of carbon dioxide) converted using the IPCC's GWP values, are given in Table 6.30. From 1995 to 2100 emissions are estimated to increase with approximately 10%.

Table 6.30 Total emissions of greenhouse gases in million tonnes of carbon dioxide equivalent

	1995	**2000**	**2005**	**2010**
Carbon dioxide, CO_2	58.5[1]	60.1	62.1	64.3
Methane, CH_4	6.3	6.0	5.7	5.5
Nitrous oxide, N_2O	2.9	3.3	3.6	3.9
HFC 134a	0.2	0.8	0.9	0.9
CF_4	0.4	0.5	0.5	0.6
SF_6	1.2	1.2	1.2	1.2
Total	**69.5**	**71.9**	**74.0**	**76.4**

[1] Actual value 58.1

6.9 Effects of measures

The forecast for Sweden's energy supply up to 2010 points towards an increased supply of fossil fuels and thereby increased carbon dioxide emissions from combustion. To be more exact, carbon dioxide emissions from combustion are expected to increase by 5 million tonnes during the period 1995-2010.

The policy instruments that influence carbon dioxide emissions changed during the period 1990-1996. Taken together, the changes have entailed tougher measures aimed at reducing or restraining the increase of carbon dioxide emissions. The policy instruments in effect on 1 September 1996 have a greater restraining effect on carbon dioxide emissions than the instruments in effect on 1 January 1990. In the following discussion, these policy instruments are called the 1996 instruments and the 1990 instruments, respectively. The question that arises is how much more effective the 1996 policy instruments are than the 1990 instruments.

To answer this question, we will compare the expected change in carbon dioxide emissions up to the year 2010 with the 1996 versus the 1990 policy instruments. In other words, we will compare the emissions forecast from Chapter 6, which represents the outcome of the 1996 instruments, with a scenario that describes the outcome of the hypothetical case where the policy instruments are not changed after 1990.

It should be pointed out that the comparison contains a large measure of uncertainty and must therefore be interpreted with great caution. The uncertainty stems from the fact that the comparison applies primarily to future carbon dioxide emissions, i.e. it involves comparing one projection of carbon dioxide emissions with another. Both of these projections are associated with uncertainty. The forecast represents an attempt to predict changes in carbon dioxide emissions up to the year 2010, with a point of departure in the situation that existed in 1995 and based on assumptions regarding changes in the general economic situation, changes in individual sectors, changes in fuel prices, etc., which are in themselves uncertain. The hypothetical scenario is an attempt to describe the change in carbon dioxide emissions that *could* have been the case if the 1990 policy instruments had remained in effect from 1990 to 2010.

The background data for the comparison derive from calculations with the computer model MARKAL-MACRO, which is an optimization model that works according to the principle of maximizing socioeconomic welfare[38]. The model couples together a description of the energy system with a description of the rest of the economy. Energy use, energy prices and economic development are determined in the model as an outcome of the calculations.

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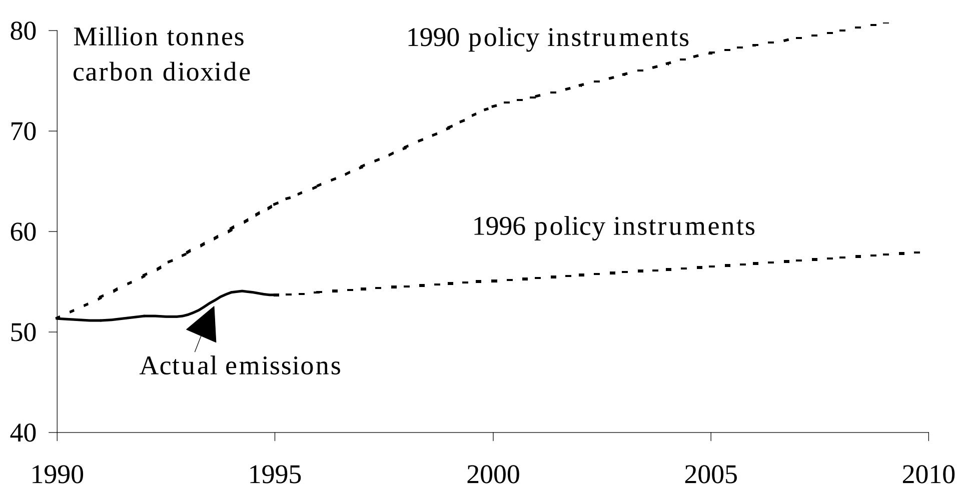
[38] The calculations are presented in their entirety in a coming NUTEK report. The MARKAL-MACRO-model is described in Manne, A.S. and Wene, C-O., 1992, MARKAL-MACRO: *A linked model for energy-economy analysis*, BNL-47161, Department of Applied Science, Brookhaven National Laboratories, Long Island, New York. Rededited in J.-Fr. Hake *et al* (Eds), *Advances in systems Analysis*, Konferenzen des Forschungszentrum Julich, volume 15/1994, Julich: Forschungszentrum, Zentralbibliotek, 1994. The database used in the model is described in Nyström, I. and Andersson, G., *Documentation of the Swedish MARKAL-MACRO databas*, Chalmers university of technology, I-EST-95-4, 1995.

The difference between carbon dioxide emissions with the 1990 and 1996 policy instruments has been calculated with the model. The results are presented in Table 6.21 and Figure 6.8. Figure 6.8 shows, firstly, actual carbon dioxide emissions between 1990 and 1995, and a forecast of their continued development up to 2010 based on the 1996 instruments. Secondly, it shows the hypothetical development of carbon dioxide emissions between 2000 and 2010 with the 1990 instruments. It has been obtained by adding together the emissions forecast and the difference in emissions development between the 1990 and 1996 instruments calculated by the model. Model-related simplifications have been necessary that make the result for 1995 less reliable. From 2000, however, the result is deemed to give a good idea of the difference between the two policy instrument packages.

In the calculations, the 1996 policy instruments consist of the energy and environmental taxes that were in effect on 1 September 1996. By “energy taxes” is meant the pure energy taxes including the value-added tax on energy, and by “environmental taxes” is meant the carbon dioxide and sulphur taxes. Furthermore, the 1996 policy instruments include the nitrogen oxide charge for large combustion plants and the investment supports to biofuel-fired CHP, wind power, solar power and district heat distribution, as well as the production subsidy to wind power. The investment supports are assumed in the calculations to be available during a 5-year period ending in 1996. The nitrogen oxide charge for large combustion plants and the production subsidy to wind power are assumed to be in force all the way up to 2010. The 1990 policy instruments consist of the energy taxes that were in effect on 1 January 1990. The difference between the policy instrument packages thus lies in the fact that several policy instruments – such as the carbon dioxide tax, the sulphur tax, VAT on energy, the investment supports and the production subsidy to wind power – were introduced during or after 1990. Moreover, the 1990 energy tax differs from the 1996 energy tax.

Figure 6.8 Carbon dioxide emissions, industrial processes excluded, with 1990 and 1996 policy instruments



As far as nuclear power is concerned, the same assumption applies as in the forecast in Chapter 6. One reactor of average size (5 TWh) is decommissioned prior to 2000, while the remaining reactors are operated for an assumed technical life of 40 years. This means that the reactors that are left after 2000 will be decommissioned after 2010.

For technical model-related reasons, it has not been possible to include all types of measures in the calculations. These include the programme for more efficient energy use and research and development activities. The programme's effects on energy use have, however, been estimated in another context[39]. Based on these calculations it is possible to estimate the effects of the programme on carbon dioxide emissions (see Appendix 1). The results of the model calculations have been supplemented with this estimate. The effects of research and development activities are much more difficult to quantify and have accordingly not been taken into account in the analysis. The effects of wind power on carbon dioxide emissions have also been estimated outside of the model calculations.

Table 6.31 Calculation of difference in carbon dioxide emissions between 1996 and 1990 policy instruments, broken down by sector and policy instruments, million tonnes per annum

	2000	2005	2010
Sector			
Energy and transformation industries	-7.2	-8.2	-10.8
Industry	1.2	2.1	2.3
Residential, commercial, institutional	-7.8	-11.3	-11.0
Transportation	-3.7	-4.1	-4.2
Total	-17.5	-21.5	-23.7
Policy instruments			
Investment support	-0.7	-0.7	-0.7
Programme for more efficient energy use[1)]	-0.2	-0.2	-0.2
Carbon dioxide and energy tax, transportation	-3.4	-3.9	-4.3
Carbon dioxide and energy tax, industry and energy sectors[2]	-13.2	-16.7	-18.5
Total	-17.5	-21.5	-23.7

1) The expected effect of the programme within the residential sector.
2) Including the effects of VAT

The difference in carbon dioxide emissions between the 1990 and 1996 policy instruments is evident from both Table 6.31 and Figure 6.8. The model calculations indicate that the 1996 policy instruments lead to an energy system that results in both a lower level and a slower rate of increase of carbon dioxide emissions. The greatest contributions to the difference in carbon dioxide emissions between the 1990 and 1996 policy instruments come from the three sectors electric power and heating plants; residential, commercial and institutional premises; and transportation.

According to the model, in the electric power and power plants it is primarily the difference in the fuel composition in district heat and CHP production that explains the difference in carbon dioxide emissions. With the 1996 policy instruments, much more biofuel and less coal and oil are used compared with the 1990 instruments.

[39] NUTEK R 1996:68, "Evaluation of NUTEK's programme for more efficient energy use"..

Also according to the model, the difference in carbon dioxide emissions in the residential, commercial and institutional sector is explained by the fact that the 1996 policy instruments lead to a faster and larger-scale implementation of conservation measures within space heating and other electricity use than the 1990 instruments. Energy conservation is achieved in part by means of technical measures such as supplementary insulation and more efficient household appliances, and in part by means of changed priorities such as a lower indoor temperature and fewer heated rooms.

Finally, the difference in carbon dioxide emissions in the transport sector is explained by the fact that the 1996 policy instruments result in higher fuel prices than the 1990 instruments and thereby a lower demand for transport.

The model calculations primarily provide an idea of the influence of the policy instruments on carbon dioxide emissions from the different sectors. The calculations also provide guidance when it comes to determining the influence of individual instruments on carbon dioxide emissions. In combination with supplementary estimates of the influence of the investment supports on carbon dioxide emissions (see Appendix 1), an overall picture of the effects of the policy instrument packages and the relative effectiveness of the different instruments is obtained. Table 6.21 shows that for all forecast years, more than 90% of the difference in carbon dioxide emissions can be attributed to the energy and environmental taxes plus VAT on energy. It is important to note that the lower taxation of industry’s energy use leads to a slight increase in emissions from this sector. This increase is, however, compensated for by greater reductions in other sectors.

6.10 Projections after 2010

The directives for the national report further call for the country’s best predictions of future carbon dioxide emissions even beyond the time horizon of 2010. In Sweden’s case, a number of calculations, in scenario form, of the development of the energy system have been carried out during 1994/95 on behalf of the Energy Commission. The scenarios extend up to the year 2020. They should be regarded as the best available projection.

In these calculations it was assumed that GDP would grow by an average of between 2 and 2.5% annually during the coming 25-year period. It was further assumed that the useful life of the nuclear power reactors is 40 years, which means that more than half of their capacity will remain in 2020. The calculations show that energy demand will increase, but the rate of increase will be lower than the rate of growth of the economy, just over 1% per annum. Electricity demand is also projected to increase by just over 0.5% annually. On the supply side, natural gas condensing power, CHP in the district heating system and wind power are assumed to have replaced the power previously generated in the decommissioned nuclear power reactors. The prices of energy raw materials, coal, oil and natural gas, are predicted to increase in Sweden, by about 30% in real terms, during the next 10–15 years as demand rises and the supply of cheap electricity from hydropower and nuclear power becomes inadequate, at the same time as the scope for international trade in electricity becomes more limited. These factors will lead to an increase in carbon dioxide emissions from the energy system by about 50% during the period 1995–2020, to a total of about 80 million tonnes per year. Compared with 1990, the increase will be nearly 30 million tonnes. The increase is mainly a consequence of the replacement of nuclear power by natural gas, but also of the fact that total energy demand is expected to increase.

7. Impact of climate on technical systems

7.1 Climate scenarios

According to the IPCC (2995), the earth's average temperature has increased by about 0.5° in the past 100 years. The increase lies within the range of natural variation, so its immediate cause cannot be determined. However, all signs indicate that the atmospheric concentration of carbon dioxide and several other greenhouse gases is increasing as a result of emissions caused by man. An increase in the atmospheric concentration of carbon dioxide and other greenhouse gases will lead to a global temperature rise, accompanied by regional changes in temperature and precipitation that may be either smaller or greater than the global changes.

The scenarios indicate a greater increase of the mean temperature in the winter, about 3°C, than during the summer, about 2°C. Precipitation is expected to increase by 10-15 mm, the greatest increase in the winter months. Precipitation is very difficult to predict, but large variations will become more common. Increased cloudiness and a possible increase in the frequency of storms, at least in the short term, plus generally greater variability in the climate are probable effects of a climatic warming.

The type of precipitation cannot be predicted by models, but analogical reasoning suggests that thunderstorms, which are now more common in southern Sweden, would also become more common further north. With thunderstorms the rains will also become more intense. The influence of precipitation and cloudiness on the temperature has not yet been evaluated. This is also true of the vegetation. Recently, attention has also been turned to evapotranspiration. This has been found to be particularly important for Sweden, where the modelling work suggests that we will have a negative runoff, in other words drought in large parts of southern and central Sweden (Saelthun et al., 1995).

A sea level rise is a probable result of global warming, chiefly due to expansion of the water masses. Sea level rise is not a primary problem in all of Sweden, since the northern part of the east coast is still slowly rising as a result of the most recent glaciation. However, the west coast and parts of the coast of Skåne may be affected, particularly as regards erosion and undermining of coastal structures.

Areas that have a long ground frost period today will have thaw-frost-thaw cycles during a greater part of the year than now, with long periods with heavy wet snow alternating with ice formation. Geotechnically, the soils in southern and northern Sweden differ, as does the composition of the vegetation. This may affect the drainage pattern in the event of a changed precipitation pattern.

The changes in atmospheric chemistry and emissions of ozone-depleting gases lead to increased ultraviolet radiation, which can have a synergistic effect on certain systems or processes. Nowadays, thinning of the ozone layer is a reality over Sweden as well, where the ozone layer has thinned by 5-8% during the past decade.

Figure 1. Models up to 2030 (Rodhe 1990)

Climate changes in the Nordic region (except Iceland) in 2030	
Temperature:	+2° in the summer
	+3° in the winter
Precipitation:	+10 mm/month during the summer
	+15 mm/month during the winter
Sea level:	+20 cm

7.2 Impact of climate on technical systems in Sweden

Technical systems in our society are often not designed to adapt to rapid changes in external physical conditions. Examples of what extreme types of weather can do to technical systems are provided in news reports from other parts of the world where floods, hurricanes and heat waves (an example from last summer was when Moscow's airport had to be closed in the middle of the day due to softening of the tarmac on the runways) have caused problems in the infrastructure. The most serious disturbances that can occur are if the water supply should be threatened or if a major power station dam should burst.

Technical systems with a short economic life can be replaced and adapted retroactively. In the case of more long-term investments which also require expensive modifications, certain problems can arise in connection with a changing climate. Extreme values are of very great interest in the discussion of the consequences of a hypothetical climate change. Numerous societal functions are designed for these extreme values. Examples are wind and snow loads on buildings, water supply systems, power supply systems, dams and flood control works, to name just a few examples. It is therefore important not to stare blindly at mean values in the analysis of different climate scenarios. This requires high resolution and precision in the atmospheric circulation models on which the climate analysis is based.

