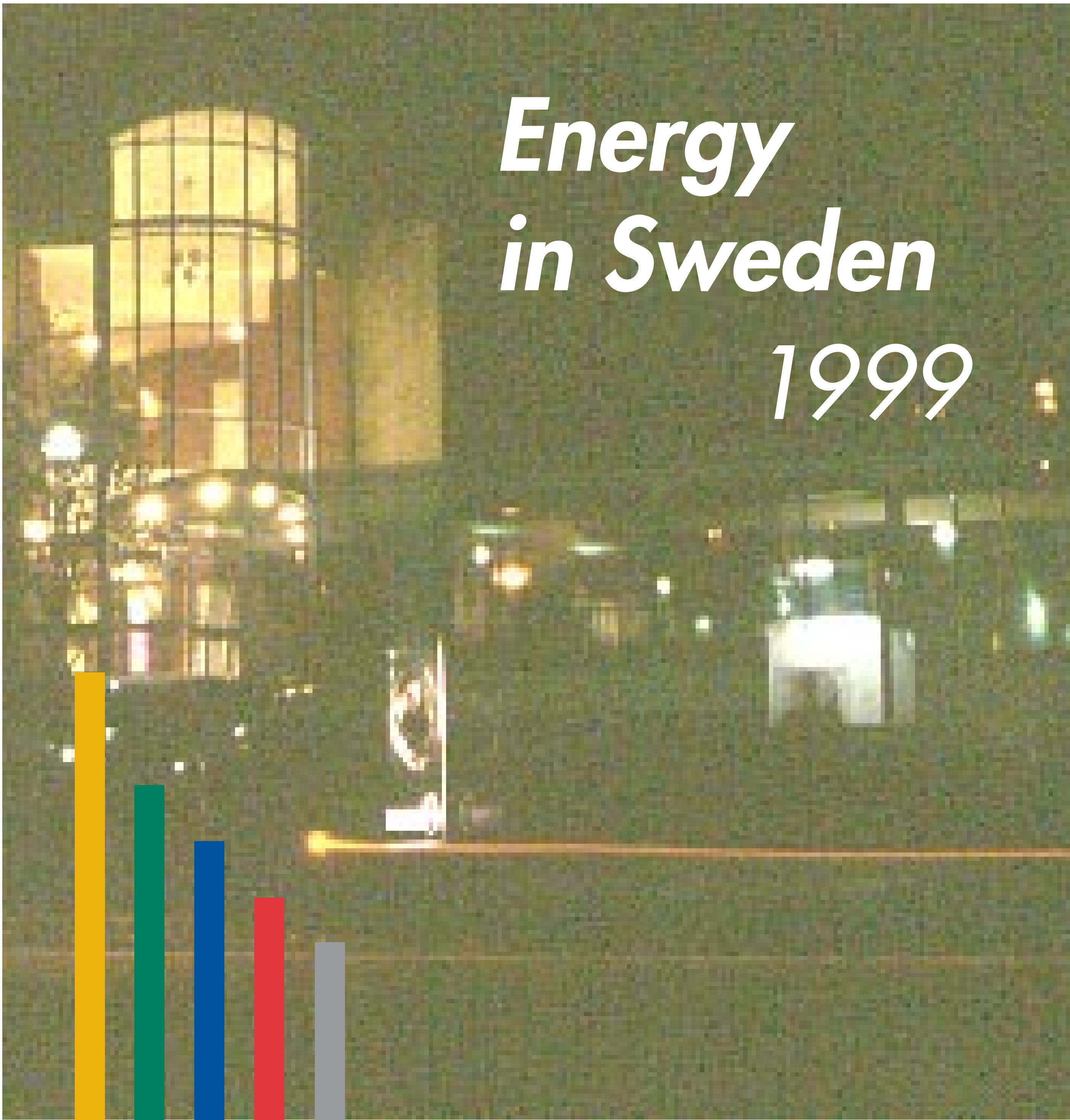
Energy in Sweden 1999



Swedish National Energy Administration

ET 82:1999
Production: Ordförrådet Bertil Örtenstrand AB
Translation: Angloscan Manuscript Ltd.
Printed by: Alfa-Print AB, Sundbyberg
Print run: 5 000 copies
December 1999
Cover photograph: Hasse Cedergran

Energy in Sweden is published annually, in Swedish and English, by the Swedish National Energy Administration. A special version, containing only the tabular data, is also available. In addition, the diagrams can be ordered from the Energy Administration in the form of a set of overhead pictures. Energy in Sweden, together with a number of other publications of current interest, can be ordered from the Energy Administration: for details, see the inside of the cover.

Further general information is available from the Department for External Communications.

Statistical information has been provided by, and is available from Department for Energy Policy Analysis. For general statistics, contact Becky Petsala: for information on the electricity market and power production, contact Stefan Goldkuhl: for district heating and district cooling, contact Maria Stenkvist: for the biofuels market, contact Stefan Holm or Måns Norberg: for the oil and coal markets, contact Claes Aronsson: for energy gases, contact Agnes von Gersdorff: for the residential and service sectors, contact Agneta Tisell: for industry, contact Niklas Johansson: for the transport sector, contact Åsa Leander: for prices and taxes, contact Agnes von Gersdorff or Måns Norberg, and for environmental aspects, contact Åsa Leander.

Project Leader: Maria Stenkvist, e-mail: maria.stenkvist@stem.se

Our telephone number is +46 16 544 20 00.

Further information on the Energy Administration and its publications is available at www.stem.se.

Preface

The energy markets are undergoing a process of rapid change as a result of many factors, including a shift in the emphases of energy and environmental policies in Sweden and elsewhere.

In recent years, Swedish energy and environmental policy has increasingly concentrated on establishing or improving long-term conditions for effective energy markets. Restructuring of the Swedish electricity market, greater internationalisation and the effects of the energy system on the environment and on climate are important factors that influence this policy and thus the development of energy markets.

Sweden's energy policy, as decided by the Swedish Parliament in 1997, is to provide secure short-term and long-term supplies of electricity and other energy on competitive terms. The country's energy policy is intended to create the conditions for efficient use and cost-efficient supply of energy, with minimum adverse effect on health, the environment and climate, while at the same time assisting the move towards an ecologically sustainable society.

An extensive energy policy programme has been started in order to facilitate restructuring and development of the energy system. The main thrust of this work is in the form of a substantial long-term concentration on research, development and demonstration of new energy technology. A new public authority, the Swedish National Energy Administration, was set up on 1st January 1998, with responsibility for implementing most of the energy policy programmes and coordinating the work of restructuring the energy system.

In addition, the Administration is also responsible for monitoring developments in the energy and environmental fields and for providing information on the current energy situation. This covers aspects such as changes in the structure and pattern of energy supply and use, energy prices and energy taxes and the effects of the energy system on the environment.

Part of this work is represented by the annual publication of 'Energy in Sweden', which is intended to provide decision-makers, journalists and the general public with a coherent and easily available source of information on developments in the energy sector.

This publication includes a presentation of developments in the energy system in Sweden, expanding the perspective to an overview of the international energy markets. Finally, it includes a presentation of the relationship between energy and the environment. ■

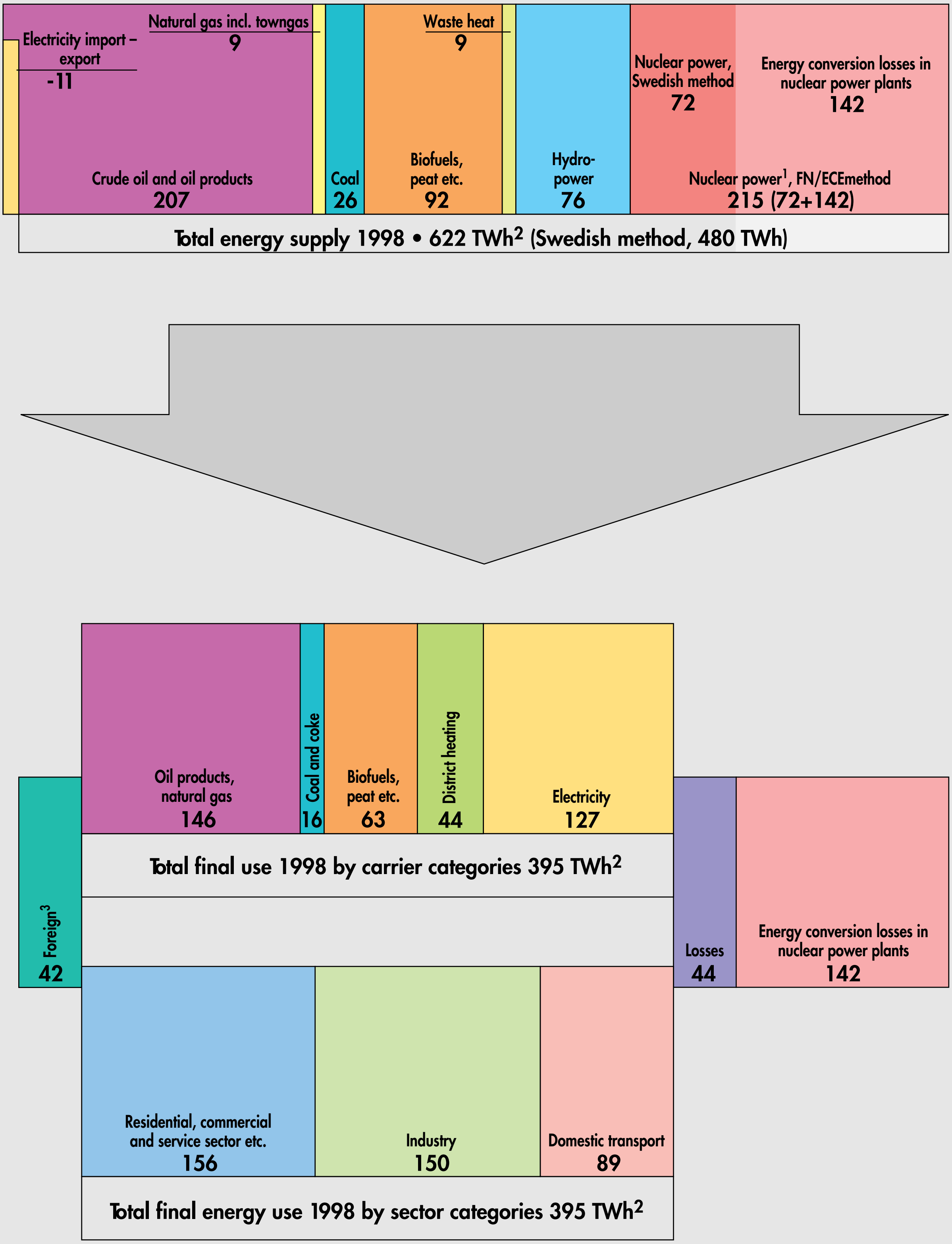
Stockholm, December 1999

Thomas Korsfeldt
Director-General

Becky Petsala
Head of Department,
Department for Energy Policy Analysis

Figure 1 • Energy supply and use in Sweden 1998, TWh

The same diagram, expressed in PJ, can be found on page 37.



[1] The UN/ECE method includes the energy conversion losses in the nuclear power plants in the total energy supply which is the difference from the Swedish method.

[2] Preliminary figures. Due to rounding up or down of these figures, total figures may not always agree exactly with the sums of the individual items.

[3] Foreign maritime trade and energy for non-energy purposes.

A country's total energy use can be expressed in a number of ways. Figures 2a and 2b show Sweden's total energy use as expressed by two different methods. The first method, which we call the Swedish method, is that which has hitherto been employed in official Swedish material, including Energy in Sweden. The second method, the international method, is that recommended by UN/ECE, and is usually employed in international statistics.

The difference between the two methods lies in the way in which the energy supply from nuclear power is treated. The international method considers the gross thermal output from the reactors, i.e. before conversion to electricity, while the Swedish method considers the electrical energy output. This means that the international method includes the energy conversion losses in the nuclear power stations, which is the difference from the Swedish method.

According to the international way of presenting the figures Sweden's energy supply has increased by 36 % between 1970 and 1998, from 457 TWh to 622 TWh. Average energy supply from 1970 to 1998 has been about 532 TWh/year.

The constituents making up the total energy supply have changed considerably over this period. In 1970, crude oil and oil products accounted for 77 % of the total energy supply, but had fallen to 33 % (43)[1] by 1998. Nuclear power production started during the period, while hydro power production during a statistically average climatic year increased somewhat. This latter output is based on a mean value of statistics concerning inflow to the reservoirs for the period 1950–1990. Today, nuclear power can produce about 220 TWh/year (72 TWh/year by the Swedish method) and hydro power can produce about 64 TWh/year under normal precipitation conditions. The total proportion of overall energy supply provided by hydro and nuclear power has increased from 9 % in 1970 to 47 % in 1998, (31 % when calculated by the Swedish method). The proportions of energy supply represented by coal, coke, biofuels, peat etc. have also increased relative to that of crude oil and oil products. In 1970, coal and coke supplied 4 % of the country's energy, with biofuels, peat etc. supplying a further 9 %. By 1998, these proportions had increased to 4 % (5 %) and 15 % (19 %) respectively[1].

One of the factors that causes total energy supply to vary from one year to another is temperature. 1970 and 1996, for example, were colder than average. Calculated by the Swedish method, this means that energy supplies in those two years were higher than would have been the case in a normal year. 1998, on the other hand, was warmer than an average year, and so energy supply was less than would otherwise have been the case.

[1] *The figures in brackets indicate the energy supply proportions of the respective fuels as calculated by the Swedish method.*

Figure 2a • Total energy supply in Sweden 1970-1998

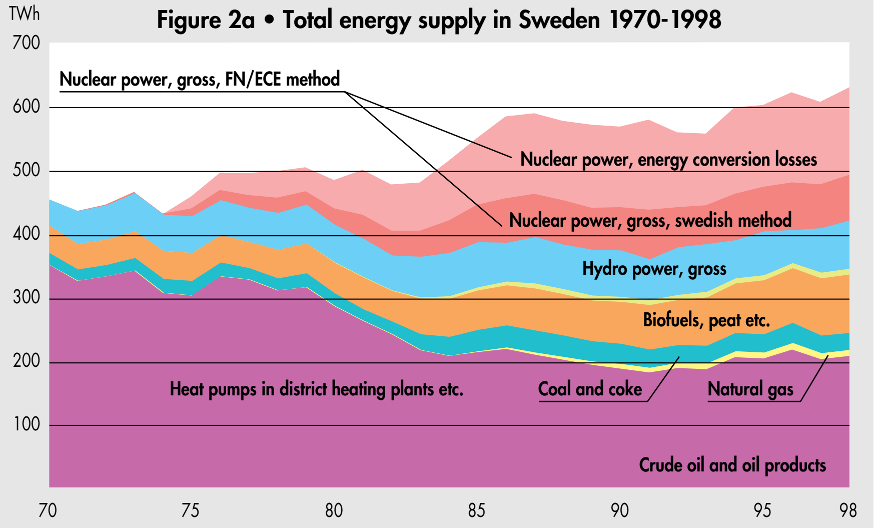
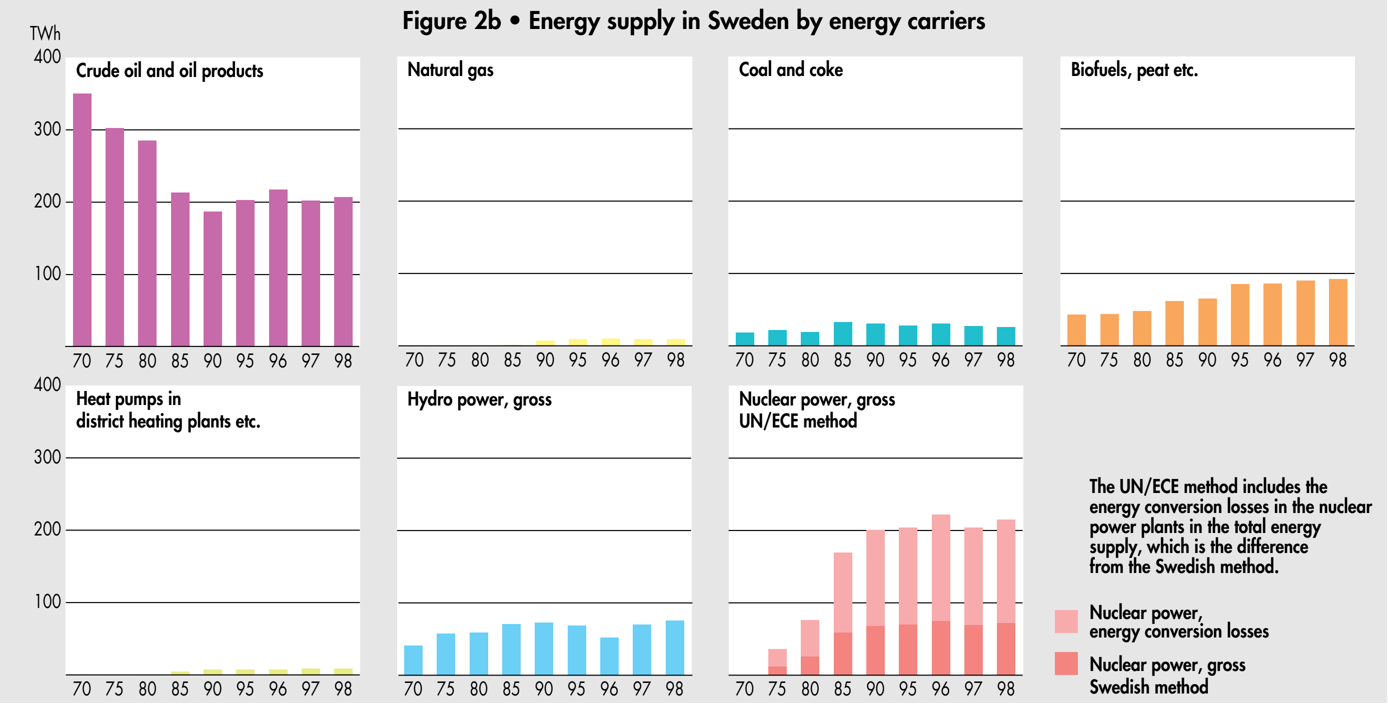