What distinguishes our age is that man has built a remarkable socioeconomic system during a period when this was possible. The climate was stable enough for the development of an infrastructure that has permitted the maintenance of an advanced society. A drastic change in the climate or extreme weather conditions with the changes this would bring could pose great risks to people in exposed areas, both physical risk in the form of flooding and water shortages with their consequences.

A sensitivity analysis of the vulnerability of certain technical systems to climate change has been compiled in the Swedish Environmental Protection Agency's project group "Climate change and UV-B radiation". This has not involved any research; the purpose has rather been to try to predict what problems might arise in conjunction with a changed or variable climate, and to determine whether any preparedness exists in society to cope with such changes. There may therefore be advantages that do not emerge in the report. Together with last year's report to the Government on effects on our ecosystems, the analysis will form a part of the Swedish Environmental Protection Agency's "Future study 2021".

The technical systems that have been studied are: corrosion in different societal systems, hydrological systems, geotechnical systems and energy systems.

7.3 Corrosion

Corrosion is an economic problem of large proportions. A multitude of complex processes which are affected by physical, chemical and biological factors are involved. The general principles are:

1) high temperature, like cold, reduces corrosion
2) small temperature variations have no effect
3) dampness is a crucial factor

Temperature has a complex effect on corrosion: On the one hand, the corrosion rate increases with the temperature, since the rate of the electrochemical and chemical reactions, as well as the rate of diffusion, increases. On the other hand, a higher temperature (at temperatures above 0°C) also leads to faster drying of the moisture film that is present on material surfaces, which results in a shorter time of wetness (the time during which the relative humidity exceeds 80%). Relative humidity is linked to the temperature, but a change in a degree or two has little or no effect, while a couple of degrees can be of some importance.

A – If the temperature rises, the time of wetness may be affected (TOW = f(T>0°C, RH>80%)
1) the time of wetness is shortened – does not affect corrosion
2) same or longer time of wetness – accelerates corrosion
B – If the number of occasions with temperatures <0°C is reduced

The variations and the extremes are more important than a small increase in the mean temperature.

Corrosion rates are low in subarctic and arctic regions. The time of wetness, which is linked to corrosion, varies in different parts of Sweden and Europe. In Gällivare, corrosion is low because temperatures <0°C prevail during much of the year. If the time with temperatures <0°C decreases, corrosion will increase. South and Central Sweden comprise a relatively homogeneous region. Salt-saturated winds from the sea affect corrosion along the west coast. Depending on the topography, the effect further inland can be detected up to a distance of between one or two kilometres to several tens of kilometres.

Malmö and Stockholm have the same annual mean values of relatively humidity. Nevertheless, moisture-related degradation is a much more important factor in Malmö than in Stockholm. Most areas in the temperate climate zone have a time of wetness of 2500–5500 h/y (in Stockholm 2900 h/y). Stockholm’s inner city has a shorter (700 hours) time of wetness than e.g. the countryside between Enköping and Uppsala. This is because a big city generates heat, which leads to a higher temperature – higher evaporation – shorter time of wetness. The level of air pollution is crucial for the corrosion rate, which means that corrosion is higher in urban areas that in the countryside.

The concentration of air pollutants is often of crucial importance for the rate of atmospheric corrosion. The air contains pollutants in three states: gases, solid particles and substances dissolved in tiny droplets of water or on a liquid film on the surface of the solid particles. Dry deposition of pollutants is worse than acid rain. Acid rain is rinsed off as more rain falls, while the dry-deposited pollutants dissolve in a condensate film and remain in place for a longer time. They can thereby penetrate into porous materials such as brick.

Ultraviolet radiation affects all organic material. In combination with acid rain, metals are particularly affected. Previously, sulphur compounds (SO_2) have been dominant, but due to changed emissions rules they are now diminishing, while nitrogen oxides (NO_x) are increasing. There is also a strong synergy effect between these compounds. When ground-level ozone is present, sulphur compounds are oxidized to a more aggressive form. Zinc, which is present in e.g. lampposts, sheet metal on buildings and cars, is sensitive to corrosion.

Experiments aimed at studying the effect of acid precipitation and UV radiation in which plastic materials are either exposed freely to the elements or are protected from the rain and sun have shown clearly that the plastics degrade faster where they are exposed freely. Cost/benefit analyses of organic systems, e.g. paint coatings on wood and metal surfaces, have also shown that degradation of painted wood is accelerated when the surface is freely exposed. The results also show that corrosion is worse in areas with high pollution levels.

7.3.1 Buildings

The climate influences the degradation of building materials on building façades and roofs. Such degradation is normally the result of interaction with external factors such as the elements (weather and wind), as well as interaction between different materials and material properties.

Knowledge of the influence of climate and environmental factors on the degradation of exterior sheathing materials on buildings is necessary to be able to make reliable predictions of maintenance needs and lifetime.

Relevant factors are relative humidity, temperature, precipitation and the presence of pollutants and corrosion products on the surface. The local topography and the combination of wind and precipitation (driving rain) are, in addition to the properties of the material, of great importance. Proper design of buildings is important to prevent the ravages of the elements.

Congelifraction (frost bursting) does not actually cause fatigue failure. Every porous material has a critical moisture content. At temperatures below 0°C, the water in the pores freezes and causes mechanical congelifraction.

Wind is the climate factor that is most neglected when planning buildings, despite the fact that it greatly influences our perception of both the indoor and the outdoor environment. Wind gives rise to pressure differentials over different building surfaces. These pressure differentials can affect the performance of e.g. ventilation systems. It may also be necessary to make allowance for wind loads in designing exposed building components.

The dispersion of air pollution in relation to buildings and other structures is important both from a health viewpoint and from the viewpoint of their catalytic effects on corrosion. Rain in combination with wind can cause water to penetrate into porous materials. If these wind effects occur frequently, severe problems can occur due to moisture penetration. Moisture penetration in porous materials such as brick walls rarely occurs in the interior of the country, but does occur along open stretches of coast. This is primarily an economic problem, but can also constitute a health hazard by giving rise to allergic reactions.

There is a strong link between climatic factors and the effects of air pollution on building materials. Pollutants are deposited on the surface by dry deposition (adsorption of gases or deposition of particles) or by wet deposition (rain, snow). Nitrogen compounds, which are acidic, attack zinc, limestone, rendering, plastics and wood. In combination with sulphur compounds, they increase corrosion of copper, electrical contacts, etc. Ozone is aggressively oxidizing, and together with acid rain it reinforces photochemical processes. Under the influence of acid rain on organic materials, hydrolytic degradation of cellulose takes place in wood materials.

Ultraviolet radiation has exhibited a noticeable effect on materials. UV radiation, which splits molecular bonds, plus air pollutants which act as catalysts are highly reactive agents. They attack materials that are covered with organic surface coatings. Such materials are common in the infrastructure, for example in paints, plastics and jointing mastics, which can be anticipated to give rise to large cost increases in the event of increased UV radiation. Measured values of ultraviolet radiation on S/90° surfaces are 10–30% higher than on horizontal surfaces and 7–14% higher than on S/45° surfaces. Southern façades receive 12–40% higher UV radiation than northern façades.

7.4 Hydrological systems

7.4.1 Hydropower and dam safety

Ample water resources are of crucial importance for hydroelectric power generation. The volume of water available is sensitive to the annual distribution of precipitation and extreme values. The balance between precipitation and evaporation determines how much water is available. These relationships can be determined with great accuracy by mathematical models. The models make it possible to calculate the consequences of a climate change if we know the change in temperature and precipitation.

A Nordic climate scenario developed in the Nordic project “Climate Change and Energy Production“ (Saelthun et al., 1995) predicts an increase in both temperature and precipitation in the entire region. This scenario was used for hydrological simulations for assessment of hydropower production, but they are also relevant for assessments of water resources.

The Nordic scenario assumes a temperature increase in Sweden of about 4°C over a period of a hundred years. This is a considerable change, but still not more than the natural range of variation in Sweden’s annual mean temperature of about 3.7°C that was measured during the period 1961–1990 (Bergström 1994).

The hydrological calculations in the Nordic project indicated increases in water volumes and thereby in the potential for hydropower generation in those parts of the Nordic countries with the greatest precipitation, which in the case of Sweden is in the westernmost mountains. In Sweden the results pointed towards a decrease in the other parts of the country, especially in eastern Gotland, where the climate is so dry.

According to the above climate scenario, a climate change would bring about great changes in water resources. Milder winters will mean shorter periods with snow and thereby less need to store water, since the flow will be more even over the year. This is not particularly surprising in itself, since Sweden has large climatically related variations even with today's climate. The mild winters of recent years, for example, have reduced the size of the spring flood in southern Sweden and led to increased water runoff.

The effect of climate on electricity consumption is another factor that must be taken into account when analyzing the impact of climate change on hydroelectric power generation. Calculations indicate a decrease in consumption by about 1.3% per degree of increase in the annual mean temperature in Sweden, due to a reduced heating requirement. This is however a very uncertain figure in a hundred-year perspective, since we cannot foresee the structure of the energy supply system so far into the future.

The occurrence of extreme values is usually of greater interest than average values of water discharge. It is usually extreme values that serve as the design parameters for technical systems, regardless of whether it is a question of extreme flows or extreme drought. However, it is more difficult to draw conclusions about extreme water conditions. Taking these reservations into account, the conclusion can be drawn that the spring flows will generally decrease. Winter flows will become more common, and in some cases may exceed today's flows.

Even if the calculations are subject to strong reservations and cannot be used as a basis for decisions, they have a value as a basis for sensitivity analyses. They show that we must be prepared for rather drastic changes in water flows if a permanent climate change occurs, regardless of the direction of that change. This applies to both extreme values and average conditions. The risk of impact applies to both the average water discharge values and the extreme values that are often used as design parameters for technical systems.

Experience from the Swedish hydropower system and physical planning in both regulated and unregulated river valleys show that there is a tendency to underestimate the variations of nature even with today's climate. The seriousness of the problem has been confirmed by numerous severe floods in the past few decades. This has led to a review of the methods for calculating design flows for dam installations, resulting in a thorough re-evaluation of the safety of the hydropower system in this respect (Flow Committee, 1990). Furthermore, the need for a mapping of risk zones has been pointed out by, among others, the recently concluded government report on dam safety (SOU, 1995:40). This is also an international problem. Recent flooding in the valleys of the Mississippi, Rhine and Meuse rivers are only a few examples. It is worth noting that the 1990 Flow Committee did not consider the time ripe for taking climate predictions into account in formulating the new guidelines for calculation of design flows for dams. Reservation was, however, made for the possibility that a permanent change in the precipitation climate in the future may necessitate a review of the guidelines.

7.4.2 Human settlements in the risk zone

In view of the flooding that has occurred on repeated occasions in recent years (including 1993 and 1995), the National Board of Housing, Building and Planning initiated a study of the consequences of such flooding for the planning of human settlements and for the rescue services in the event of high water flows. The first phase of the work – which has been conducted in cooperation with the National Rescue Services Board, the Swedish Power Association, the river regulation associations, the County Administrative Board in Västernorrland County, and the Swedish Association of Local Authorities – has resulted in a mapping of risk zones on the Umeälven and Vindelälven Rivers. The risk of ground collapse and landslides has been investigated by the Swedish Geotechnical Institute (SGI), which carried out investigations along the southern Göta River. This mapping will serve as a basis for recommendations for in connection with physical planning and the issuance of building permits along watercourses.

7.4.2.1 Flooding risks
A set of maps has been produced showing the risks of flooding along our major rivers. The map set pertains to one regulated river (Umeälven River) and one unregulated river (Vindelälven River). Previously, risk areas have been identified by traditional investigation methodology using aerial photography (Voxnan/Edsbyn). The new methodology is based on existing map material, where virtually all maps except the overview map are suitable. The thrust of the proposal is to show water level lines on all maps, for example 100-year or 1,000-year flows.

The purpose of the continued work under the leadership of the National Board of Housing, Building and Planning is to identify risk areas for all our rivers, including the regulated ones. It is particularly important to identify areas where changes are occurring, for example at roads and building sites. The intention is not to issue any general prohibitions against building below a given level but to serve as a guideline for future building.

Eventually this work will result in the issuance of guidelines for construction of dwellings. Planning, map materials and other background material will serve as a basis for assessment of various building measures. The background material is being collected via a questionnaire sent out to local government officials. Then a trial planning will be carried out by the National Board of Housing, Building and Planning to gain concrete experience of using the recommendations that are the end result of the entire investigation. The infrastructure recommendations should apply to the entire country.

7.4.2.2 Ground collapse and landslide risks
The investigation of ground collapse and landslide risks that has been conducted along the southern Göta River will be methodically coordinated by the National Board of Housing, Building and Planning with the results from the investigation of flooding risks so that recommendations can be coordinated.

The risk of ground collapse and landslides must be taken into account at the comprehensive physical planning level in order to mitigate the risks to people and property. Ground stability can be improved (reduces the likelihood of collapse and slides) by reinforcement measures; otherwise all activity that would result in loss of life and property or harm to the environment in the event of a collapse or slide must be discontinued or avoided.

Areas prone to landslides include:

1) areas with dwellings built above steep underwater slopes that are being eroded due to wave activity from e.g. passing vessels.
2) areas subject to flooding or prolonged rainfall, making the sediments water-saturated.

A potential slide risk is also posed by the water supply pipes that run across and alongside the river, should they begin to leak. The hydropower-related regulation of river flow helps to mitigate the slide risk due to heavy flows. Another risk element is the possibility that toxic sediments might be washed into the river, affecting the quality of its water, which is used as drinking water.

7.4.3 Water supply and sewerage

Drinking water supplies in Sweden are based to a large extent on raw water taken from groundwater sources and lakes and subjected to subsequent purification treatment. After treatment the drinking water is distributed to subscribers in water distribution systems consisting primarily of pipes made of steel, cast iron, PVC and polyethylene. The oldest parts of the water distribution systems in Stockholm are from the mid-19th century. Wastewater is conducted via stormwater and sanitary sewers to sewage treatment plants. The sewer systems are made primarily of concrete, clay and PVC pipes. Modern water supply and sewer systems have a technical life of between 200 and 300 years.

Factors that affect the piping systems are:

- raw water quality
- external and internal corrosion in the piping system
- precipitation and flooding
- pollution from users, land and buildings
- ground movements
- lake and groundwater levels

At a higher air temperature, the water temperature of the lakes may rise, resulting in poorer raw water quality. Problems can arise in the form of blue-green algae, which produce toxins and deplete the water of oxygen (roughly a doubling of biological activity for every 10° of temperature increase). The production of algae has a great influence on which technology can be used for treatment.

If evaporation increases more than precipitation, this also means that the lakes’ water turnover rate and groundwater recharge will be affected, which can impair the drinking water supply. Consumers will get slightly warmer and therefore not as good-tasting drinking water. This can, however, be counteracted by large investments in the form of new intake pipes for raw water.

There are no large margins for increased precipitation in the sewer systems, which are designed to cope with a certain quantity of rainwater. Increased precipitation and more intensive rains can cause more frequent basement flooding and sewage overflow into receiving bodies of water. This also leads to an increase in the quantity of stormwater to sewage treatment plants, resulting in larger total discharges of pollutants.

As an effect of soil acidification, external corrosion of metals in the ground will increase, shortening the lifetime of the water distribution networks.

A sea level rise of 10 cm means increased seepage into the sewer system in extreme weather situations, especially in harbour areas. In Kristianstad, for example, it sometimes happens that the sea level is so high that the water cannot run out. This will increase the load on treatment plants unless targeted investments are made in the sewer system. Intrusion of salt water in Lake Mälaren, which serves as the major source of water for Stockholm and other towns around the lake, is not likely in the short term, but in a 100-year perspective it could happen.