Figure 2b • Energy supply in Sweden by energy carriers

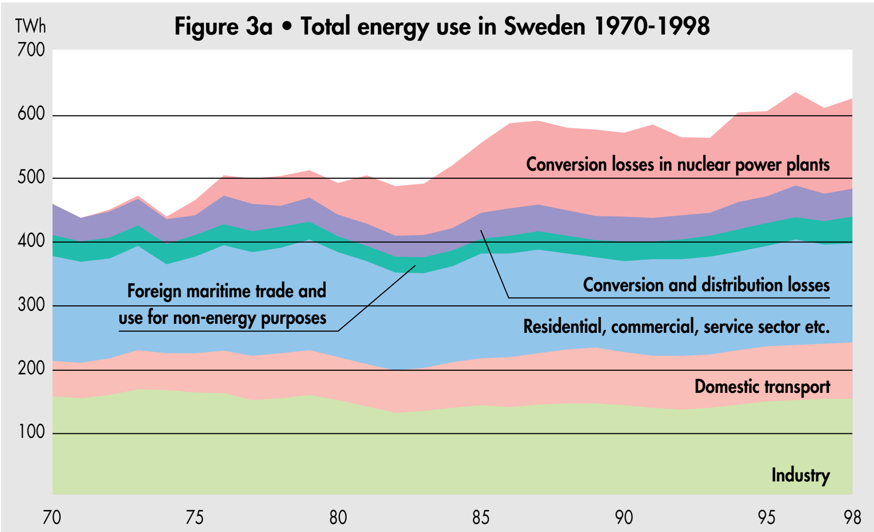


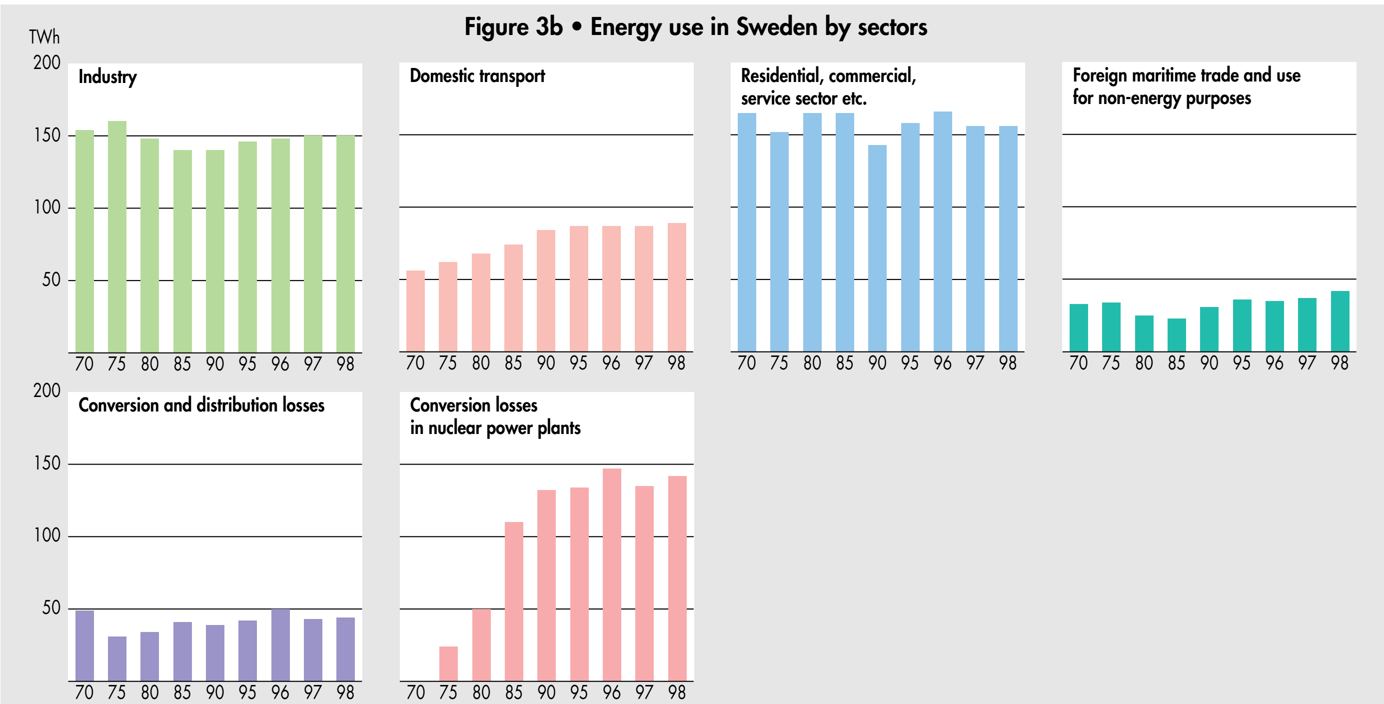
Total energy use can be divided up into three categories. First is what is known as the total final energy use, i.e. use within the three sectors of residential/services etc., industry and internal (i.e. domestic) transport. This category accounts for the majority of all energy use. The second category comprises losses, by which are meant distribution losses associated with the supply of electricity, natural gas, town gas and blast furnace gas, district heating, conversion losses in heat and electricity production (although the losses associated with hydro power production are not included), conversion losses in refineries and coking plants and, finally, the energy sector's own use of energy. The third category of energy use comprises bunker oil for international shipping and coal and oil products used as raw materials and feedstocks for applications such as the plastics industry. This non-energy post also includes lubricating oils and oil products used in the building and civil engineering sectors, e.g. asphalt, surface coatings etc.

The relative proportions of final energy use accounted for in the first group by industry and the residential/service sectors etc. have gradually changed between 1970 and 1998. The industry and residential/service sector proportions have each fallen in relation to the transport sector. Industry's proportion has fallen from 41 % to 38 %, and the residential/service sector from 44 % to 40 %, while the internal transport sector's proportion of the country's total energy use has risen from 15 % to 22 %.

The variations that occur from year to year are due mainly to economic conditions and to climate conditions. The years from 1988 to 1995 were warmer than normal, for example, which partly accounts for the reduction in energy use by the residential/service sector etc. up to 1995. 1996, however, was colder than normal, which explains the increase relative to the previous year. 1998 was again warmer than normal, resulting in a fall in energy use between 1996 and 1998.

As can be seen from Figure 1, total final energy use in 1998 amounted to 395 TWh. To this must be added 42 TWh for overseas shipping etc. and 186 TWh for losses, giving a total energy use of 622 TWh for the year. ■





1998 was the third year of the restructured electricity market in Sweden and Finland: Norway had restructured its electricity market in 1991. 1998 was characterised by growing competition in the electricity market and good availability of hydro power, which kept prices in the power exchange very low. Several new players, such as oil companies, have established themselves as sellers of electricity. Some concentration of ownership has been noted in the last three years, particularly in the Swedish market. Strategic investments are being made by the larger power utilities, with the aim of increasing their market shares. This action is manifesting itself in such ways as take-overs, purchase of shareholdings, alliances and the establishment of subsidiary companies in Sweden and in other countries.

In principle, it can be said that the production and trading sectors of the Swedish electricity market can be divided up into four spheres: three consisting partly of foreign companies, with the fourth consisting of Vattenfall and its Swedish working partners. One sphere consists of the French EdF and Graninge. The second comprises the Finnish EVO, working with Stockholm Energi in a common company, Birka Kraft, which also includes Gullspång. The third sphere consists of Sydkraft, with the German Preussen-Elektra and the Nowegian Statkraft.

Electricity use

Figures 4a and 4b show the growth in electricity use in Sweden since 1970. On average, use has increased by 3 % per annum since 1970, amounting to almost 144 TWh in 1998. Although electricity use increased by 5 % per annum from 1970 until 1986, there has been a considerable easing off in the rate of growth since then, so that electricity use increased by only 0.4 % per annum from 1987 to 1998.

The greatest increase is to be found in the residential and service sector, where electricity use has increased by an annual average of 4 % since 1970, to more than 70 TWh in 1998, or about half of the country's total electricity use. Most of this increase is due to a change from oil to electricity for heating, coupled with greater use of electricity for building services systems.

The use of electricity in the residential and service sector varies with temperature. 1998 was warmer than an average year: in statistically average temperature conditions, the use of electricity for heating would have been about 0.9 TWh more.

In industry, the use of electricity has increased on average by 1.8 % per annum since 1970. During 1998, industrial use amounted to almost 54 TWh, equivalent to 37 % of the country's total use of electricity. This industrial use is closely linked to conditions in a

Figure 4a • Use of electricity in Sweden 1970-1998

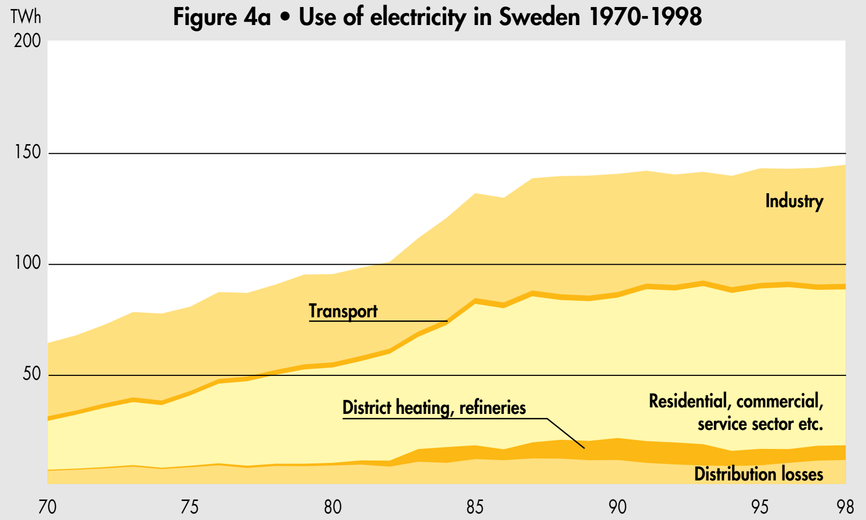
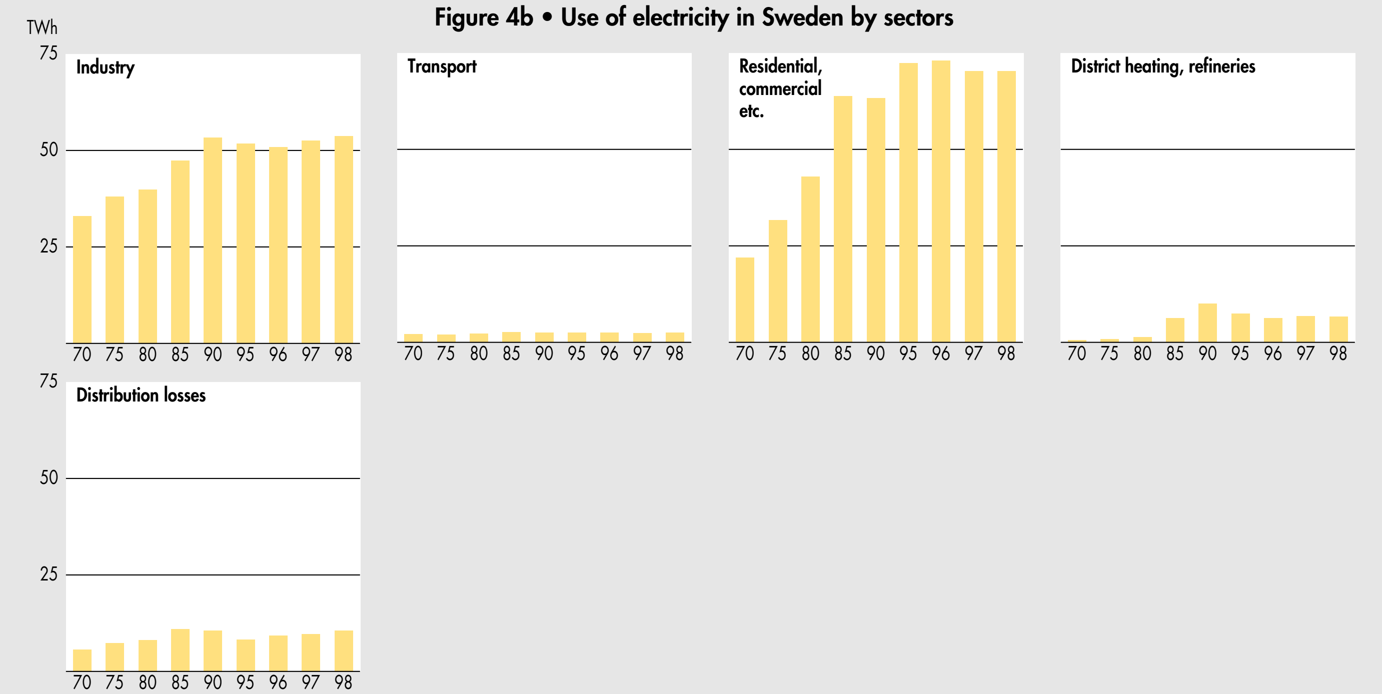


Figure 4b • Use of electricity in Sweden by sectors



small number of important sectors: the pulp and paper industry, for example, uses about 40 % of all the electricity used in industry.

Between 1970 and 1983, industrial output grew by 0.8 % per annum, with the average annual rate of increase of electricity use during the period amounting to 1.9 %. During the boom years of 1983–1989, industrial output rose by 2.8 % per annum on average, and electricity use by 4.3 %. However, during the subsequent recession years from 1990 to 1992, industrial output fell by an average of about 4.5 % per annum, accompanied by a corresponding average fall of 3.3 % per annum in the use of electricity in industry. After 1992, industrial output has risen again, with a resulting rise of about 1.1 % per annum in electricity use.

Electricity is also used for transport – mainly railborne – (2.5 TWh in 1998) and for district heating and refineries (6.7 TWh in 1998). Total electricity use also includes the losses associated with the transmission of electricity, amounting to 10.7 TWh in 1998.

Supplies to interruptible electric boilers are also included in the figures for total electricity use. Until restructuring of the electricity market in January 1996, they served as a regulator for the system, being available only at times when adequate supplies of cheap electricity were available. However, since restructuring, the power companies no longer distinguish between such supplies and other supplies, whether to industry or to the residential and service sector, although supplies to electric boilers in district heating systems are still identified.

Electricity production

Electricity is produced in Sweden by power plants that may be owned by the State, by local authorities, by industry or by commercial utilities. Six larger power companies together produced about 133 TWh, or 92 % of Sweden's total electricity output, in 1998. The country's two largest producers, Vattenfall and Sydkraft, together accounted for over 70 % of the total production.

Most of Sweden's electricity is produced by hydro power or nuclear power, as these sources have the lowest production costs at present, but some is produced by more expensive forms such as combined heat and power plants, oil-fired cold condensing plant, gas turbines or wind power.

Combined heat and power plants produces both electricity and heat simultaneously. It is employed in industry, where the heat is used for internal process requirements, and in district heating plants, where the heat is generally supplied to public district heating systems.

→

Figure 5a • Electricity production in Sweden 1970-1998

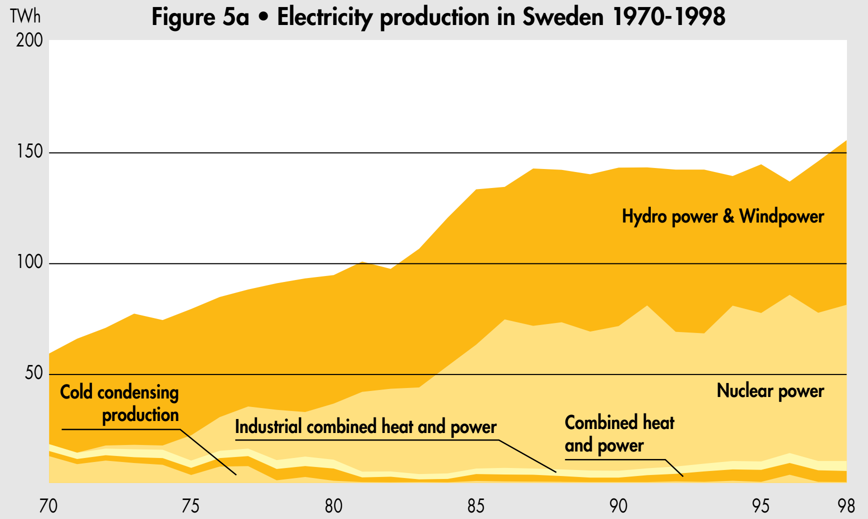
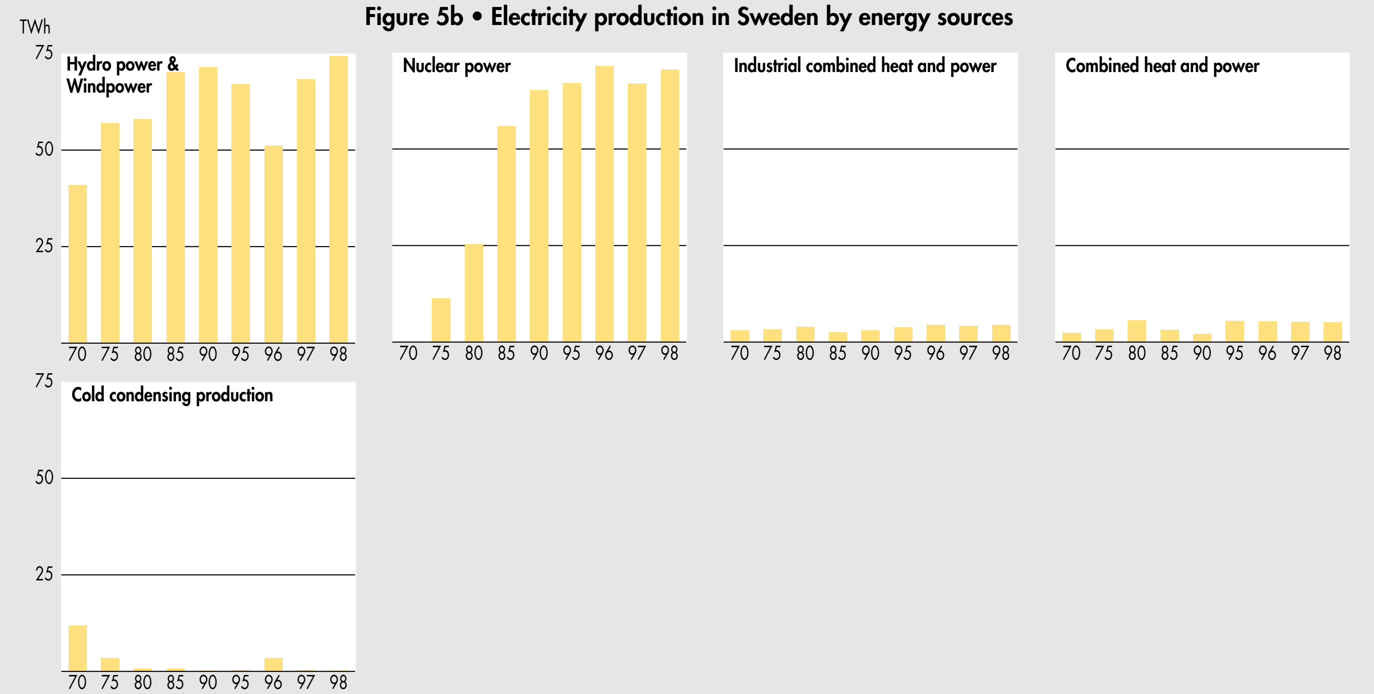