Ground movements in conjunction with thawing of the frozen ground or groundwater lowering are directly reflected in a larger number of breaks in water and sewer pipes. If a warmer climate results in reduced frost heave, the effect will be positive, but the reverse is true if thaw-freeze-thaw becomes a more drawn-out process. Land use in the Lake Mälaren Valley has a clear influence on water quality in the lake.

The drinking water supply is particularly dependent on electricity. Large water works have backup power plants. Mobile backup power units exist for local water pumping stations.

Water supply problems may arise in Stockholm if the scenario with 20% evaporation becomes reality. If precipitation doesn't increase and evaporation has to be calculated based on normal precipitation, evaporation will be 40%! Lake Mälaren's summer outflow is about 10 m^3/s. Withdrawal in the summer can be 8 m^3/s, which is virtually the entire volume. Similar problems could arise at other places, especially along the east coast.

7.4.4 Industrial and process waste water

At a higher frequency of precipitation, the quality of raw water to industry could be affected negatively. An increased hydrological load on humic-rich soils around the catchment area for raw water could cause increased leaching of coloured and oxygen-consuming pollutants. Reduced water quality could then cause problems with certain product quality parameters.

This could probably be counteracted by a more effective and heavier dosage of treatment chemicals in the raw water treatment stage.

Another negative effect is an increase in the temperature of the incoming water. It is then highly likely that bacterial activity in the water will increase. This will lead to growth of deposits in pipelines and probably also a risk of increased growth in cisterns. At worst, this could also lead to a higher bacterial content in the end products of industry.

A rise in the sea level by about 20 cm by the year 2030 should not have any great effect on industrial plants along the northeast coast of Sweden, given the ongoing rate of land uplift. A possible negative effect is increased problems with discharge of wastewater from outfall pipes that are already low-lying today. It should be possible to counteract this with increased pump capacity. If the problems turn out to be greater than anticipated, it may be necessary to raise the entire sewer system from its current level.

Ground thaw does not cause any problems today with subsurface pipes in southern and central Sweden. The problems are greater in the northern parts of the country, but with a warmer climate these problem areas should shrink further as the ground frost period becomes shorter. However, uncertainty in this respect is great, since a drawn-out thaw-freeze period may also be the case.

7.4.5 Port facilities

Land uplift, air pressure, wind direction, wind force and the period of time during which the wind acts in a certain direction are crucial parameters in the design of seaports on the Baltic Sea. In Lake Mälaren, additional design factors are precipitation, meltwater and evaporation. The water level varies in the Baltic Sea, while the level in Lake Mälaren is kept at about 4.14 m above the lock threshold in the Karl-Johan lock in Stockholm.

A higher average temperature will lead to greater evaporation from Lake Mälaren, but this can be compensated for by reduced discharge. Higher precipitation will mean that the level of Lake Mälaren will rise, but this can be compensated for by increased discharge. Sea level rise will be compensated for, at least in the short term, by land uplift along the east coast. The rate of land uplift varies from about 0.8 m/100 years along the Gulf of Bothnia to 0.4 m/100 years along the coast of the central Baltic to a transgression in the southern Baltic of about 0.1 m/100 years.

The quays in the port of Stockholm are 2 m high, which means that they are not sensitive to a small change. They could tolerate a change of ±0.5 m. At high water, however, difficulties can sometimes arise even today at ferry berths, especially at fixed berths.

If the sea level rises, the height of bridges may pose a problem to pleasure boat traffic (Lidingö Bridge, Stocksund Bridge and old Skanstull Bridge).

A fluctuation of ±0.5 m around the normal water level is acceptable in the port of Gothenburg as well. Water level increases of 1 m have occurred during strong westerly winds, resulting in flooding in the city. A prolonged rise in the mean water level has occurred on certain occasions. This can affect container handling in conjunction with heavy winds during loading and unloading. Costly alterations would be required if the mean water level were to rise more permanently. Ferry harbours are generally more sensitive to small variations.

The height of bridges can pose a problem on the west coast with a half a metre rise in the mean water level, since the water level can rise as much as 1.5 m more during severe weather. The consequences of a change in runoff in the Göta River are not known.

Ports are dependent for their operation on reliable supplies of electricity and water and smooth functioning of sewer and transport systems. It is not known today what the effect would be if these services were to be disrupted.

The vulnerability of the ports of Stockholm and Gothenburg to the projected climate changes up to the year 2030 is not particularly great.

7.5 Geotechnical systems

7.5.1 Roads

Design-basis factors for roads are climate and traffic load. Ground frost is the crucial design-basis factor north of the Lake Mälaren Valley today. If the climate grows warmer, the ground frost limit will move northward and designing for ground frost will become less important. It is estimated that for 20% of the roads where ground frost is the crucial design factor today, traffic will be the design-basis factor in the future. This means that road structures will be made thinner, resulting in a cost reduction of about SEK 100 per metre of new road. In southern Sweden the maintenance costs will be less, while they will presumably increase in central Sweden, since the number of alternations between thaw and frost is expected to increase there. The effect for the country as a whole will be limited, since the greatest traffic works are in southern Sweden. The same reasoning applies to the use of studded tyres. Some road deformation can be expected in a warmer climate, but the cost of winter road upkeep will nonetheless presumably decrease by several hundred million kronor.

The construction season will be extended. Less frost heave will also make it more profitable to build concrete roads further north in the country. They have a longer technical life, and probably cause less impact on the environment.

Total salt consumption in the country will decrease if the number of days with slippery roads declines. This would have a positive effect on the national economy, but also on car corrosion. The outcome is not clear, however, when comparison is made with Germany which, despite a milder climate, salts its roads much more than Sweden.

Way up north the warmth will have negative consequences in reducing the number of ice roads and shortening their useful season. This will in turn require more bridges to be built.

If groundwater levels in the country rise, this will lead to drainage problems on many more roads than today.

An increase in winter precipitation will mean more snow in the colder parts of the country, and thereby a shallower frost depth due to the insulation effect of the snow. On the other hand, snow clearance costs will go down in the southern parts of the country, whereas they will increase in the north. For the forestry industry, roads closed today due to frost damage cost about SEK 800 million per year.

Acidification of soil and acid rain will cause lead, which is bound in the soil along the roadsides at high pH, to be released if the pH declines. If the water runs slowly, the contaminants will be absorbed by the vegetation (organic nitrogen traps), while this will not happen if the quantity and flow velocity of the runoff is great. Natural purification will not work if the spring flood comes before the frost has gone out of the ground.

Sea level rise may necessitate moving some roads along the west and south coasts, since erosion will make them risky to drive on.

Another effect of an increase in UV radiation is that road surfaces, markings and signs will age faster than today.

During 1994, the National Road Administration published new rules for road construction, based in part on modern technology and theories and in part on updated climate information.

Rules for reinforcement and improvement of the existing road network will also be issued during 1995–96.

7.5.2 Bridges

If the climate becomes warmer with milder winters and more precipitation, many bridges in the country may suffer erosion problems and need to be strengthened. This is only true, however, provided that water levels and flows in our watercourses are appreciably higher in the future than today, at least periodically. Greater variations with more extreme flows at other times of the year may cause erosion problems are more places than today.

7.6 Energy systems

The consequences of electric power failures were recently described in "The threat and risk report" (SOU 1995:19). These are disaster scenarios, where the main emphasis is on defence aspects, but in some cases there are parallels with what might happen as a consequence of greater variability in the climate. This is particularly the case with electric power (SOU 1995:20) and water (SOU 1995:21). The report deals with a chain of events (storm – wet snow – cold – salt coatings on power lines – line breakage – power outages – tree clearance – fault tracing) which can have great effects on society. Following is a brief summary of events that demonstrate the vulnerability of the systems to changes in climate:

In severe weather situations, the electric power system can suffer serious outages caused by storm winds, heavy wet snow with subsequent cold and salt coating, causing brief interruptions in the power supply. There is some capacity for automatic washing of salt-coated lines, but to a great extent this must be done manually. Other scenarios are windthrown trees across roads, causing accidents without the alarm and rescue services working. Hospitals are overloaded. The casualty hospitals have some form of emergency power, but its capacity varies. The district medical centres and old-age homes have no emergency power at all.

Water works and sewage treatment plants, energy utilities and industries (refineries, petrochemical plants and the process industry) are particularly sensitive to losses of power and water supplies. It is important to shut down the plant quickly before any major damage occurs. The risk of fires increases during sudden power outages. Only a few industries have emergency power. Computers and other technical equipment go down when power poles are knocked down and switching substations are knocked out.

The infrastructure collapses. Food distribution, which is dependent on transport, comes to a halt because petrol pumps don't work. Grocery stores become dark and cold, freezers and refrigerators don't work and food spoils. Rail traffic is down due to salt on the lines, windthrown trees, etc. The major airports have emergency power for up to 70% of their normal needs, mainly for the lights on the takeoff and landing runways. Telephone stations have their own emergency power generators that work as long as they have fuel, while small stations have a capacity for 6–12 hours' operation. Radio and TV have to transmit on emergency power.

7.6.1 Electric power – the trunk-line system

The national power transmission grid in Sweden consists of about 15,000 km of lines. Normally, ice loads occur on lines north of the Dalälven River at elevations over 400 m above sea level at temperatures between 0°C and -2°C. Problems occur along the northeast coast as well when the Bothnian Bay has not frozen. Moisture-laden air is then brought in over the land and cooled off. Winds along the whole northeast coast cause problems at elevations from 400 to 600 m above sea level. If the temperature rises a degree or so, the risk of ice load can increase, increasing the risk of power outages.

Transmission lines are designed for an ice load of 3 kg/m and conductor. In severe weather, wires in the line can have an ice layer of up to 10 kg/m and conductor. The wires then become so heavy that poles and cross-arms break. Operational disruptions on lines can take weeks to repair.

Corrosion of poles, stays and stay anchors will also increase if the temperature rises, just as pressure-impregnated wooden poles will suffer greater decay if the decay period per year is extended. The risk of power interruptions will increase (pole collapse) and the costs of inspections and repairs will increase. Poles that are impregnated with creosote, as well as old oil and new PVC cables, are affected by UV radiation. Today glass is used as an insulation material, but in the future composite materials will be used, which are unfortunately more sensitive to UV radiation. It is possible to protect against UV radiation, but it is not known what other effects such protective material may have on recipient waters and on water supply and sewage systems.

The national power grid has tree-proof transmission pathways, so the risk of operational disruptions caused by windthrown trees falling on lines should not increase. At a higher carbon dioxide concentration, the growth rate of trees will increase, which will raise the cost of tree clearance in transmission pathways. Felling of edge trees and compensation to landowners for these trees will also increase. Tree damage is not an extreme costs, but operational disruptions can have serious consequences.

Ground damage could increase if the climate gets warmer. A shorter period with frost in the ground could impede maintenance and construction work on mires, through which transmission lines are often run today in northern Sweden.

7.6.2 Regional and distribution networks

Power lines and equipment in transformer stations and switching substations are designed to function at extreme temperatures. Regional lines (130–70 kV) and distribution networks (0.4–40 kV) are designed with respect to geographic location when it comes to wind and ice loads. This means that areas near the west coast are given reinforced insulation to withstand salt coating. Near the west coast, more insulation is used and special equipment is installed for washing of salt-coated plant parts.

If the frequency of salt storms (and thunderstorms) increases, the frequency of outages in the power grids will increase, which means reduced availability. Extensive salt coating can lead to long outages. It is difficult to improve existing plants to make them more resistant to salt. The salt problem is worst for the highest lines and the switching substations, which are part of the trunk-line system. A higher wind frequency may pose a problem, since even today salt from the Atlantic is sometimes blown in over the mountains and deposited far inland. Salt coating may then become a more widespread problem.

Power transmission involves some energy losses, which cause heating of lines and equipment. With increasing power transmission, it is therefore a normal phenomenon that equipment may have to be replaced or reinforced due to excessive heating. A moderate increase in the ambient temperature may accelerate such wear in some cases.

Large temperature variations which greatly change the pattern of electricity consumption from heating in the wintertime to cooling in the summertime may have a great effect. Changes in electricity consumption are mainly of economic interest and mainly affect the consumer. But it is possible that electricity consumption will increase, since the biggest difference in a warmer climate is that cooling and air conditioning equipment becomes more necessary and more common. More rain is probably not a problem, but wet snow and ice is. The availability of the electric power system will initially be reduced, but probably not to any drastic extent. In the long run, countermeasures may be taken if the electricity consumers are prepared to pay for them.

7.6.3 Gas

There are four types of gas pipes in the Stockholm town gas network. They were laid during different eras in the more than 140-year history of the gas system. Cast iron pipes jointed and caulked with lead, steel pipes connected using the same jointing technique, steel pipes with welded joints (which constitute more than half of the gas piping system), and in recent years PE plastic pipes.

Distinguishing characteristics of the different gas line types:

– The cast iron pipes are brittle and can crack if they are subjected to stresses, e.g. due to ground movements.
– Socketed pipes, of both cast iron and steel, have a tendency to leak at the joints if subjected to ground movements.
– Steel pipelines corrode where the corrosion protection is inadequate.
– PE pipelines are much more resistant to both ground movements and corrosion.

Experience shows that warm winters tend to reduce the frequency of breaks in the cast iron pipes, caused by cracks in the material. It is possible that this means that ground movements, for example those caused by ground frost, will decrease in Stockholm as the temperature rises. It is unclear whether this trend will be affected by a simultaneous increase in quantities of precipitation. Large quantities of snow may act as insulation so that the rising temperature, in combination with the insulating snow cover, may lead to reduced frost depth. If this is true, it should be favourable for the gas lines in terms of both cracking and joint leaks in the socketed sections.

In the scenario with a lower groundwater table and extremely dry periods, subsidence will occur more frequently, which could have a negative effect on the pipes.

Corrosion is a slow process that proceeds over a long period of time before the damage can be detected by the occurrence of a leak. Increased precipitation should mean that more of the gas lines will be surrounded by water during certain periods. There is not enough knowledge today to know whether this will increase the corrosion rate. The quality of the precipitation, acid rain, is presumably more crucial than the quantity. The cost of leak detection and repairs is about SEK 25 million annually.

8. Financial support and contribution to the financial mechanism

8.1 Financial support through bilateral initiatives

General
Sweden's foreign aid policy goals include prudent management of natural resources and consideration for the environment. With these principles as a point of departure, Sida pursues environmental work along two main lines. One is to integrate environmental aspects and environmental thinking in all of its activities wherever possible. For example, Sida's spending authorization for 1977 states that Sida shall promote follow-up of the UNFCCC in its regular foreign aid. The second main line is a concentration on strategically important areas. To some extent, such efforts are integrated in Sida's cooperation with programme countries and other important cooperation countries, but Sida also has a special environmental appropriation which is supposed to be used primarily for method development, trials and pilot programmes, and for strategically important activities for which country framework funds cannot be used. The appropriation for special environmental initiatives for the years 1995/96 was over SEK 300 million and for 1997 over SEK 200 million. In addition, Sida also has a multilateral environmental appropriation of SEK 25 million for certain activities within the framework of the UNFCCC.

Sida's action programme for sustainable development
In January 1996, Sida adopted an action programme for sustainable development with five priority theme areas, two of which are particularly relevant from a climate perspective: sustainable forestry and environmentally sound energy consumption and production. Initiatives for sustainable forestry have more indirect effects in preventing climate change, while Sida's energy policy entails direct measures to limit emissions of greenhouse gases.