Figure 5b • Electricity production in Sweden by energy sources



Oil-fired cold condensing power stations and gas turbines are used today primarily as reserve capacity for use during years with low precipitation and resulting low hydro power production. The substantial expansion of nuclear power generation capacity since the beginning of the 1970s has greatly reduced the proportion of electricity supplied from oil. In addition, the restructuring of the electricity market has resulted in several reserve power stations being taken out of use for economic reasons. During 1998, the installed capacity of cold condensing oil-fired plant was reduced by 1 930 MW, leaving a total of 850 MW at the end of the year.

There are also about 420 wind power plants in the country, with an installed capacity of 174 MW, but their contribution to the total electricity balance is still very small (0.3 TWh in 1998). 87 new wind power plants, with an average capacity of 600 kW, were installed in Sweden in 1998, to provide an overall increase in capacity of about 52 MW (42 %).

Figures 5a and 5b show the proportions of output from different types of production plant since 1970. In 1998, the country produced 154 TWh of electricity, of which 74 TWh (48 %) were hydro power. Hydro power production was higher than normal as 1998 was a wet year. Nuclear power produced over 70 TWh or almost 46 % of production. Together, hydro power and nuclear power provided over 93 % of the country's total electricity supply, with combined heat and power plant producing 6 %.

Trade in electricity

Electricity is traded between parties such as producers, distributors and sales companies. Not only is it bought and sold within Sweden, but also with other countries to which there are transmission links. Nord Pool, a Nordic power exchange, which is jointly owned by Statnett SF, the Norwegian grid operator, and Svenska Kraftnät, its counterpart in Sweden, has been operating for Norwegian and Swedish traders since 1996. Over the last three years, the number of parties in the market, and the quantities of electricity traded, have increased substantially.

The changes in the electricity markets in the three Nordic countries (Norway, Sweden and Finland) have opened up the countries' grids to all parties, so that customers have been able freely to select their suppliers – which in principle also includes those in other countries. Swedish producers are therefore able to sell electricity directly to customers in Denmark, Norway or Finland, while producers in those countries can also sell to customers in Sweden.

Figure 6 • Sweden´s electricity imports 1998

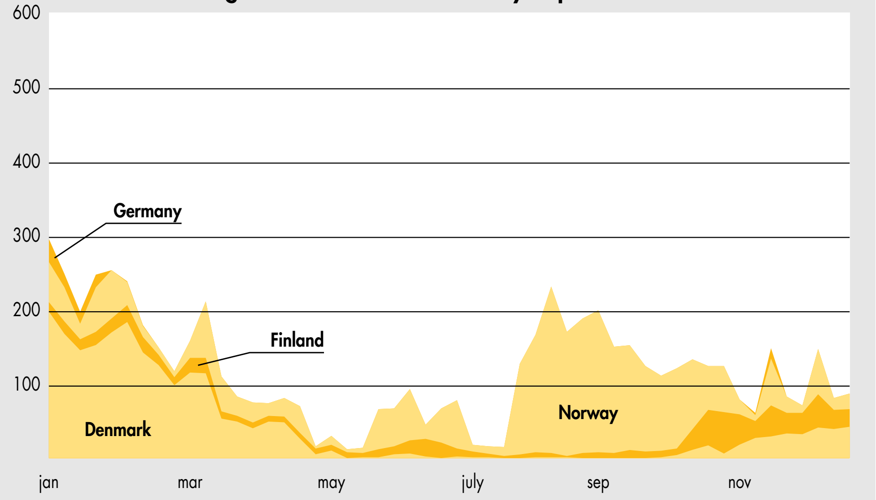
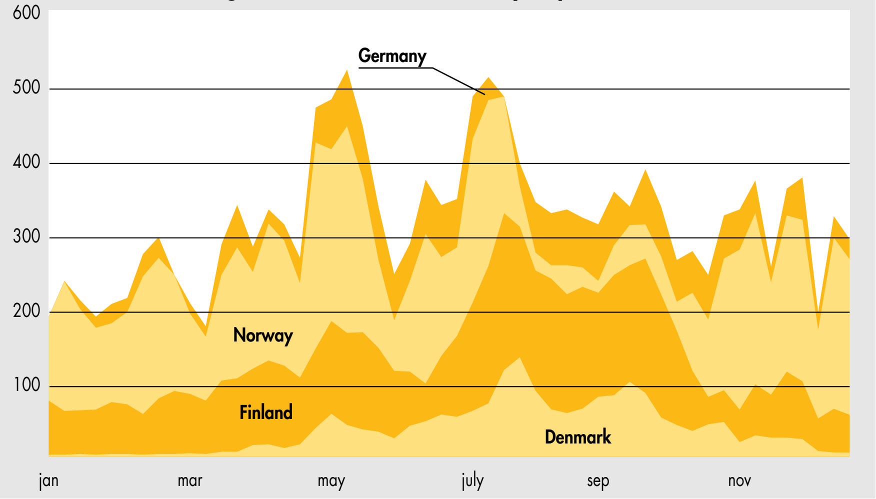


Figure 7 • Sweden´s electricity exports 1998



Source: Swedish Power Association.

Trade in electricity between the countries varies from year to year, both in terms of quantities and overall direction. Economic conditions affect the demand for electricity, and may not be the same in each country. Trade in electricity can then help to balance temporary national deficits or surpluses of electricity. However, the most significant influence on the overall directions of power flow is the amount of water, and thus of hydro power production, in the Norwegian system, and to a considerable extent also the corresponding Swedish conditions. In years with high precipitation, Norway and Sweden are net exporters of power to Denmark. During dry years, the flow of power is reversed, so that Denmark becomes a net exporter to Norway and Sweden, which means that the Danish power system provides reserve capacity for the Nordic electricity production system.

Sweden's total import of electricity in 1998 amounted to 6.1 TWh, which is a substantial drop from the 1997 import of 10.2 TWh. Most of this electricity was purchased from Norway, followed by over 2 TWh from Denmark, 0.9 TWh from Finland and 0.1 TWh from Germany.

Total exports of electricity to neighbouring countries in 1998 amounted to 16.8 TWh, which is an increase of 3.9 TWh over the previous year. Sales to Denmark and Finland increased, while those to Norway fell. However, some of the power flows are simply transiting flows between countries. In total, Sweden was a net exporter of electricity in 1998, amounting to 10.7 TWh. Figures 6 and 7 show how the power flows varied during the year. ■

During 1998, use of biofuels, peat etc. amounted to over 92 TWh. Fuels included in this category, and mostly produced in Sweden, are:

- black liquors from pulp mills
- wood fuels (logs, bark, sawdust and energy plantations)
- refuse
- peat, and
- straw and energy grasses.

They are used in four main areas:

- the forest products industry
- district heating plants
- the single-family house sector, and
- electricity production.

The forest products industry

The forest products industry uses much of its by-products for process heat and electricity production. Black liquors remaining after chemical processing of wood to produce wood pulp are burnt to recover chemicals.

Black liquors can be produced and used only within the pulp industry, and provided over 33 TWh of energy (excluding electricity production) in 1998. Wood fuels in the form of raw materials residues are used in both the pulp industry and in sawmills. They consist mainly of wood chips, bark and other waste from the manufacturing processes. Use is also made, although to a lesser extent, of wood fuels produced by on-site forest chipping of wood unsuited for other commercial purposes.

In 1998, the pulp industry used a total of 6.8 TWh of such materials for energy production, while sawmills and other woodworking industries used 9.6 TWh.

District heating plants

A total of almost 26 TWh of indigenous fuels were used in the district heating sector in 1998. Of this, wood fuels accounted for 14.7 TWh, unrefined tall oil and black liquors for 1.6 TWh, refuse for 5.0 TWh, peat for 3.1 TWh and other fuels for 1.3 TWh.

The use of wood fuels by the district heating sector has more than quadrupled since 1990. In 1998, use rose by 1.0 TWh or 7 % relative to the previous year. The main form of the fuels is felling waste and forest by-products. However, processed fuels such as briquettes and pellets have also been increasingly used in recent years, as has tall oil (a residue from pulp production), with total use from these sources amounting to 3.7 TWh during the year.

Refuse has been used for district heating production since the 1970s, and now provides about 5.0 TWh. Improved sorting at source may reduce the potential quantity of domestic refuse available for use as fuel, although at present the supply of combustible waste exceeds capacity. There is potential within the industrial sector for increasing the use of (primarily) salvaged wood fuels, which at present are not used for energy production. Some fuels of this type, such as refuse, salvaged timber, worn-out vehicle tyres etc., have been imported in recent years, but the quantity is difficult to estimate.

The use of peat in 1998 amounted to 3.1 TWh, which is 0.1 TWh less than during the previous year. Production is dependent on the weather, and can therefore vary from →

Figure 8a • Use of biofuels, peat etc. in industry 1980-1998

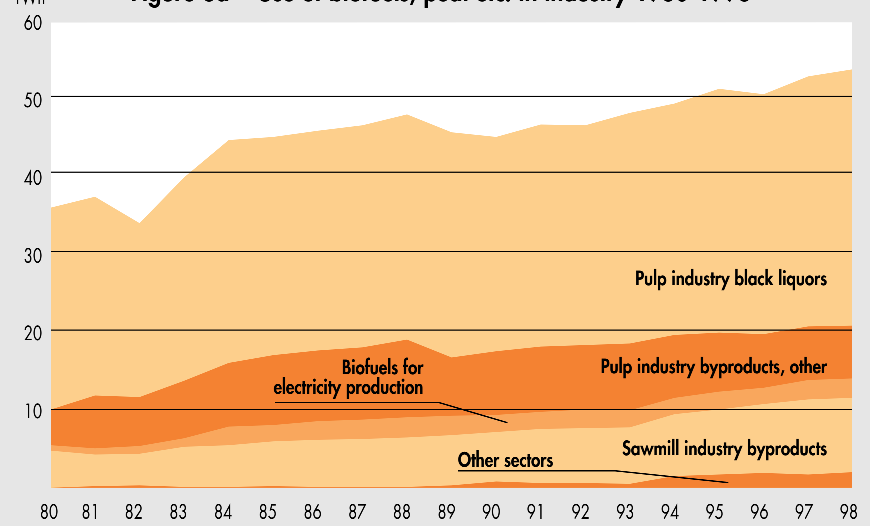
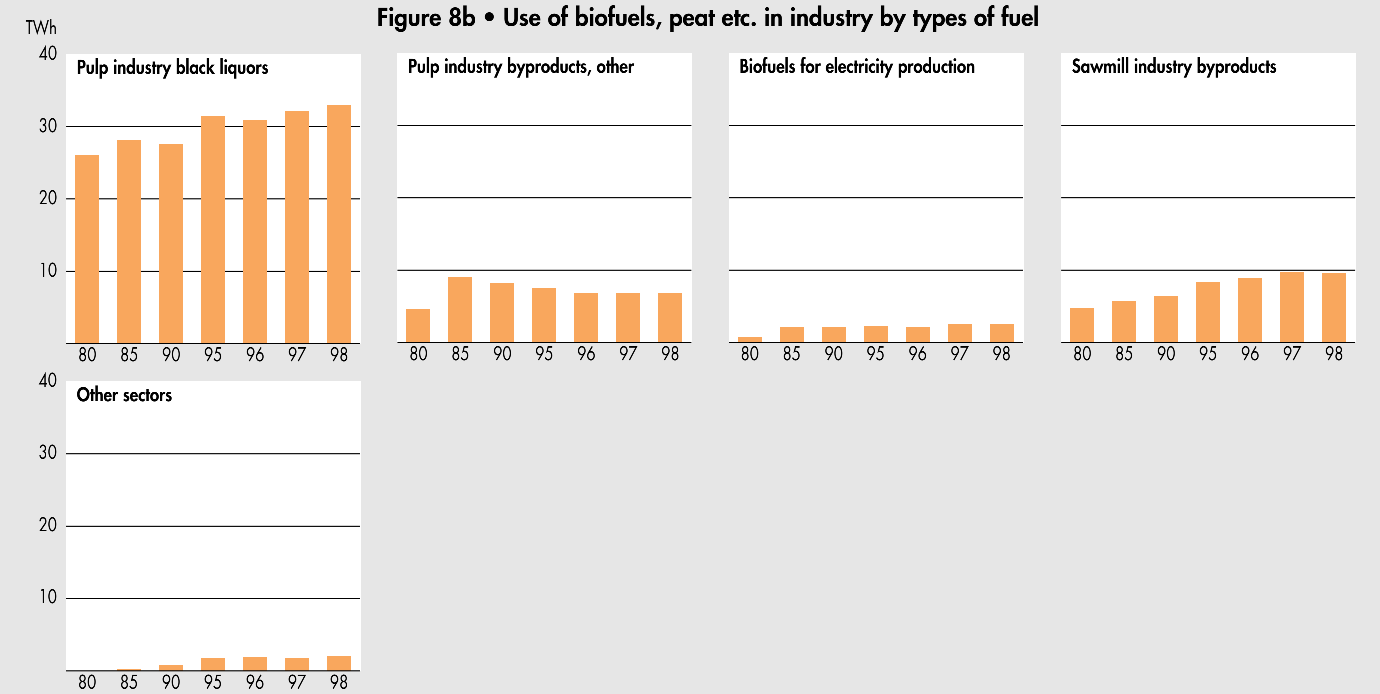


Figure 8b • Use of biofuels, peat etc. in industry by types of fuel



year to year. Production in 1998 amounted to 380 000 m^3, which was very much less than the average for the 1990s, and only about 11 % of that for 1997. During good years, stocks are built up for use in future years if less should be produced.

Relatively restricted use has been made of energy crops such as energy forests and energy grass since the beginning of the 1990s. The use of straw as a fuel is also marginal. About 0.10 TWh of energy forest fuels were used during the year, complemented by lesser quantities of straw and energy grass. There is considerable potential for greater use, but the area planted with such crops has decreased in recent years, covering only 14 500 hectare in 1998. The main reason for this decrease is that such land is being used for the cultivation of more profitable crops, such as cereals.

There has been a relatively extensive commercial importation of biofuels during the year, in the form of such as wood fuels, salvaged wood, tall oil, crushed olive stones and peat. Quantities are difficult to estimate, but have increased in recent years, and are estimated as amounting to about 7–9 TWh in 1998. Imports account for about 35–40 % of the supply of biofuels for district heating plants. They are imported at prices which are below those on the home market, which means that they exert a certain price press on indigenous biofuels. For some individual heating plants, imported fuels form a substantial part of their fuel supply. The potential of biofuels is considerable, both in terms of availability as a raw material and of their possible use in Sweden and in neighbouring countries, and so an increasingly important trade in biomass fuels could develop in the future.

The single-family house sector

About 11 TWh of wood fuels, mainly in the form of logs and chips, were used in single-family houses in 1998. Wood firing is commonest among property-owners with good access to forests, e.g. in agricultural or rural areas. The use of processed biofuels (pellets and briquettes) is relatively low in this sector, amounting to 0.5 TWh in 1998.

Electricity production

3.8 TWh of biofuels were used for electricity production. Of this, over 1 TWh was produced from wood fuels in combined heat and power plants supplying district heating. Of the remainder, 1.2 TWh were produced from wood fuels in industrial combined heat and power plant and 1.3 TWh from black liquors. The use of biofuels other than wood fuels and refuse for electricity production is marginal. ■