Sida supports the development of companies, environmental authorities, environmental organizations, research institutions and other bodies in the energy sector by strengthening of their competence. Sida also supports energy efficiency improvements at all levels from energy generation to end use. Support is given in different ways to the introduction and application of energy based on new sustainable energy sources.

Sida requires environmental impact assessments for all energy initiatives, regardless of working methods and financing method. A guiding principle is the precautionary principle. Activities which are aimed at perpetuating a non-sustainable system and which obstruct a necessary change are not to be given support.

As far as research in the climate field is concerned, Sida gives support to three regional energy research networks: The African Energy Policy Research Network (AFREPREN), the Asian Regional Research Programme in Energy-Environment-Climate (ARRPEEC), and Renewable Energy Technologies in Asia (RETsAsia). Sida is also supporting a project on megacities’ emissions of greenhouse gases which is being conducted by the Tata Energy Research Institute (TERI) in India.

The Stockholm Environment Institute (SEI) is receiving support for the project “Climate and Africa - An Assessment of African Policy Options and Responses”, whose purpose is to support countries in their development of climate strategies and in their national and regional policies so that they can meet the requirements made in the Convention.

8.2 Contribution to the financial mechanism

Sweden’s contribution to the financial mechanism provided for in the UNFCCC, the Global Environmental Facility (GEF), is paid from the multilateral appropriation. Sweden has contributed a total of about SEK 650 million to the facility during the pilot phase and through 1997. Negotiations are currently being held concerning replenishment of the facility, and Sweden intends to continue to give strong support to GEF.

9. Climate-related research in Sweden

The Swedish Riksdag (parliament) has dealt with the question of research and development as an integral part of its continued strategies against climate change. In preparation for the 1977 Research Bill, thirteen principal funders of Swedish environmental research have presented the report "Research and Development for a Better Environment 1996" (Swedish Environmental Protection Agency Report 4569). It is the Government's judgement that the priorities proposed in the report of the Swedish Commission on Climate Change, "Climate-Related Research" (SOU 1996:39), agree well with the guidelines in "Research and Development for a Better Environment 1996" and the Swedish Environmental protection Agency's earlier priorities within climate research. It is further stated that within scientific climate research, priority should be given to basic climate research. Studies of fundamental physical processes need to be intensified in order to build up a scientific base. A better understanding of the fundamental processes is needed to be able to study the effects of climate change on ecosystems and the socioeconomic sectors, particularly agriculture, forestry and fishing. The technical climate-related research, which is mainly being funded by NUTEK, should focus on development of alternative fuels, efficiency improvements and conservation of electricity. Finally, socioeconomic climate research should focus on policy instruments, lifestyle questions and social planning.

9.1 Scientific climate-related research

Scientific research on global climate change is being coordinated through two international programmes: the International Geosphere-Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP). The IGBP is mainly concerned with biological and chemical processes, while the WCRP focuses on physical processes related to climate change. In Sweden the research is coordinated by the Swedish National Committee for the IGBP/WCRP.

Up until 1995, funding was provided mainly via the Natural Science Research Council (NFR), the Swedish Environmental Protection Agency (NV), the Swedish Council for Forestry and Agricultural Research (SJFR) and the National Board for Industrial and Technical Development (NUTEK). In recent years, other funding sources have come into play, such as the EU and the Foundation for Strategic Environmental Research (MISTRA). However, the national budget crisis has necessitated a cut in the appropriation to the Swedish Environmental Protection Agency, which will mean one less funding agency in the future. The Government's ambition is that MISTRA will compensate for the Agency's environmental research. Research is conducted primarily at the universities, as well as at the Swedish Meteorological and Hydrological Institute (SMHI) and the Environmental Research Institute (IVL).

Through membership in the EU, certain parts of northern Sweden have received special funds, regional development aid. These funds have led to the establishment of a Climate Research Centre at the Environmental and Space Research Institute (MRI) in Kiruna. This Centre will conduct "Research on climate change with a focus on polar vegetational zones and glaciers".

The research aims at combining the classical biological, geological and glaciological research at Abisko and Tarfala with modern satellite information to answer present and future questions surrounding one of the more complex environmental problems: Global climate change.

Since Sweden joined the EU, Swedish researchers have been successful in participating in EU projects. The EU's fourth framework programme runs from 1994 to 1998. Among the special programmes are several associated with climate issues. The special programme Environment and Climate focuses on climate and climate change through studies of "basal processes of climate changes and special climate changes which include the fluxes between atmosphere, sea, land surface, inland ice sheets and the biosphere".

Climate research is most strongly represented within Environment and Climate theme 1: "Research into the natural environment, environmental quality and global change". This part accounts for roughly half of the total programme budget (ECU 247.75).

Closer integration between scientific and socioeconomic research is advocated by MISTRA. MISTRA was started with money from the wage-earner funds in 1994. Its main purpose is to support response option research, but both basic research and effect research are included in its programme. Four of the MISTRA programmes are climate-related:

1) Development of solar cells (MSEK 35), until 2000.
2) Batteries and Fuel Cells for a Better Environment (MSEK 20), until 2000.
3) Remote Sensing for the Environment (RESE) (MSEK 45), until 1999.
4) SWECLIM, Swedish Regional Climate Modelling (MSEK 33), until 1999.

Another funder of climate-related research is the Nordic Environmental Research Council (NMR). The Nordic environmental research programme, which embraces three areas, has a duration from 1993 to 1997 (DKK 25 million per year). Research on climate change is being led from the Norwegian Institute for Air Research (NILU) in Norway.

There are three main themes in the climate programme:

1) Climate processes and climate models - atmospheric physics and dynamics, chemical cycles, oceanographic dynamics.
2) Former climate and climate change.
3) Interaction with ecosystems.

SJFR, Swedish Council for Forestry and Agricultural Research
The climate-related research funded by SJFR mainly concerns forests, but also to some extent the use of agricultural lands. The research is mainly concerned with forestry, the vitality of spruce forests, the role of nitrogen in the forest and forest soil, and biodiversity in a changed climate. Special research projects with a clear link to the climate issue are "Biogeochemistry in tree farming", "Ecological agriculture - strategies for future land use" and "Whole-tree physiology with a focus on coal and nitrogen cycling". The previous large climate research programme is now being wound up.

NFR, Natural Science Research Council

The Natural Science Research Council has a priority area in "global biogeosphere dynamics", which focuses on climate research. Within the programme committees are a few other projects having to do with climate change.

FRN, Swedish Council for Planning and Coordination of Research
A few projects concerned with societal aspects of the climate issue are being conducted at FRN.

9.1.1 Climate change

IGBP-related research
Through the IGAC (International Global Atmospheric Chemistry Project), Sweden has especially emphasized projects that have to do with the exchange of greenhouse gases and other trace gases between the biosphere and the atmosphere. The studies are concerned with ecosystems both at northern latitudes and in the tropics.

Swedish participation plays an important role in the European EU project SINDICATE (Study of the Indirect and Direct Influences on Climate of Anthropogenic Trace-gas Emissions). A climate model comprises the core, and this model includes chemical substances and chemical transformation processes. The Swedish contribution is focused on simulations of the global sulphur cycle and particularly aerosol formation from anthropogenic sulphur emissions and the impact of the aerosol particles on the climate.

Swedish researchers are collaborating with researchers from other Nordic countries in JGOFS (Joint Global Ocean Flux Study). The ongoing Nordic project on studies of the fluxes of carbon dioxide between the atmosphere and the Norwegian Sea is related to JGOFS. Swedish researchers are working with a high-resolution regional atmosphere model for this region. A measurement station on Spitsbergen performs high-quality measurements of carbon dioxide and other atmosphere components.

During the past few decades, Swedish researchers have devoted great interest to integrated ecological and hydrological studies in the Baltic Sea. This research has been able to be used within LOICZ (Land-Ocean Interactions in the Coastal Zone). Special studies have been conducted of the cycling of organic carbon in the coastal zone and of biological feedback mechanisms in the Baltic Sea.

Sweden is participating in BAHC (Biosphere Aspects of the Hydrological Cycle) with a project called NOPEX (Northern Hemispheric Climate Processes Land Surface Experiment). The purpose of the project is to increase our understanding of the hydrological and meteorological factors that govern the processes of energy, water and coal exchange in the ground-vegetation-atmosphere interface. A measurement programme concerning processes that take place during the winter, WINTEX, is in the start-up phase.

Swedish research is making substantial contributions within two of the focal areas within GCTE (Global Change and Terrestrial Ecosystems). The first is "Ecosystem physiology", where field experiments on the ecosystems of the boreal forest are being conducted. These studies are being complemented by studies of trace gases and by hydrological studies within BAHC. The second priority area for Swedish research activities within GCTE is modelling of structural changes of ecosystems on a regional, continental and global level as a result of climate change. This research has established close connections with the paleoclimatological research within PAGES (Past Global Changes) and is particularly concentrating on a global approach for developing dynamic models for determining the climatic conditions that set limits for the Earth's biota, both today and in the past. The Swedish activities within PAGES are focused on changes during the past 20,000 years. Swedish research is also being conducted in the Arctic and the Antarctic through the Swedish Polar Research Committee.

WCRP-related research
Swedish research priorities within WCRP-related research are in three main programmes.

GEWEX (the Global Energy and Water Cycle Experiment) is a combination of field experiment and theoretical modelling which is focused on studying hydrology and energy fluxes in the climate system.

One programme within GEWEX which is of particular Swedish interest is BALTEX (the Baltic Sea Experiment). The most important scientific goals of BALTEX are to determine the variability of the fluxes of energy and water over time and space within the Baltic Sea's drainage basin, and to link them to the global circulation systems in the atmosphere and the seas. BALTEX, which is intended to be carried out jointly by the Baltic Sea states, is now concluding its planning phase. Sweden has an important role in the execution of the project, and a special Swedish committee has been set up.

NOCLIMP (Nordic Climate Modelling Project) is a joint Nordic project financed by the Nordic Council of Ministers. The project has relevance for GEWEX since one of the objectives is to study the sensitivity of large climate models, GCMs (General Circulation Models), to moisture-cloud-radiation processes. The influence of these processes on low-frequency atmospheric variability is also being investigated. A large-scale global model is being used by Swedish researchers in this work.

The purpose of the CLIVAR (Climate Predictability and Variability) Project is to collect and analyze data. Databases with meteorological, hydrological and oceanographic data are necessary to understand variations in the climate system. SMHI has long been working to create such databases. With the advent of MDC (Environmental Data Centre) in Kiruna, data collected in conjunction with research projects will, after the end of the project period, become available to outside users.

WOCE (World Ocean Circulation Experiment) is a global project where Swedish contributions are being made in Nordic cooperation concentrated on studies of the exchange of pelagic and benthic water in the North Atlantic over the ridge between Greenland and Scotland.

A Swedish programme for regional climate modelling has been established with support from MISTRA. The programme includes university research groups in meteorology, hydrology and oceanography, plus a new climate research centre (Rossby Centre) at SMHI in Norrköping. The objective is to calculate regional climatic scenarios for the next 50-100 years based on global scenarios produced at climate research centres in Germany and England. Dynamic atmosphere models similar to those used for weather forecasts are being used to calculate the scenarios. Supercomputer capacity is needed to carry out the programme, and the calculations will be performed with the new parallel-processing computer at NSC (National Supercomputer Centre) in Linköping.

9.1.2 Effects of climate change

Swedish Environmental Protection Agency
The Swedish Environmental Protection Agency is funding research activities on the consequences of climate change on Nordic ecosystems. The following subjects are being studied within the research programme “Climate change and UV-B radiation” (1990-1998):

- Release and uptake of greenhouse gases
- Effects of global climate change on northerly terrestrial ecosystems
- Effects of increased UV-B radiation on northerly ecosystems

Important knowledge that is lacking today is how the fluxes of greenhouse gases, sources and sinks, and processes interlinked therewith, interact. Research in the Agency’s climate research programme aims at establishing a budget for the greenhouse gases carbon dioxide, methane and nitrous oxide. Priority questions are how climate change affects the decomposition and cycling of organic matter and how nitrogen regulates carbon cycling. Special work is being done to estimate the methane flux from Swedish wetlands for the purpose of predicting how the decomposition of organic matter in mires will be affected by climate change and increased loadings of sulphur and nitrogen.

Since a climate change will probably be noticed first at northerly latitudes, according to the UN Intergovernmental Panel on Climate Change (IPCC), a large programme of research has been launched at the Abisko Scientific Research Station in Lapland. Studies are being conducted of effects of an elevated temperature, elevated carbon dioxide concentration and increased UV-B radiation on arctic heath vegetation. The results will provide an overall picture of how the different processes influence interspecies competition and biological diversity. Studies of six selected species are included in the circumpolar programme ITEX (International Tundra Experiment), which was initiated in 1990 through the North Sciences Network/MAB (Man and the Biosphere). Today some 20-odd measurement stations are included in this work.

A better understanding of how rapidly a natural forest adapts to climate change is needed as a basis for estimates of how great the effects of climate change may be on the forest. This process is being studied through modelling of the spatial dynamics of natural hardwood (broad-leaved), mixed and softwood (coniferous) forests. The models also take into consideration the nature of the soil, hydrology, etc. Paleodata are being used to validate the model results. Change in the northern limit of the coniferous forest has been documented, and whether an elevated carbon dioxide content in the atmosphere has a fertilizing effect on the forest is being studied within the programme.

The influence of increased UV-B radiation in the marine environment is being studied on the Swedish west coast. Both pelagic and benthic systems are being studied. An important question is whether the shallow soft bottoms, which serve as spawning grounds, are affected by penetrating UV-B radiation via competition which affects biological diversity in these sensitive areas. Another question is how nitrogen cycling is affected by increased UV-B radiation.

9.2 Technical and socioeconomic climate-related research

Swedish climate-related technical and socioeconomic research is integrated with long-standing research programmes within the energy and transport sectors. Besides the climate aspect, these programmes have other goals as well, such as increased energy efficiency, reduced oil dependence, reduced emissions of acidifying and toxic substances, etc. The most important R&D projects within the energy and transport sectors are described below, with a special emphasis on areas with more direct climate aspects. Besides these activities, research and development is also being pursued within the power industry, the transportation industry, etc. Support to technical development work, introduction support for new energy technology and different types of demonstration programmes for new technology are described in Chapter 5 above.

9.2.1 Energy research

Research at NUTEK of relevance to the climate issue

The National Board for Industrial and Technical Development's research activities for an environmentally sound energy system focus on possible substitutes for fossil fuels and improvements in energy use efficiency.

The energy research programme begun in 1975 aims at improving efficiency in the Swedish energy system and developing renewable energy sources towards the ultimate goal of a sustainable system. A selection of the research programmes and project areas funded by NUTEK is presented in the following.

The research programme "General energy system studies (AES)" has as one of its purposes to support research aimed at adapting the energy system to meet stricter requirements on environmental and climate-related consideration. The funds allocated for the programme amount to about SEK 9 million per year. Activities within the programme are aimed at shedding light on socioeconomic aspects of energy and environmental policies with the aid of national economics theory and research methodology. Among the tools that have been developed is the technical optimization model MARKAL, which can provide guidance for decision-makers in finding the most suitable energy mix under given conditions and based on different environmental restrictions.

Given Sweden's natural resources, a Swedish energy system based on renewable energy sources will naturally be dominated by biofuels and hydropower. NUTEK's research in the field of fuel technology is mainly concerned with biomass-based energy production. An increased use of biofuels is largely motivated by a striving to mitigate anthropogenic carbon dioxide emissions by replacing fossil fuels.