Figure 9a • Use of biofuels, peat etc. in district heating 1980-1998

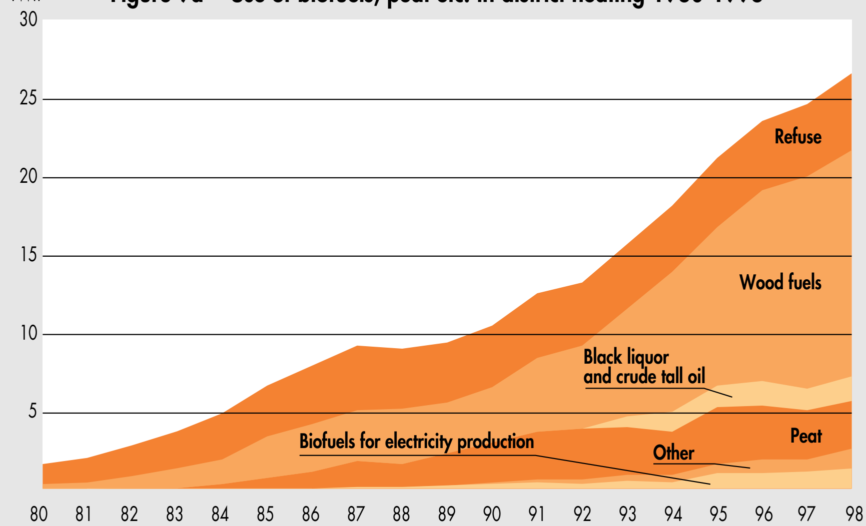
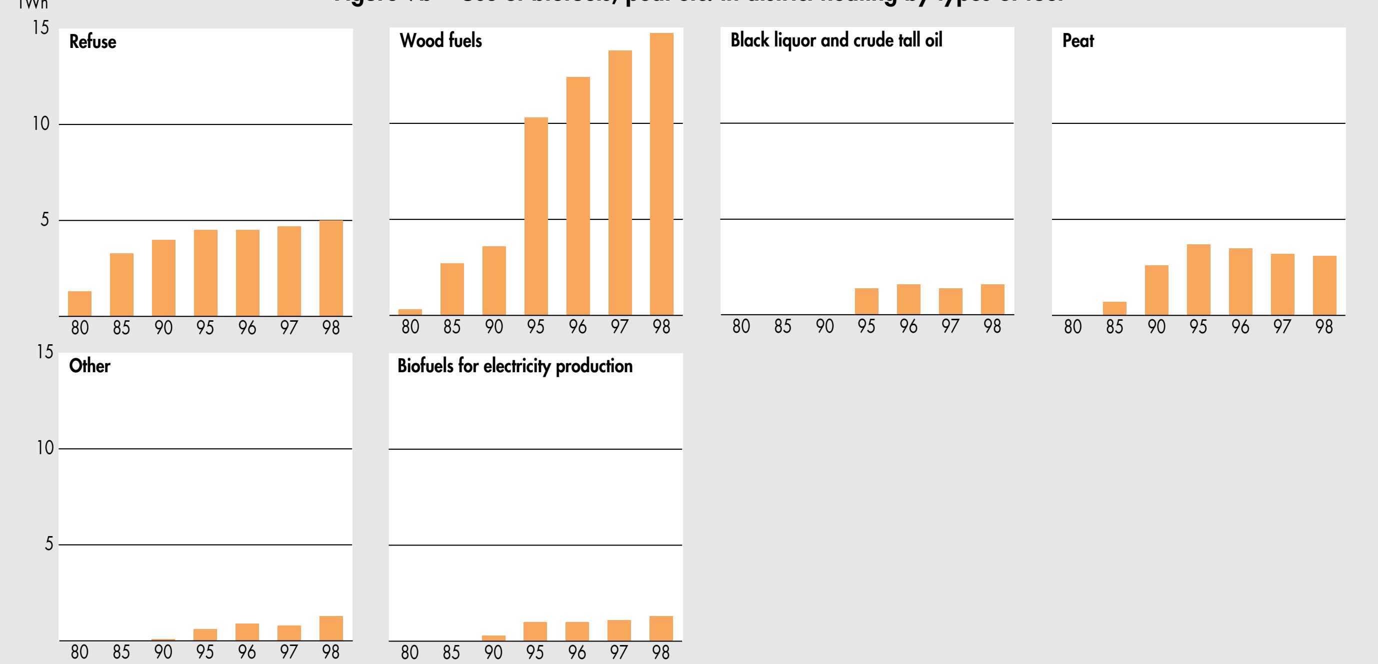


Figure 9b • Use of biofuels, peat etc. in district heating by types of fuel



District heating

District heating is often defined as a public heating system intended for supplying heat to most buildings under contractual arrangements between the supplier and the user. It is produced in and supplied from hot water boiler plants and combined heat and power stations, the latter producing heat and electricity simultaneously. Some of the district heating utilities also supply district cooling which, instead of delivering heat to buildings, removes it from them. There are also heating systems which supply heat to, for example, only a limited residential area, and these are known as group heating systems. They are generally smaller than district heating systems, although some group heating systems are very large.

It was in the 1940s that local authorities began to look at district heating. Its use spread during the 1950s and 1960s as a result of the excellent opportunities presented by the extensive investments in new housing and other buildings that were being made during that period. At the same time, there was also a substantial need for modernisation or replacement of boilers in the country's existing building stock. Group heating systems expanded and were gradually linked up into larger systems, with a particularly substantial expansion of district heating over the period from 1975 to 1985.

District heating is most competitive in areas of high building densities. High capital costs for the mains network mean that it is difficult for systems to be viable in lowdensity detached house areas, where the ratio of mains length to kWh of heat supplied increases.

Until the beginning of the 1980s, most district heating systems were operated as local authority services. However, during the 1980s and 1990s, most have been restructured as limited companies owned by local authorities. There were about 220 companies supplying heat in Sweden in 1998. Of them, 163 were members of the Swedish District Heating Association, an organisation that represents its members' interests. 68 % of the companies were owned by local authorities, 13 % were privately owned, 10 % were owned by the State and 9 % were operated as local authority services.

The nominal connected load in 1998 amounted to about 23.5 GW, supplied through about 10 700 km of mains. During the year, 44.1 TWh of heat were supplied, equivalent to 45.4 TWh after correction for statistically average climatic conditions. 61 % of the heat was supplied to residential users, almost 30 % to the service sector and almost 9 % to industry.

A total energy input of 50.4 TWh, made up of 37.7 TWh from fuels and 12.7 TWh from electric boilers, heat pumps and waste heat, was needed to supply this quantity of heat. In 1980, over 90 % of the fuel input for district heating and CHP plants was in the form of oil. Nowadays wood fuels, peat, refuse etc. are the main energy sources for district heating systems, accounting for 25.5 TWh, or over 50 %, of the total energy input in 1998. Other energy inputs included oil (5.5 TWh), heat pumps (7.4 TWh), coal and blast furnace gases (3.4 TWh), natural gas and LPG (3.3 TWh), waste heat (3.6 TWh) and electric boilers (1.8 TWh). Over 2 TWh of electricity were used to power the heat pumps, while a further 1.8 TWh were used in the plants for powering pumps, operating effluent treatment plants etc.

The change to other energy sources can be partly explained by changes in the taxation system applying to the energy sector, intended to reduce the use of fossil fuels. Another reason is the good availability of electricity for several years, favouring the use of heat pumps and interruptible electric boilers. For many years, electrical energy for use in these boilers was exempt from tax. However, after restructuring of the electricity industry in 1996, there are no longer any special contracts or regulations governing their use. Production from large heat pumps in district heating plants has been increasing slowly over the last few years, due to the fact that electricity prices have been at the same level as fuel prices for hot water boilers.

The high proportion of electricity as an input energy source for district heating systems has meant that losses have been reduced: conversion and distribution losses amounted to 6.3 TWh, or 13 % of the total quantity of district heat supplied. This can be compared with a value of about 20 % during the 1980s, when energy production was dominated by oil.

→

Figure 10a • Use of district heating 1970-1998

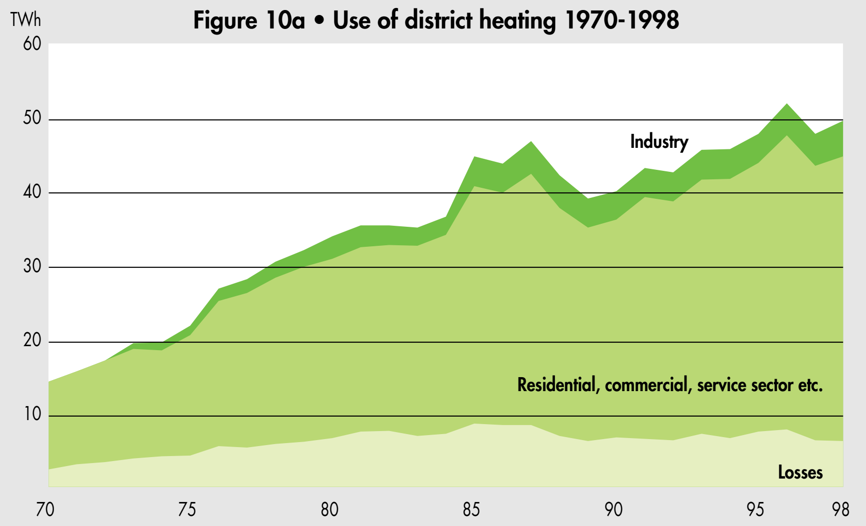
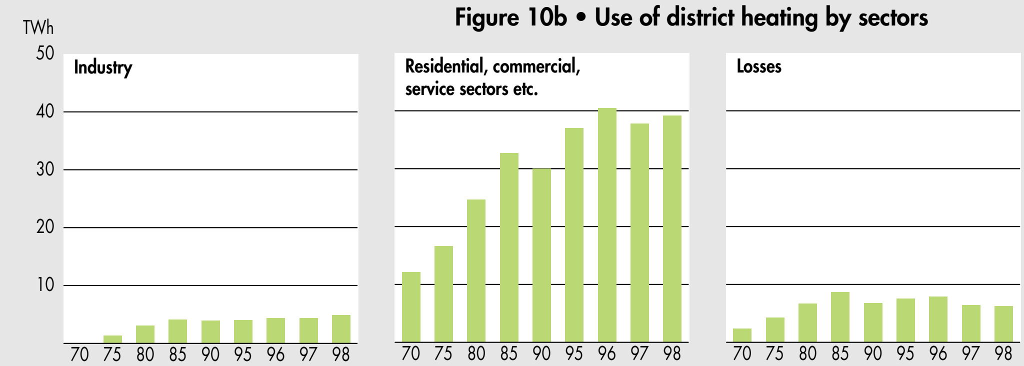


Figure 10b • Use of district heating by sectors



District cooling

District cooling may its appearance in Västerås in 1992, during which year about 1.2 GWh (0.001 TWh) of district cooling was supplied through about 1 km of mains. Stockholm Energi started to supply district cooling to central Stockholm in 1995, taking the cooling from sea water in Lilla Värtan or from the evaporators of its district heating heat pumps.

The principle of district cooling is similar to that of district heating: cold water is produced in a large central plant and distributed through pipes to customers. District cooling is used primarily by offices and shops, although also for the cooling of various industrial processes.

The market for district cooling has expanded strongly in the six years since its introduction, caused by such factors as new building regulations, the greater use of computers, more awareness of the importance of good working conditions, a relatively extensive expansion of the distribution system and the entry of new suppliers to the market.