The research programme "Sustainable production of biofuels from forestland" deals with environment-related aspects of fuel removal from the forest, and has a budgetary frame of about SEK 10 million per year. Considerable knowledge exists concerning the biological and soil-chemical consequences of increased biomass removal from the forest. This suggests that a large forest fuel programme can be initiated within the framework of a good environment and sustainability. The research is aimed at studying the long-term effects on the productivity of the forest soil and possible compensatory measures such as ash recycling. Net emissions of climate-affecting gases in connection with energy-related use of forestland will be determined. It is important that the forest should continue to act as a net sink for carbon dioxide even with increased biofuel removals.

The research programme "System studies Bioenergy", with an annual budget of SEK 7 million, relates both to production and use of biofuels and covers technical, economic and administrative systems. One purpose of the system studies is to clarify the total effect on energy and material flows of the utilization of different biofuels. It is urgent to develop system solutions for how an increased use of biofuels can be utilized to mitigate net emissions of climate-affecting gases in the most cost-effective manner possible from a socioeconomic point of view.

Energy forest can, in a longer time perspective, provide an important contribution to the increasing use of biofuels. The research has led to greater basic knowledge of the biology, ecology and cultivation technique of the energy forest. The emphasis in NUTEK's work on energy forest cultivation lies on plant breeding and measures that make forest cultivation more reliable. SEK 10 million per year is being allocated for this research.

The research and development programme for biochemical production of ethanol from wood materials is a three-year programme that started in 1993. The research is focusing on studies of two types of processes for converting lignocellulose into ethanol: Acid hydrolysis, and enzyme-assisted hydrolysis. Work is also being conducted on producing better yeast varieties that increase the ethanol yield. The programme has a total budget of SEK 45 million. NUTEK has also been funding ***research in the field of "Alternative fuels"*** for several years. Motor vehicle fuels produced from biomass will be able to be used in the future to mitigate the environmental and climatic impact of the transport sector. The project area aims at a long-term accumulation of knowledge regarding production of motor vehicle fuels from renewable raw materials.

Landfills are the largest anthropogenic source of methane emissions to the atmosphere in Sweden. Since 1989, NUTEK, together with the waste management industry, has funded a project package aimed at building up knowledge and developing methods for recovering methane from sanitary landfills in an optimal manner. Changes in waste management and waste streams are expected to lead to a considerable reduction in the landfilling of waste. Nevertheless, landfill gas recovery will be important in the future as well for preventing methane emissions and reaching the environmental goal of reducing methane emissions from landfills by 30% by the year 2000. Continued ***research in the field "Waste-to-energy"*** is being focused on system studies of energy recovery and waste management in a holistic perspective, incineration of various segregated waste fractions, and production and use of biogas from reactor digestion and landfills.

Within the field of inventorying of sources and sinks for greenhouse gases, NUTEK is funding research concerned mainly with energy-related land use. Within the field of fuel technology, research is also being supported pertaining to methane fluxes from peatlands and how the net emission of climate-affecting gases is affected by land drainage, peat cutting and peat burning.

Research activities in the ***project area "Combined Heat/Power technology"*** are largely focused on renewable energy sources. The activities include R&D concerning CHP (co-generation) processes adapted to biofuel, wind power, hydropower, solar cells, fuel cells, solar heating, district heating and heat pumps, as well as energy storage and carbon dioxide separation.

New ***thermal processes for electricity generation*** will play an important role for the Swedish energy supply when new power-generating plants are built. Research in this field, along with research on bioenergy, comprises a central part of the Swedish energy research programme. The research is focusing on work processes for electric power production or combined heat and power (CHP) production that have the potential to be developed into resource-efficient and environmentally friendly energy production plants.

Biofuels play a prominent role in this work. Furthermore, special programmes are being conducted on gas turbines and material technology. At the initiative of NUTEK, a consortium for gas turbine technology has been formed between three universities and industry. An important driving force for the development of the gas turbine is the progressive tightening-up of requirements on low emissions of harmful substances.

NUTEK has put together a special consortium for ***research on wind power***. The research is being conducted in close cooperation with wind turbine manufacturers and energy utilities. NUTEK is also funding, together with the power industry, a number of R&D projects having to do with technology, standardization, noise and integration of wind power in electricity grids. A renewed survey of wind conditions is currently being carried out. A study of the visual effects of wind turbines on the landscape has been commenced and will produce guidelines for the siting of wind turbines.

NUTEK has drawn up guidelines for the national-interest aspects of the wind power programme. Land areas with room for 1 TWh of wind power production, about 1,000 normal-sized turbines, have been designated as being of national interest. NUTEK also wants areas for the production of an additional 1 TWh to be identified for future needs.

NUTEK has, via a consortium with a number of power companies, carried out a technology procurement of wind turbines. The procurement led to a reduction in the price of electricity produced by wind power by about 20 percent. The cost of wind power electricity is now comparable to that of electricity produced in, for example, new gas-fired power stations. Moreover, the procured wind turbine makes less noise than its predecessors.

NUTEK-funded ***research concerning solar cells*** has been highly successful. Thin-film solar cells based on copper indium diselenide (CIS) with an efficiency of 17% have been produced, which is a world record. Together with MISTRA, the Foundation for Strategic Environmental Research, NUTEK has decided to finance a solar energy centre in Uppsala for research on solar cells and solar energy materials. NUTEK and MISTRA have allocated a total of SEK 70 million over a period of 4.5 years for this purpose.

Fuel cells is a field that has received increased attention in recent years, since fuel cells can produce electricity with high efficiency and low environmental impact. Fuel cells are light and compact and convert chemically bound energy in a fuel directly to electrical energy and heat without going via mechanical work. Research in Sweden is concentrating on molten carbonate fuel cells (MCFC) and has resulted in new electrode materials.

Development of ***district heating technology has reduced emissions of carbon dioxide and other pollutants***. District heating plays a central role in the Swedish energy system, mainly due to its environmental advantages and the ability of CHP plants to produce electricity as well as heat. NUTEK has long supported research and development concerning both the district heating systems themselves and various technologies for heat and power production within the district heating sector. These efforts have helped make Sweden one of the leading nations in the world in the use of district heating.

The cost of ***solar heating*** has fallen drastically over the past ten years, and the technology has been refined. Nevertheless, solar heating is still too expensive to compete with other heating. NUTEK has therefore initiated an extensive joint research and development project involving manufacturers of solar heating plants, researchers and housing companies. The goal is to be able to demonstrate solutions that greatly reduce solar heating costs by the year 2000.

The industrial research programme "Alternative refrigerants" is focusing on research and development of environmentally acceptable refrigerants without CFCs and HCFCs. The programme is being co-funded by Swedish refrigeration and heating companies, and NUTEK is funding 40% of the total annual budget of SEK 10 million. The research is aimed at hastening the development of new CFC- and HCFC-free refrigeration, heating and air-conditioning equipment. Among other things, new types of heat exchangers designed to use ammonia have been developed. The work within the programme and rapid technical progress have also led to the use of hydrocarbons as refrigerants in commercial activities.

The goal of NUTEK's ***research programme within "Fluid beds, Combustion/Gasification"*** is to maintain and strengthen Sweden's leading expertise within the field. The research is focused on an increased use of biofuels, more efficient energy production and environmentally better performance. There is a great emphasis on biomass gasification and catalytic combustion. The annual budget for NUTEK's activities is about SEK 25 million.

Research within the ***project area "Energy-intensive industry"*** is aimed at efficient energy use in industrial processes and products within energy-intensive sectors of industry: the pulp and paper industry, iron and steel works and the chemical industry. The research, with an annual budget of about SEK 13 million, is focused on the development of energy-efficient processes, energy-efficient and environmentally sound product development, re-use, waste minimization and reduced emissions to air and water. A characteristic shared by all the energy-intensive sectors is highly complex factory systems. System-oriented research aims at integrating whole processes in an energy- and resource-optimal fashion with the aid of new methods and analytical tools.

Joint international research projects
Sweden is participating in a large number of joint international research projects in the fields presented above. These include various EU programmes such as Environment and Climate, Joule, Thermie Drive, Brite-EuRam, AIR and others. Sweden is also participating in projects within the framework of the OECD countries' cooperation in the energy field in the IEA (International Energy Agency). One of the IEA projects is IEA Greenhouse Gas R&D, whose purpose is to clarify the conditions for separation, handling and storage of carbon dioxide

from fossil-fuelled combustion plants, and GREENTIE (Greenhouse Gases Technology Information Exchange), whose purpose is to spread knowledge of energy technologies and systems that can reduce emissions of climate-affecting gases internationally, especially to developing countries. The joint project *Greenhouse Gas Balances of Bioenergy Systems* is aimed at establishing common analytical methods for determining greenhouse gas balances for bioenergy systems, and to use these methods in choosing bioenergy strategies to counteract emissions of greenhouse gases. Swedish is also participating in the IEA's *Climate Technology Initiative*.

Table 9.2.1 NUTEK's grants to energy research 1995 (18 months), SEK million

Bioenergy research	Fuel technology	65	
	Energy-related transport research	21	
	Bioenergy research, general	3	
	Total		89
Energy research	Energy-related basic technologies	98	
	Power/Heat supply	34	
	Energy-intensive industry	20	
	Energy research, general	7	
	Total		159
Grand total:			**248**

Swedish Council for Building Research

The sphere of operations of the Swedish Council for Building Research (BFR) is defined as follows:
"Research, development and experimentation concerning changes in and design of the built-up environment with the aid of planning, building and management. The Council's sphere of responsibility also includes research, development and experimentation concerning energy conservation and new energy systems for buildings."

In the long run, changes in buildings and the transportation infrastructure can have considerable effects. By means of a strategic planning of buildings and traffic systems, local and regional authorities can contribute towards reducing energy use. Together with the Swedish Transport and Communications Research Board, BFR has built up research settings which develop models, methods, etc. around the relationships between buildings and transportation infrastructure. Above all, this research aims at improving understanding of the sector's overall approach and systems interrelationships.

Energy use in buildings has not increased during the past 25 years, despite the fact that the heated area has increased by more than 40%. Today technology is available to reduce energy use in direct-heated single-family homes by up to 50% with an unchanged or even improved indoor climate. More or less the same applies to apartment buildings.

Solar heating research has focused on big systems for the production of heat with the aid of solar collectors. Sweden is the world leader in this field today. However, solar heating is still not economically competitive on the market, other than in exceptional cases.

Due to its R&D and a previously extensive experimental building programme, Sweden was long in the front line when it comes to large and medium-sized heat pump systems. Today, heat pump research is more long-range and is primarily being pursued within framework programmes at universities. It is primarily concerned with new refrigerants and more efficient systems.

Sweden is an international leader when it comes to energy storage as well. Certain technologies are already competitive, for example short-term storage of various kinds, storage in steel tanks and in certain aquifers. Others stand on the threshold of commercial introduction, e.g. aquifer storage, borehole storage and pit storage.

Table 9.2.2 BFR's grants to energy research 1997, SEK million

Programmes	total	of which energy R&D
Energy research	15	15
solar heating		
heat pumps		
energy stores		
energy systems		
energy-efficient buildings and installations		
information and documentation		
Building research	159	approx. 5-10
Building research		
buildings and infrastructure		
energy-efficient buildings		
information and documentation		
Experimental building	20	1)

1) In previous years approximately one-third has been energy research.

9.2.2 Transportation research

The Swedish Transport and Communications Research Board, KFB, has several programmes involving research, development and demonstration (RD&D) relating to climate questions. The linkage to climatic impact is often one part of a larger perspective in these programmes.

Besides the regular programmes, KFB has a special interdisciplinary programme focusing on environment-related transportation research. The purpose is to bring about a coordinated approach to traffic-related environmental problems and to obtain a holistic view in these questions. Climate issues are included as a very important part of these projects.

KFB is also responsible for the RD&D programmes “Biobased fuels” and “Electric and hybrid vehicles”. They are financed by funds outside of KFB's regular grants, are time-limited and assume a high degree of co-financing with parties in the business community.

Biobased fuels

The programme was initiated in 1990 when the Riksdag appropriated SEK 120 million to KFB for support to development and demonstration projects concerning motor alcohols.

KFB has formulated the following purpose of the programme:
- to increase knowledge of the motor alcohols' long-term usefulness, environmental potential and cost picture.
- to clarify if and under what conditions motor alcohols are ripe for a large-scale introduction.

The assignment now also includes biogas, i.e. methane from renewable raw materials.

The emphasis in the work lies on field tests with vehicles including both heavy vehicles (trucks and buses) and passenger cars - Flexible Fuel Vehicles, FFVs. Fleet tests with buses and trucks are being conducted in three cities of various size, and the same is true for biogas vehicle tests. Heavy vehicles powered by mixed fuel, about 15% ethanol and 85% diesel oil, are operating at several places in Sweden, and there are now more than 150 FFVs in the country, and the number is steadily increasing.

Considerable resources are also being allocated to *development* of engines and peripheral equipment, e.g. catalytic converters. The Luleå Institute of Technology and Scania have jointly developed pure ethanol engines for buses, and in a similar manner the Chalmers University of Technology in Gothenburg and Volvo have cooperated in the development of truck engines for ethanol operation. The Royal Institute of Technology in Stockholm is developing new materials and designs for catalytic converters for bioengines.

Evaluations concerning above all health, environment, technology and economy are another important task within the programme. Researchers at the Lund Institute of Technology have characterized emissions of both regulated and non-regulated substances from ethanol engines with different catalytic converters. The Institute of Environmental Medicine at the Karolinska Institute has assessed the health risks of emissions from alcohol-powered vehicles.

Prior to the conclusion of the biofuel programme, KFB is conducting a *system study* which will analyze most aspects of a large-scale introduction of biobased motor vehicle fuels.

Electric and hybrid vehicles

This programme is also supposed to shed light on the various consequences of a more large-scale introduction of electric and hybrid vehicles. One of the main purposes of KFB's efforts is therefore to gather data for a long-range introduction plan which, by means of various incentives, can counteract the competition problems which often arise at a system change. KFB will therefore:
- examine the possibilities of introducing electric and hybrid vehicles in a shorter and longer time perspective.
- ascertain the effects in various respects of an introduction of electric and hybrid vehicles.
- promote the introduction of electric and hybrid vehicles to the extent this is warranted by positive socioeconomic effects.

Electric and hybrid vehicles cannot compete today economically with existing vehicles. Through extensive demonstration tests subsidized by the government, a large number of vehicles will be put in service. This will give various stakeholders and future users an opportunity to assess the vehicles, their performance and their most suitable areas if application. The drivers' experience will help the manufacturers to develop the vehicles of tomorrow. Moreover, various solutions with regard to charging and infrastructure will be tested. Tests with vehicle fleets are under way in different parts of Sweden, including the three big cities.

NUTEK's contributions to transport research

NUTEK is planning and funding RD&D programmes and competence centres within a number of fields to foster increased cooperation between the business and academic communities. These RD&D programmes and competence centres are mainly concerned with transport means and energy systems. NUTEK is also giving support to large development and demonstration projects. The RD&D programmes concern engines and propulsion systems as well as environmentally sound vehicles and more general fields of technology such as combustion technology, catalytic conversion and production of alternative fuels. The activities also include technology procurement of electric vehicles, information technology for transportation and logistics for industry.

Table 9.2.3 NUTEK's programmes for transportation technology, RD&D programmes and projects (1996, SEK million per year)

Engine-related combustion	10
Electric and hybrid vehicles	8
Alternative fuels	22
ethanol	15
biogas	2
others	4
IEA	1
Environmentally sound vehicles	15
Competence centres, about	15
Total, about	**70**

NUTEK is in charge of Swedish participation in the EU's framework programme for research and development concerning transport means and energy systems within Industrial and Material Technologies (Brite Euram) and Non-Nuclear Energy (Joule/Thermie) at DG XII.

10. Education and awareness-raising of the public

In 1993, the Riksdag (Swedish parliament) voted to allocate funds for climate-related information and education. The purpose was to inform the public concerning the effects of climate change, what must be done to limit the risks, and the importance of individual behaviour. Teachers and students in upper-secondary school were regarded as an important target group. Politicians were regarded as another important category of message recipients.

In 1994, within the framework of this assignment, the Swedish Environmental Protection Agency published a study kit on the risk of climate change with facts about climate change and with linkages to lifestyle questions. The material was mainly aimed at teachers and students in grades 6-9 of compulsory school and in upper-secondary school, but also at adult education associations and others who worked with education. The study kit was called "Imagine the weather in 25 years…" and contained a video, fact sheets and rules for a simulation game concerning negotiations for a protocol to the UNFCCC.

The campaign was backed up by teacher training days at the schools of education and by a seminar for active teachers at upper level compulsory schools and upper-secondary schools in Sweden. Particular emphasis was placed on methodology for benefiting from and analyzing the media's reporting and angling of the problems surrounding the climate issue.

An evaluation performed in the spring of 1996 showed that the Agency's study material has been received very well by both teachers and students. The material has attracted attention due to the nature of the subject per se, but also due to its pedagogical approach. In December 1996, approximately 700 study kits had been distributed to the country's 900 upper-secondary schools.

To support the work with local Agenda 21, the Agency also produced a special "idea book". The purpose was to use a number of "good examples" of local campaigns to reduce emissions of carbon dioxide in particular in order to show possible ways to achieve emissions reduction. Signs are already visible among Sweden's municipalities of a clear willingness to reduce greenhouse gas emissions. Within the framework of the local Agenda 21 work, for example, several municipalities prepared "climate plans" describing strategies for emissions reductions. An example is Växjö Municipality in southern Sweden, where a decision was made in 1996 to gradually phase out fossil fuels from the municipality's energy and heat production.

The Agency has also placed particular emphasis on communicating the message in the IPCC's Second Scientific Assessment (1995). There have been both targeted efforts and mass campaigns. For example, a popular magazine was published in 1996 aimed at the target group of policymakers and teachers. A summary of the IPCC's "Summary for policymakers" was also published in 1996. Through cooperation with the Federation of Swedish Industries, the information has also been communicated to industry.

Appendix 1 Sector-specific assumptions, methods and results, plus calculations of the effects of adopted measures.

Industry

The forecast model for energy consumption in the industrial sector is based on assumptions concerning future production in the different sectors and how specific energy use (counted as kWh/SEK of production value) in each sector will develop. The latter factor is based on knowledge and projections of e.g. technological development, production changes and capital stock renewal.

We have based our assumptions regarding industrial production up to the year 2010 on calculations with NUTEK's industrial structure model ISMOD. The results of the modelling show that the average annual growth in production values will be 2.2%. Growth is projected to be 1.4% per annum between 1995 and 2000. For the period 2000-2005, the growth rate is projected to increase to 2.6% per annum, and for the period 2005-2010 the growth rate is projected to be 2.8% per annum[40].

The energy-intensive sectors are projected to grow more slowly than most other sectors. In the pulp and paper industry, production is calculated to grow more slowly than the average and actually decrease between 2000 and 2005. The average production growth rate in iron and steel works is calculated to be 1.6% per annum for the entire period 1995-2010. The growth rates for the iron and steel industry and for the pulp and paper industry are, however, very uncertain, since large-scale investments are currently being made in these sectors. The chemical industry is expected to grow rapidly, by an average of 3.9% per annum. The highest growth rate is expected in the less energy-intensive parts of the sector. Production in the engineering industry is calculated to increase at an even pace during the entire the forecast period, by an average of 2.9% per annum.

Among other sectors, the graphic arts, rubber, petrochemical and wood products industries are expected to show the highest growth. The lowest growth is expected in the mining and nonferrous metals industries.

Table B1.1 Industry's production values during 1990-2005, SEK billion, 1991 prices and annual percentage change

[40] The ISMOD model's growth rates for the sectors of industry have been used in the forecast. The growth rates for industry as a whole differ slightly from the growth rates presented in Chapter 6.1. This is due to a statistical difference between the sum of the sectors' production values and the ISMOD model's total production value for industry.

Sector	1990	Percent p.a.	1995	Percent p.a.	2000	Percent p.a.	2005	Percent p.a.	2010
Mining industry	10.0	1.5	10.7	-1.0	10.2	-2.8	8.8	-1.6	8.2
Food industry	104.7	0.8	109.2	-3.0	93.8	3.4	110.8	2.2	123.5
Textile industry	14.8	-3.1	12.6	-0.6	12.3	1.1	12.9	-0.3	12.7
Wood products industry	62.1	-5.3	47.2	3.5	56.1	1.6	60.7	1.8	66.3
Pulp and paper industry	69.5	1.8	75.9	1.8	82.9	-1.0	78.7	0.3	79.9
Graphic arts industry	50.9	-1.1	48.3	4.2	59.4	3.5	70.7	2.1	78.6
Rubber industry	5.8	-4.0	4.7	3.1	5.5	2.3	6.2	2.0	6.8
Chemical industry etc.	63.9	3.5	76.0	4.7	95.5	3.6	114.0	3.5	135.4
Petroleum and coal industry	26.7	0.2	27.0	3.1	31.4	2.4	35.4	2.0	39.1
Soil and stone industry	22.2	-5.1	17.1	-0.4	16.8	2.2	18.7	1.8	20.4
Iron and steel works	36.7	4.2	45.1	2.0	49.7	1.4	53.3	1.5	57.5
Nonferrous metals works	14.7	-0.3	14.5	1.2	15.4	0.8	16.0	0.5	16.4
Engineering industry	339.8	4.0	414.1	2.0	456.1	3.2	533.8	3.5	634.5
Other industry	6.6	27.8	22.4	-26.4	4.8	5.6	6.4	12.6	11.5
Industry total	**828.5**	**2.2**	**924.8**	**1.4**	**989.9**	**2.6**	**1 127**	**2.8**	**1 291**

Source: SCB, NUTEK "Industrial structure model ISMOD" and own calculations

The growth rates in the individual sectors entail a continued structural transformation. Production in the energy-intensive sectors pulp and paper, iron and steel and nonferrous metals as a share of total industrial production is expected to decrease from today's 14.6% to 11.9% in 2010, which affects final energy use. In the calculations that serve as a basis for the forecasts of energy use, it is also assumed that energy efficiency improvements take place. The efficiency improvements are mainly assumed to take place in conjunction with investments in new production capacity where new technology is utilized, but also continuously as improvements are made in existing production plants. This structural transformation and energy efficiency improvement will consequently lead to a reduction in specific energy use for industry as a whole.

The use of different fuels is determined from assumptions concerning future fuel prices and the capabilities of the different sectors to switch fuels. The capability to switch between different fuels is dependent on production technology and the capital stock.

A sector's demand for different energy carriers consists of the production value multiplied by the specific use for the particular energy carrier. Industry's total demand is the sum of the sectors' demands.

Table B1.2 Average specific energy use, kWh per SEK production value

Sector	1990	1995[1)]	2000	2005	2010
Mining industry	0 411	0.415	0.424	0.430	0.427
Food industry	0.070	0.063	0.064	0.060	0.060
Textile industry	0.074	0.077	0.078	0.075	0.075
Wood products industry	0.155	0.241	0.234	0.233	0.232
Pulp and paper industry	0.894	0.868	0.841	0.851	0.840
Graphic arts industry	0.014	0.016	0.015	0.014	0.013
Rubber industry	0.069	0.097	0.095	0.094	0.094
Chemical industry etc.	0.152	0.114	0.104	0.096	0.089
Petroleum and coal industry	0.037	0.039	0.036	0.035	0.034
Soil and stone industry	0.338	0.339	0.342	0.335	0.333
Iron and steel works	0.515	0.469	0.461	0.459	0.457
Nonferrous metals works	0.265	0.240	0.237	0.236	0.235
Engineering industry	0.035	0.028	0.026	0.024	0.023

1) The new classification of industrial sectors (SNI 92) has led to a break in the statistical series, which affects the reported values for energy use in 1995.

Industry’s energy use broken down by sectors and different fuel types is reported for the years 1990, 1995, 2000, 2005 and 2010 in Tables B1.3a-e. Actual use is reported for 1990 and 1995, and forecasts for the other three years. The sector designated “other industry” includes energy use for the “other industry” sector plus non-sectoral electricity use, pertaining to workplaces with fewer than 10 employees.

Table B1.3a Industry's energy use in 1990 by sector, TWh

Sector	Coal, coke	Biofuels	Natural gas	Oils	LP gas	District heating	Elect.	Total
Mining industry	0.8		..	1.0	..	..	2.2	4.1
Food industry	0.4	..	1.1	2.4	0.2	0.4	2.8	7.3
Textile industry			..	0.4	0.2	..	0.4	1.1
Wood products industry	..	6.4	..	0.9	..	0.2	2.1	9.6
Pulp and paper industry	0.8	35.7	0.3	4.7	0.3	0.3	20.0	62.2
Graphic arts industry				0.1	..	0.2	0.4	0.7
Rubber industry				..	..	..	0.3	0.4
Chemical industry etc.	0.3	0.5	0.7	1.0	..	0.8	6.2	9.7
Petroleum and coal industry				0.3	..	..	0.7	1.1
Soil and stone industry	3.5	..	0.3	1.9	0.7	..	1.3	7.5
Iron and steel works	10.4	..	0.3	1.7	1.6	0.1	4.8	18.9
Nonferrous metals works	0.7			0.3	0.2	..	2.7	3.9
Engineering industry	0.2	..	0.3	2.5	0.5	1.1	7.2	11.8
Other industry	0.0	0.0	0.1	0.4	0.2	0.2	2.5	3.4
Industry total	**16.9**	**42.8**	**3.2**	**17.6**	**4.1**	**3.6**	**53.7**	**141.9**

.. Values less than 100 GWh
Note: Biofuels, peat etc. also includes waste liquors in the pulp and paper industry. Coal and coke also includes coke gas and blast-furnace gas. The figures may containing rounding-off errors.

Table B1.3b Industry's energy use in 1995 by sector, TWh

Sector	Coal, coke	Biofuels	Natural gas	Oils	LP gas	District heating	Elect.	Total
Mining industry	0.7			1.1	..	..	2.5	4.5
Food industry	0.2	..	1.4	2.1	0.5	0.3	2.4	6.9
Textile industry			..	0.4	0.1	..	0.4	1.0
Wood products industry		8.4		0.8		0.3	2.0	11.4
Pulp and paper industry	0.2	39.2	0.5	5.5	0.5	0.8	19.1	65.9
Graphic arts industry				0.2		..	0.5	0.8
Rubber industry				0.1		..	0.3	0.5
Chemical industry etc.	..	0.3	0.7	1.2	..	0.8	5.6	8.6
Petroleum and coal industry				0.3		..	0.7	1.1
Soil and stone industry	2.3	0.1	0.1	1.2	1.0	..	1.1	5.8
Iron and steel works	12.1		0.3	1.8	1.8	0.2	5.0	21.1
Nonferrous metals works	0.3		..	0.2	0.2	..	2.6	3.5
Engineering industry	0.2	..	0.3	2.2	0.5	1.2	7.0	11.4
Other industry	0.1	1.0	0.0	0.3	0.1	0.0	3.2	4.7
Industry total	**16.2**	**49.1**	**3.4**	**17.3**	**4.8**	**3.9**	**52.3**	**147.0**

.. Values less than 100 GWh
Note: Biofuels, peat etc. also includes waste liquors in the pulp and paper industry. Coal and coke also includes coke gas and blast-furnace gas. The figures may containing rounding-off errors.

Table B1.3c Industry's energy use in 2000 by sector, TWh

Sector	Coal, coke	Biofuels	Natural gas	Oils	LP gas	District heating	Elect.	Total
Mining industry	0.7			1.0	..	..	2.5	4.3
Food industry	0.2	..	1.2	1.8	0.4	0.3	2.0	6.0
Textile industry			..	0.4	0.1	..	0.4	1.0
Wood products industry		10.0		0.8		0.2	2.1	13.1
Pulp and paper industry	0.2	42.2	0.4	5.4	0.5	0.8	20.2	69.7
Graphic arts industry				0.2		0.1	0.5	0.9
Rubber industry				0.1		..	0.3	0.5
Chemical industry etc.	..	0.3	0.8	1.5	..	0.9	6.3	9.9
Petroleum and coal industry				0.3		..	0.8	1.1
Soil and stone industry	2.2	0.1	0.2	1.2	0.9	..	1.1	5.7
Iron and steel works	13.5		0.3	1.8	1.8	0.2	5.4	22.9
Nonferrous metals works	0.3		..	0.2	0.2	..	2.8	3.6
Engineering industry	0.2	..	0.3	2.3	0.5	1.3	7.3	12.0
Other industry	0.1	0.2	0.0	0.2	0.0	0.0	3.0	3.6
Industry total	**17.5**	**52.8**	**3.4**	**17.4**	**4.7**	**4.1**	**54.6**	**154.4**

.. Values less than 100 GWh
Note: Biofuels, peat etc. also includes waste liquors in the pulp and paper industry. Coal and coke also includes coke gas and blast-furnace gas. The figures may containing rounding-off errors.

Table B1.3d Industry's energy use in 2005 by sector, TWh

Sector	Coal, coke	Biofuels	Natural gas	Oils	LP gas	District heating	Elect.	Total
Mining industry	0.6			0.9	..	..	2.3	3.8
Food industry	0.2	..	1.4	1.9	0.5	0.3	2.3	6.6
Textile industry			..	0.4	0.1	..	0.4	1.0
Wood products industry		10.9		0.8		0.3	2.2	14.1
Pulp and paper industry	0.2	40.2	0.5	5.5	0.5	0.8	19.3	67.0
Graphic arts industry				0.3		0.1	0.5	1.0
Rubber industry				0.2		0.1	0.3	0.6
Chemical industry etc.	..	0.4	1.0	1.6	..	1.1	6.7	10.9
Petroleum and coal industry				0.3		..	0.9	1.2
Soil and stone industry	2.5	0.1	0.2	1.3	1.0	..	1.2	6.3
Iron and steel works	14.4		0.3	1.9	1.9	0.2	5.8	24.5
Nonferrous metals works	0.3		..	0.2	0.3	..	2.8	3.8
Engineering industry	0.2	..	0.4	2.4	0.6	1.4	8.1	13.1
Other industry	0.1	0.2	0.0	0.2	0.0	0.0	3.3	3.9
Industry total	**18.5**	**51.8**	**3.8**	**17.9**	**5.0**	**4.6**	**56.2**	**157.8**

.. Values less than 100 GWh
Note: Biofuels, peat etc. also includes waste liquors in the pulp and paper industry. Coal and coke also includes coke gas and blast-furnace gas. The figures may containing rounding-off errors.

Table B1.3e Industry's energy use in 2010 by sector, TWh

Sector	Coal, coke	Biofuels	Natural gas	Oils	LP gas	District heating	Elect.	Total
Mining industry	0.5			0.8	..	..	2.1	3.5
Food industry	0.2	..	1.5	2.0	0.5	0.4	2.8	7.4
Textile industry			..	0.3	0.1	..	0.4	1.0
Wood products industry		11.9		0.8		0.3	2.4	15.4
Pulp and paper industry	0.2	40.7	0.5	5.3	0.5	0.8	19.1	67.1
Graphic arts industry				0.3		0.1	0.6	1.0
Rubber industry				0.2		0.1	0.3	0.6
Chemical industry etc.	..	0.4	1.2	1.6	..	1.3	7.3	12.0
Petroleum and coal industry				0.3		..	1.0	1.3
Soil and stone industry	2.8	0.1	0.2	1.3	1.1	..	1.3	6.8
Iron and steel works	15.4		0.3	2.1	2.0	0.2	6.3	26.3
Nonferrous metals works	0.4		..	0.2	0.3	..	2.9	3.9
Engineering industry	0.2	..	0.4	2.7	0.7	1.7	9.2	14.8
Other industry	0.1	0.2	0.0	0.2	0.0	0.0	3.8	4.4
Industry total	**19.8**	**53.3**	**4.2**	**18.2**	**5.3**	**5.1**	**59.6**	**165.5**

.. Values less than 100 GWh

Note: Biofuels, peat etc. also includes waste liquors in the pulp and paper industry. Coal and coke also includes coke gas and blast-furnace gas. The figures may containing rounding-off errors.

Transportation

The forecast of future transport activity is based on assumptions concerning infrastructure, future traffic intensity and transport costs, plus projected economic development. Making a forecast of energy use also requires projections of future specific fuel consumption.

The future *demand for goods transport* is determined to a large extent by how the economy as a whole changes, and by the development of individual sectors. The industrial sectors where the greatest production increase is expected are the knowledge-intensive sectors of chemistry, electrical engineering, machinery, instruments and nonferrous metals. The trend in certain service sectors – banking, consulting, postal services and telecoms – is also very positive. Diminished production is assumed in the sectors agriculture, forestry, mining and other manufacturing. This expected sector-by-sector breakdown adds up to a structure in the production of goods and services that will entail an increase in the road transport share of total freight transport. Transport by rail and ship, on the other hand, will decline. See Chapter 6.1 for assumptions regarding GDP growth.

Foreign trade is assumed to increase at approximately the same pace during the period 1960-1990. Exports will increase by just over four percent annually, and imports will increase at roughly the same rate. Net exports will be positive during the next 15 years.

It is above all forestry and manufacture of machinery, motor vehicles and instruments that are expected to contribute to increased exports. According to the calculations, only exports of agricultural, mining, iron and steel products and shipbuilding may decline in the future. The imported volume of goods such as foods, beverages and tobacco, vehicles and machinery is expected to more than double between the years 1995 and 2010.

Specific fuel consumption by trucks is assumed to decline by 0.25% per annum during the forecast period, partly as a consequence of engine development and more efficient utilization of payload capacity.

All in all, the assumed changes in industry entail a structural transformation towards more knowledge-intensive sectors. This means that the trend towards slower growth of the physical goods volumes and an increase in the goods value per unit weight will continue.

The size of passenger traffic in a country is largely dependent on the size and structure of its population. For this reason, data on the size and age composition of the population in different regions is needed for traffic analyses. The average annual population increase on a national level for the next 15 years is assumed to be 0.28%. Municipalities in the big-city regions and those near a university or college are expected to increase more than the national average. A population decrease is assumed to occur in municipalities in the forest counties (in the north), in parts of Bergslagen (central Sweden) and parts of Småland and Blekinge (in the south). The age distribution of the population varies over time as well. In 2010, the relatively large baby-boom generation will have reached retirement age. At the same time, the slightly lower birth rates during the 1980s will lead to a smaller number of people around 30 years of age. The workforce will therefore have a higher mean age in 2010 than in 1995.

Employment in different regions and sectors is another factor that influences the traffic situation[41].

To predict the travel demand and car ownership of the population in the future, it is also useful to have knowledge of incomes and private consumption in the future. In the forecast for passenger transport, income is primarily a variable that determines the probability that a person will purchase or get rid of a car. These probabilities are calculated using the historical relationship between car ownership and income. The probability factor is corrected for gender and age effects. The total income increase is calculated from figures for future GDP and productivity (pay increase potential) in different sectors. See Chapter 6.1 for assumptions regarding future growth of GDP and private consumption.

The average fuel consumption of automobiles is assumed to decline from 9.4 litres per 100 km in 1995 to 8.5 l/100 km in 2010. The fuel consumption of buses and aeroplanes (l/100 km) is also assumed to decrease during the period. Average weighted fuel consumption for new cars declined from 9.3 l/100 km in 1978 to 8.3 l/100 km in 1987 and has remained more or less unchanged since then.

Residential, commercial and institutional sector

The forecast for energy use in the residential, commercial and institutional sector is based on assumptions concerning future population growth, the residential, commercial and institutional building stock, energy prices, investment costs, technological development, private and public consumption, behavioural changes, etc.

Space heating

Et = St x At/et

Et = energy use for heating in year t
St = specific net heating requirement in year t
et = efficiency in year t
At = Residential/commercial/institutional area in year t in (m^2)

Operating and/or household electricity

et = At x Zt specific energy consumption

et = electricity consumption in year t
At = area in year t
Zt = specific electricity consumption

[41] Employment statistics originally come from the county administrative boards throughout Sweden. The forecasts made by the county administrative boards are not broken down at the level desired in this context and do not extend far enough ahead in time. The employment forecasts used in the traffic forecasts were made by the consulting firm INREGIA. However, INREGIA’s forecast has been tallied against SCB’s population forecast for all of Sweden, the municipalities’ population forecasts and the county administrative boards’ employment forecasts.

Fuel consumption is determined by the assumed price structure and the freedom to switch fuels.

Table B1.4 Energy prices in the residential, commercial and institutional sector in 1995, forecast for the period up to 2010, SEK/MWh

	1995	2000	2005	2010
Electric heating	621	640	700	730
Household elect.	860	880	940	970
Light fuel oil	380	400	414	427
Heavy fuel oil, low-sulphur	303	318	327	337
Coal	286	286	292	295
District heating	411	450	500	550

Table B1.5 Population and building stock, 1995 and 2010

	1995	% per annum	2010
Population, thousands	8837	0.28	9210
Number of dwelling units, thousands			
single-family homes	1838	0.56	1993
apartment buildings	2117	0.37	2234
Heated area in commercial and institutional premises, mill. m^2	156.5	0.77	174.5

Table B1.6 Annual mean efficiencies for existing and new single-family homes, 1995 and 2010

	Existing stock		New production	
	1995	2010	1995	2010
Electric heating	0.84	0.87	0.88	0.90
District heating	0.9	0.9	0.93	0.95
Oil	0.68	0.71	0.77	0.82
Natural gas	0.76	0.78	0.80	0.86
Fuelwood	0.6	0.65	0.70	0.74

Note: Efficiencies for different energy sources are calculated as annual means and include all boilers that use the type of energy source in question. The efficiency of electric heating, for example, includes all electric combi-boilers, electric boilers and direct electric heating.

Table B1.7 Annual mean efficiencies for existing and new apartment buildings and commercial/institutional premises, 1995 and 2010

	Existing stock		New production	
	1995	2010	1995	2010
Electric heating	0.81	0.84	0.88	0.89
District heating	0.75	0.78	0.81	0.86
Oil	0.64	0.68	0.74	0.81
Natural gas	0.69	0.73	0.76	0.84

When differences in efficiency for different heating systems are taken into account, the relative prices for the different heating methods will change marginally up to 2010.

Due to efficiency improvements, specific net use (kWh/m^2) of energy is expected to decline by about 0.2% per annum for single-family homes and by 0.3 to 0.4% per annum for apartment buildings and commercial/institutional premises. Specific use of operating and household electricity (kWh/m^2 and kWh/household, respectively) is expected to decrease by 0.3 to 0.4% per annum. The decrease in electricity use is expected to be greater during the period 2005 to 2010 than at the beginning of the forecast period. This is due to the fact that household appliances and office machines will be replaced with more efficient equipment at the end of the period.

Some efficiency improvement in energy use within different space heating systems is also assumed in the forecast. Fuelwood and oil heating are deemed to have the greatest potential for efficiency improvement.

Table B1.8 Energy use in the residential, commercial and institutional sector broken down by different user categories, 1990 and 1995, TWh

	1990 actual	Percent per annum	1995 actual	1990 corrected	Percent per annum	1995 corrected
Space heating and hot water	98.3	1.1	103.6	110.1	-1.0	104.6
Single-family homes	*45.9*	*0.3*	*46.6*	*51.6*	*-1.8*	*47.0*
Apartment buildings	*27.6*	*2.0*	*30.3*	*31.0*	*-0.3*	*30.6*
Commercial/institutional premises	*24.8*	*1.6*	*26.8*	*27.5*	*-0.3*	*27.1*
Household electricity	16.3	0.6	16.8	16.3	0.6	16.8
Single-family homes	*8.6*	*0.0*	*8.6*	*8.6*	*0.0*	*8.6*
Apartment buildings	*7.7*	*1.3*	*8.2*	*7.7*	*1.3*	*8.2*
Operating electricity on com./inst. premises	15.2	1.3	16.2	15.2	1.3	16.2
Second homes	3.0	4.0	3.6	3.3	1.8	3.6
Agriculture, forestry, rangelands, fishing etc.	8.3	-2.2	7.4	8.3	-2.2	7.4
Other use	8.6	4.7	10.6	9.0	3.6	10.6
Total	**149.7**	**1.1**	**158.3**	**162.2**	**-0.4**	**159.2**

Table B1.9 Energy use in the residential, commercial and institutional sector broken down by different energy sources, TWh

	1990 corrected	1995 corrected	2000	2005	2010
Coal	0.6	0.0	0.0	0.0	0.0
Fuelwood	12.6	11.6	12.5	11.7	11.1
Oils[1]	45.2	35.9	33.4	32.2	30.5
Gas[2]	1.5	1.8	1.7	2.1	2.5
District heating	34.5	37.5	39.2	39.9	40.6
Electricity	67.9	72.3	73.7	74.6	75.3
of which electric heating	*28.4*	*26.7*	*27.4*	*27.7*	*28.1*
Total TWh	**162.2**	**159.2**	**160.5**	**160.6**	**160.1**

[1] Incl. LP gas
[2] Town gas and natural gas

The energy system

Table B1.10 Final energy use broken down by energy carrier

		1995	Change %	2000	Change %	2005	Change %	2010
Steam coal	1000 t	1,697	1.1	1,790	0.1	1,797	1.0	1,891
Coke, coke gas	1000 t	1,368	2.0	1,511	1.2	1,607	1.5	1,731
Biofuels, peat etc.	Ktoe	7,245	2.2	8,064	0.2	8,161	0.6	8,401
Petrol	1000 m3	5,800	0.4	5,917	1.3	6,316	0.7	6,546
Light distillates	1000 m3	1,048	2.1	1,162	1.8	1,272	1.8	1,392
Diesel oil	1000 m3	3,155	0.3	3,202	0.7	3,308	0.6	3,414
Light fuel oil	1000 m3	3,345	-1.3	3,139	-0.4	3,083	-0.8	2,956
Heavy fuel oils	1000 m3	3,279	2.3	3,686	0.2	3,725	0.1	3,744
LP gas	1000 t	488	-1.2	460	1.1	487	0.9	509
Town gas	Mill. m3	99	-5.2	76	4.8	96	3.6	115
Natural gas	Mill. m3	801	1.0	843	2.7	965	4.4	1 199
Blast-furnace gas, district heating	Ktoe	70	2.4	79	0.0	79	0.0	79
District heating	GWh	41,057	1.1	43,334	0.5	44,513	0.5	45,655
Electricity	GWh	133,866	0.6	137 918	0.3	140 216	0.6	144,664

Effects of investment supports

The following assumptions have been made in the calculations of the effects of the investment supports on carbon dioxide emissions:

– Given an emission factor for coal of 0.327 Mt (megatonnes) of carbon dioxide per TWh and an efficiency for coal condensing plants of 42%, these plants give carbon dioxide emissions equivalent to 0.78 million tonnes per TWh of electricity generated.

– Given an emission factor for natural gas of 0.203 Mt of carbon dioxide per TWh and an efficiency for natural gas combined-cycle plants of 60%, these plants give carbon dioxide emissions equivalent to 0.34 million tonnes per TWh of electricity generated.

– In 1995, electricity generation gave rise to 0.073 million tonnes of carbon dioxide per TWh of electricity generated, on average.

– In 1995, energy use in the residential, commercial and institutional sector gave rise to 0.054 tonne of carbon dioxide per TWh of energy used, on average.

Investment support to biofuel-based CHP

The investment support to biofuel-based CHP is expected to yield 1.7 TWh of electricity. The calculation is based on an assumption of an average operating time of 5,000 hours per annum. In the calculations we have assumed that the heating demand would have been met by biofuel-based heat production if the investment support had not been given. This means that the effect of the support on carbon dioxide emissions is limited to the fossil-fuel-based electricity production which the 1.7 TWh can be assumed to replace. It is also assumed that the CHP plants that have received support will continue to use biofuels after the five initial years.

Based on these assumptions, the reduction in carbon dioxide emissions yielded by the investment support can be estimated to be as follows: 0.12 (average production mix in 1995); 0.58 (natural gas combined cycle); and 1.32 (coal condensing) million tonnes per annum.

Investment support and operating subsidy to wind power

Through the investment support and the operating subsidy to wind power, plants with a mean annual production of 0.2 TWh have been added to the system[42]. This corresponds to a reduction of annual carbon dioxide emissions by 0.015 million tonnes (average production mix in 1995).

Support to expansion of the district heating network

The support to the expansion of the district heating network has been estimated to lead to a reduction of carbon dioxide emissions by 0.35 million tonnes annually[43].

Programme for more efficient energy use

The initiatives within the programme for more efficient energy use in the residential, commercial and institutional sector are expected to reduce energy use in residential, commercial and institutional buildings by 2 to 3 TWh by the year 2000. This projection includes the effect of installing heat pumps, but not the effect of other electric heating conversion measures[44]. The programme's effects on carbon dioxide emissions can thus be estimated to be at most a reduction of 0.2 million tonnes annually.

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[42] NUTEK annual report 1995/96.
[43] NUTEK annual report 1995/96.
[44] NUTEK R 1996:68

Appendix 2 Temperature and hydropower variations in Sweden

Background

The supply and demand of different energy forms varies from year to year due to a number of climatic factors. The supply of electricity is affected by, among other things, how much hydropower is available, which is correlated to the amount of precipitation during the year. Demand is governed to a large extent by the outdoor temperature, with a greater space heating requirement in colder years.

In addition to hydropower and nuclear power, Sweden's electricity production is also based on oil condensing power, coal condensing power, CHP in district heating and industry, and gas turbines. Of these power sources, hydropower and nuclear power satisfy most of the demand, the base load. After this, electricity is generated by oil or coal condensing plants to meet peak loads.

Hydropower

The annual production capacity of hydropower is determined primarily by water levels in watercourses and reservoirs, which is in turn determined by the amount of precipitation. The concepts of dry and wet years are used to describe the hydropower situation during a given year in Sweden. These concepts are related to a normal-year value.

The normal-year value is based on an average of the production conditions during a 40-year period, 1950 to 1990. The value of 63.2 TWh used in recent years had been calculated for the period from 1950 to 1980, which however overestimated the normal-year production. The new normal-year value of 63.5 TWh therefore does not differ much from the old one, despite new plant construction.

The variation around a normal-year production value means that production in a dry year can be 10 TWh lower than in a normal year. Under very extreme conditions, it can be up to 15 TWh lower. In a wet year, on the other hand, production can increase by 10 TWh above the normal.

In normal years, the installed oil-fired condensing power capacity is used very little. The need for oil-fired electric power arises when drier years occur. Variations in climatic factors thereby influence energy production as well as carbon dioxide emissions. However, carbon dioxide emissions are not directly proportional to the change in energy use. A number of aspects such as water storage, the balance between imports and exports, and increased or decreased electricity demand are of importance. As the phase-out of nuclear power proceeds, on the other hand, fuel-based electricity production will grow significantly unless alternative energy sources are developed.

In the nineties, 1991 and 1994 were dry years, while 1990, 1992, 1993 and 1995 are categorized as wet years, see Figure 1. 1996 was an extremely dry year.

Figure 1. Non-spill-corrected affluence 1950–1995. The graph is based on each year's affluence (water inflow to rivers), converted to electrical energy by the mean capacity of today's hydropower plants. The rough values in the graph indicate the natural variations that occur within hydropower production.

Source: Swedish Power Association.

Temperature

The demand for electrical energy is governed primarily by the outdoor temperature. More energy is consumed in cold years than in warmer years. For electricity production, it is within the residential, commercial and institutional sector that the temperature variations are of importance, since approximately 65% of total energy use goes to space heating. Temperature variations are of more subordinate importance in other sectors, such as industry and transportation.

Is 1990 a good reference year?

1990 was the best power year ever for hydropower thanks to an unusually large amount of precipitation. Production was 8 TWh above the normal-year production.

1990 was both a warm year and a wet year. This did not alter carbon dioxide emissions from electricity production, but it did result in a good supply of electricity, which reduced the use of fossil fuels in the space heating sector. Comparing this year with a cold, or dry, year with a greater need for electrical energy from fossil fuels can lead to wrong conclusions.

In view of the large emissions variations that can occur due to the influence of the climate, it is important to normal-year-correct the carbon dioxide emissions from electricity production.

Normal-year correction

Comparability between years is disturbed by the natural climatic variations between drier and wetter and between warmer and colder years. Effects of political decisions can thereby be overshadowed by the natural variations. Some countries within the OECD communicate corrected carbon dioxide emissions to the UNFCCC in order to adjust for extreme values caused by the variability of the climate. France, the Netherlands and Switzerland temperature-correct, and Denmark corrects for its trade with electricity based on fossil fuels.

The annual variation of temperature and hydropower supply should be included in a model for calculation of normal-year corrections. These corrections should not make allowance for variations in industrial activity or nuclear power plant outages.

The purpose of normal-year correction is to adjust for extraneous causes of variations in carbon dioxide emissions. But the factors included in this correction must be simple and relevant if the results are to be credible. It is important that corrections can be made every year.

The directives for the international communications of greenhouse gas emissions to the UNFCCC will allow for reporting of both actual and normal-year-corrected values.

Degree days

The annual temperature variations can also be reported in the form of degree-days. A degree-day index for a given year indicates whether the year has been warmer or colder than normal. The number of degree-days is calculated for each 24-hour day and is the difference between the base temperature, 17°C, and the mean temperature on that day. These degree-day indexes are then totalled to give monthly and annual statistics.

During the summer half of the year, when solar irradiance contributes to heating, the number of degree-days changes only if the temperature falls below the heating limit of 10°C in May-July, 11°C in August, 12°C in April and September and 13°C in October.

The degree-day index is used to calculate, based on data on actual energy consumption, what the consumption would have been if the weather had then been "normal". The normal-year value currently used has been calculated by SMHI[45] by taking an average of all degree-days during the period 1961-1979.

Temperature correction

The degree-days calculated by SMHI are used by, for example, NUTEK to temperature-correct energy use. The degree-day index is calculated by selecting a number of localities in Sweden, evenly spread over the country. Each of the localities is weighted according to how large a portion of the country's population lives there. By multiplying the number of degree-days for the area by its weighting, and then adding together these weighted degree-days, a weighted degree-day index is obtained which is representative for the whole country.

When energy use is then temperature-corrected, a correction factor of 60% is used. The reason for this is that only a portion of energy use in households is used for space heating. Energy is also used for heating of hot water, for example, which is not dependent on the outdoor temperature.

Which fuels are temperature-corrected?

Emissions of carbon dioxide are calculated by multiplying fuel consumption by different emission factors. The fuel is, however, considered to be affected to varying degrees by the outdoor temperature and is therefore divided into different fractions depending on how much is to be corrected. The fractions can, however, vary depending on the calculation case.

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[45] SMHI = Swedish Meteorological and Hydrological Institute.

Following are some examples of the energy sources that are temperature-corrected by NUTEK:

Steam coal
Fuelwood etc.
50% of the light distillates
Light fuel oil
Heavy fuel oils
15% of the LP gas
Natural gas
50% of the town gas
District heating
Electric heating (Approximately equal to 40% of total electricity consumption in the sector)

Calculation model
Annual statistics on consumption of concerned fuels are collected by Statistics Sweden, SCB. They are corrected according to how the temperature has varied, with the aid of degree-day indexes from NUTEK. The difference between actual and corrected annual consumption is converted by means of conversion factors to real emissions values.

District heating and electrical energy use is also corrected. For these systems, however, the fraction of the total consumption that was of fossil origin is estimated. For district heating use, this is done with the aid of annual statistics from the District Heating Association, and for electrical energy with the aid of statistics from Vattenfall (see below).

Production of hydropower also varies due to external conditions. The actual annual production, which is obtained from NUTEK, is corrected against a normal-year value of 63.5 TWh. The over-/under-production of electrical energy from hydropower during a year (compared to a normal year) is added together with the over-/under-consumption of electrical energy of during the same year (compared to a normal year). A general assessment is made that there is a 7% fossil content there.

The three steps are added up and reported in parallel with the actual emissions value.

Table 1. Emissions of carbon dioxide for 1990-1995, actual and normal-year-corrected value, million tonnes.

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
Total anthropogenic emissions	**55.45**	**55.18**	**56.03**	**56.02**	**58.48**	**58.11**
Normal-year-corrected	**57.62**	**55.82**	**57.54**	**57.07**	**58.77**	**58.47**

Appendix 3 The ELFIN model

The Elfin model is a power balance model, i.e. a model that simulates the operation of an electricity production system at a given load. Given the load and data for the power sources included in the production system, ELFIN calculates how much energy the different power sources are expected to generate when the load is to be covered at the lowest cost possible. Furthermore, the model calculates the system's marginal cost and variable costs.

Input data for the different power sources are variable costs, installed capacity and variations in utilization time during the year. Each year is divided into 13 separate periods, called typical weeks. The power sources are utilized - to cover the load in the typical week - in order of cost. Hydropower is divided into regulated and unregulated hydropower. The unregulated hydropower is used before other power sources, while the regulated hydropower is used to minimize the production costs of the typical week.

As far as load is concerned, a load curve is given for each typical week, consisting of values for power demand every hour in chronological order. The marginal cost for each typical week is calculated by weighting together the variable costs for the power sources that are the most expensive at any given time in proportion to the time they are operating on the margin. Then the marginal costs for the different typical weeks are weighed together, taking into account the length of the typical weeks, to obtain the short-term marginal production costs for the year.

Appendix 4 Emission Inventory 1990 and 1995

IPCC Standard Data Tables

1. Greenhouse gas inventories for Sweden 1990-1995

Emission inventories for greenhouse gases for 1990 and 1995 have been compiled for the Swedish National Communication 1997. The emission estimates are reported in accordance with the IPCC Guidelines for National Greenhouse Gas Inventories and covers anthropogenic emissions by sources and removals by sinks, of all greenhouse gases not covered by the Montreal Protocol. IPCC Standard Data Tables for 1990 and 1995 are found in the end of this appendix.

CO_2-emission estimates have been calculated by Statistics Sweden on the basis of fuel consumption statistics. Emission data for industrial processes, solvents, agriculture, land use change and forestry and waste for other greenhouse gases than CO_2 are estimated by the Swedish Environmental Protection Agency (Swedish EPA), who also has compiled the complete inventories.

Below follows comments on the tables and changes in emission estimates, compared to the first national communication. Some nationally used emission factors and comments to these have also been compiled.

1.1 Comments on the IPCC Standard Data Tables

1 Energy

1A Emissions from fuel combustion in connection to energy production, heating and transport. Statistics Sweden has calculated all CO_2-emissions and also emissions of other greenhouse gases from stationary combustion (1 A 1-5). Emission figures are determined as the product of fuel consumption, fuel thermal value and emission factors. Thermal values for fuels and emission factors are provided by the Swedish EPA. These emission factors are based on results from measurements, studies of internationally used emission factors and judgments of relevance to national conditions.

1A1 Combustion of waste, except hazardous waste, is included in "combined heat and power generation" and "heat plants". For coke works, only their own consumption of gas is included. Calculation of emissions originating from production of blast furnace gas are based on gas, not coke, to avoid double counting. Gas not used at coke works is reported under 1A1a.

1A2 Emissions from fuel combustion in industry. Off-road vehicles and other machinery in industries are included for CO_2-emissions only. Emissions of other greenhouse gases from off road vehicles are included under 1A3e, "Transport; Other".

1A3 Emissions from road traffic and other mobile sources, except international transports. A new model for calculation of air emissions from road traffic is currently used at the Swedish EPA. Earlier reported figures have been accordingly revised. A brief description of the new model is given after the comments on the tables. Data on emissions from civil aviation, navigation and railways of other greenhouse gases than CO_2 have been submitted by the respective national authorities. Emissions from off road vehicles and other machinery of other greenhouse gases than CO_2 are included in

"Transport; Other".

1A4 Emissions from combustion of fuel wood ("Traditional Biomass Burnt for Energy") is included in 1A4b, "Residential". In the first national communication, combustion of fuel wood was reported seperately under 1A6, "Traditional Biomass...". Off-road vehicles and other machinery in agriculture/forestry/fishing are included for CO_2-emissions only. Emissions of other greenhouse gases from off road vehicles and machinery are included under 1A3e, "Transport; Other".

1A5 CO_2-emissions from military fuel use, according to data from the Swedish National Defence.

1A6 See comment for 1A4.

1B2 Estimate of indirect emissions of CO_2, calculated from carbon in NMVOC-emissions from distribution of oil products.

2 Industrial Processes

Estimate of CO_2-emissions are calculated by Statistics Sweden and are based on information about production and use of raw material etc. Data on emissions of other greenhouse gases are mainly collected from the annual environmental reports from industries to the supervising authorities. These data often originate from measurements etc. In the first national communication, CO2-emissions from industrial processes were collected from environmental reports.

A Iron and Steel;
Emissions from manufacturing of steel and ferro alloys. Calculation of CO_2-emissions are based on the use of dolomite in manufacturing of iron pellet and an estimate of CO_2-emission from anodes, used in manufacturing of ferro alloys.

B Non Ferrous metals;
Emissions from aluminium production and primary and secondary metal works. Estimates of CO_2-emissions are based on the use of coal electrodes in aluminium production. Estimates of other greenhouse gas emissions from environmnetal reports, compiled by different primary and secondary metal works.

C Inorganic Chemicals;
Emissions of N_2O and NO_x from production of nitric acid and fertilisers, data collected from environmental reports.

E Non Metallic Mineral Products;
Cement; Calculation of CO_2-emissions are based on the use of limestone in the manufacturing of cement. Emission figures for NO_x collected from environmental reports.
Lime; Manufacturing of burnt lime, CaO.
Other; i e mineral wool production and glass industry. Estimates of CO_2-emissions from manufacturing of mineral wool are based on the use of dolomite, estimates of CO_2-emissions from glass industry are based on the use of limestone, soda and dolomite. Emission figures for NO_x collected from environmental reports.

F Other;
Included in "Other" is combustion of hazardous waste, pulp and paper industry and chemical industry/non energy purposes. CO_2-estimates are based respectively on the amount of combusted hazardous waste, emissions from lime kilns and use of propane in chemical industry.

3 Solvents and other Product Use

Indirect emissions of CO_2 have been calculated from carbon in emissions of NMVOC from solvents and other products. The emission figures for NMVOC originate from two reports by the Swedish EPA (SNV 4312 and SNV 4532)

4 Agriculture

4A,B Emissions of CH_4 from enteric fermentation and manure management. Emission estimates have been calculated with emission factors recommended by IPCC as well as nationally used factors.
The nationally used emission factors are based on a report from Swedish EPA(SNV 4144). A comparison between calculations in accordance with the methods recommended by IPCC and the estimates for Swedish conditions (SNV-report 4144)

indicated that the national method should be used when estimating CH_4-emissions.

4D Emissions of N_2O from agricultural soils. Emission estimates have been calculated with emission factors recommended by IPCC. The low estimate is considered appropriate since Sweden has a cold climate, comparatively little nitrogen is used as fertiliser and the deposition of nitrogen is also comparatively lower.

6 Waste

6A Emissions of CH_4 from solid waste disposal in landfills. A new estimate of methane emissions for 1990 and 1995 has been done at the Swedish EPA. The calculations are based on statistics for the amount of deposited organic waste, the theoretical potential for gas from landfills and the amount of recovered gas.

6B Emissions from combustion of waste is included in 1A1aii, "Combined heat and power generation" and 1A1aiii "Heat plants".

1.2 Model for calculation of emissions from road traffic

The Swedish Environmental Agency has recently started to use a new model for calculation of emissions from road traffic. The model is an improvement of the earlier used method for calculation of emissions and the computer programme comprises several types calculation possibilites. Input data includes description of vehicles, including emission factors as well as correction- and deteriaration factors, data on vehicle use and different vehicle types, fuel use and fuel descriptions etc. There are numerous emission factors available, e g for cold starts and hot emissions, and a more detailed account can be obtained at Swedish EPA.

1.3 Emission factors for CO_2 for fossil fuels and carbon sources

Fuel Type	Unit	Thermal value GJ/unit	CO_2 g/MJ	Field of Application
Coal	metric ton	26.50	90.7	All use
Coke	metric ton	28.05	103.0	All use
Wood (biomass)	toe	41.87	96.0	All use
Peat	metric ton	9.91	107.3	Electricity & heat prod.
Peat	metric ton	6.12	97.1	Use in industry
Municipal Solid Waste	metric ton	9.52	32.7	Electricity & heat prod.
Industrial Waste	metric ton	1.96	27.4	Use in industry
Other	toe	41.87	60.0	All use
Residual Fuel Oil (Eo 1)	m^3	35.59	75.3	All use
Residual Fuel Oil (2-5 Ls)	m^3	38.94	76.2	All use
Residual Fuel Oil (2-5 Ns)	m^3	38.94	76.2	All use
Motor Gasoline	m^3	31.40	72.6	All use
Aviation Gasoline	m^3	32.70	72.3	All use
Kerosene	m^3	34.50	73.1	All use
Diesel Oil	m^3	35.59	75.3	All use
Black Liqour (biomass)	toe	41.87	108.0	All use
LPG (town gas)	1000 m^3	16.75	77.5	All use
Coke Oven Gas	1000 m^3	16.75	60.0	All use
Blast Furnace Gas	1000 m^3	3.35	103.0	All use
LD Gas	1000 m^3	8.37	199.9	All use (iron works)
Propane	metric ton	46.05	65.1	All use

Emitted amount (metric ton) = Fuel use * Thermal value * 1000 * emission factor / 1 000 000

1.4 Emission factors for agriculture, 4 A & B

Type of animal	Enteric Fermentation kg CH4/head/year	Manure Management kg CH4/head/year
Dairy cattle	154	6
Non dairy cattle	73	4
Sheep	15	0.19
Goats	21	0.12
Horses	18 (IPCC recommendation)	1.4
Swine	1.5 (IPCC recommendation)	4
Poultry		0.078