In 1998, there were 16 producers of district cooling, supplying a nominal load of almost 207 MW through over 60 km of mains, and meeting a load of about 0.2 TWh (180 GWh). Demand is expected to continue to increase, in response to greater pressure for comfort cooling and the replacement of existing individual refrigeration/air conditioning plants by more environmentally sound alternatives. ■

Figure 11 • District cooling supplied 1992-1998

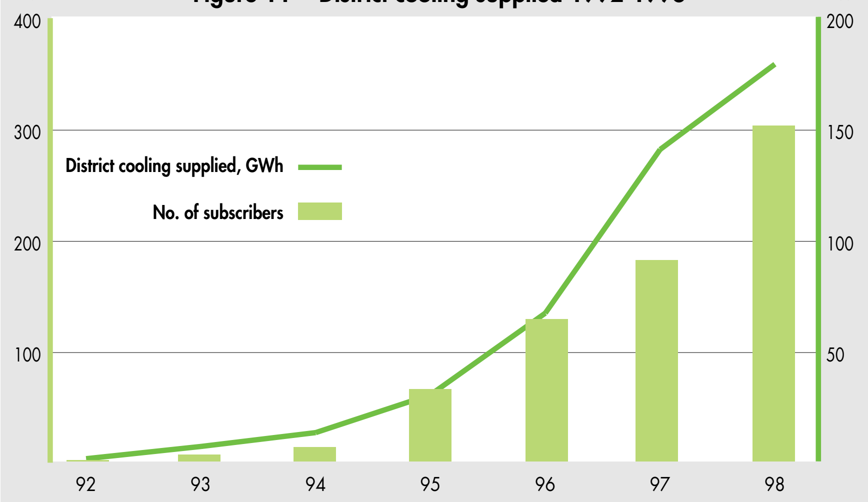


Figure 12a • Energy supplied to district heating 1970-1998

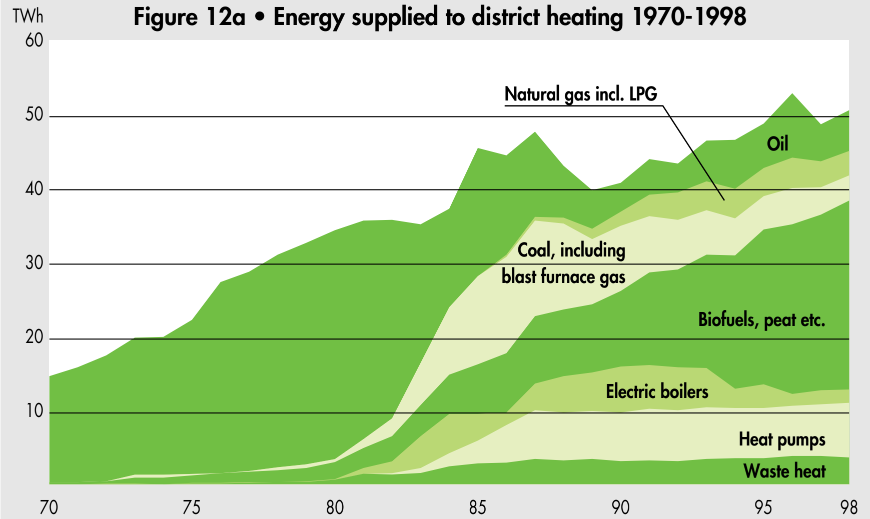
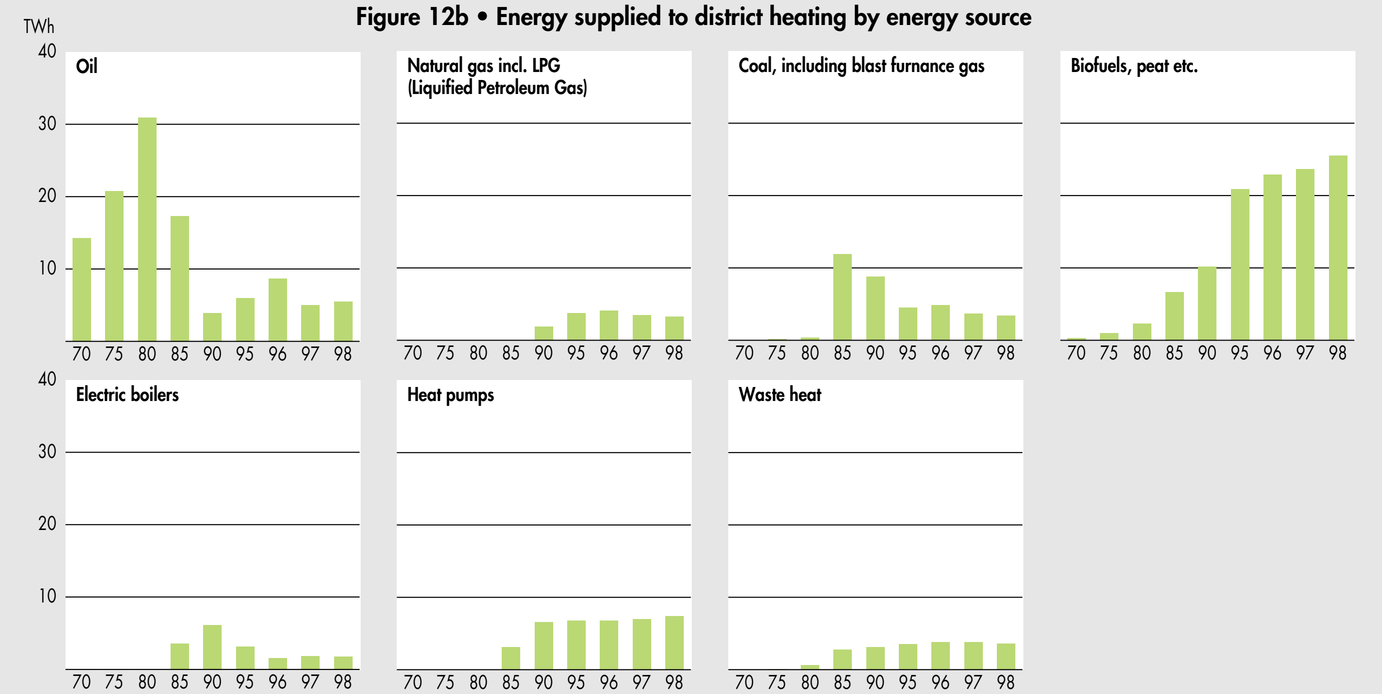


Figure 12b • Energy supplied to district heating by energy source



Sweden used almost 17 million m³ of oil in 1998, which represents a reduction of 47 % since 1970. Since the oil crises of the 1970s, it has been Swedish energy system policy to reduce the country's use of oil.

During 1998, the total import volume was at the same value as during 1997. 39 % of the total import volume of over 31 million m³ was imported from Norway.

About 60 % of the country's crude oil imports in 1998 came from the North Sea and 8 % from Saudi Arabia. Sweden has been a net exporter of refinery products since 1989: exports in 1998 amounted to over 3 million m³, primarily to Denmark, Germany and Poland.

The use of oil products in Sweden has declined rapidly, particularly since 1979. The main reduction is in the use of fuel oils: deliveries of fuel oils in 1998, for example, amounted to somewhat less than 7 million m³, which is a 67 % reduction since 1977. Fuel oils have largely been replaced by electricity and district heating for heating purposes, although the expansion of nuclear power production and the country's natural gas network have also played a part.

Sweden's entry into the European Union in 1995 has meant that Swedish foreign trade statistics with EU countries are now collected in a completely different manner than hitherto. The change also indirectly affects the collection of statistics with non-EU countries, and so data is not fully comparable with that for earlier years.

Starting in 1997, data has been supplied directly by the oil companies to Statistics Sweden, which means that foreign trade statistics are now more accurate than they were in 1995 and 1996. ■

Figure 13 • Swedish imports of crude oil and petroleum products, 1972-1998 by country of origin (million tonnes, net)

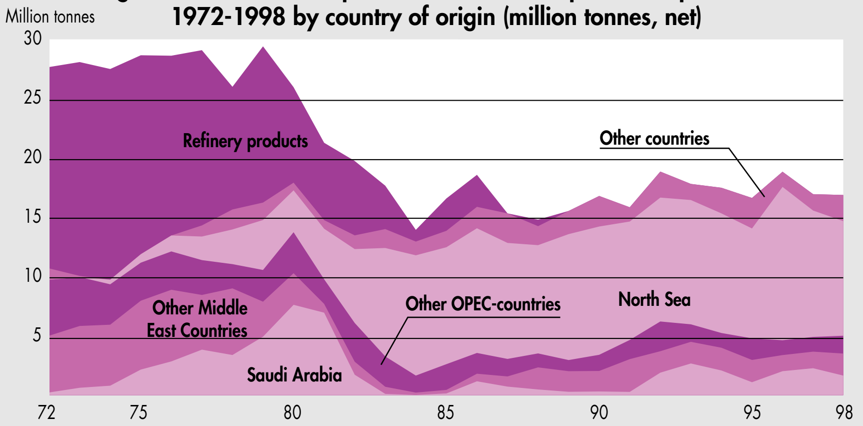


Figure 14a • Use of oil products 1970-1998

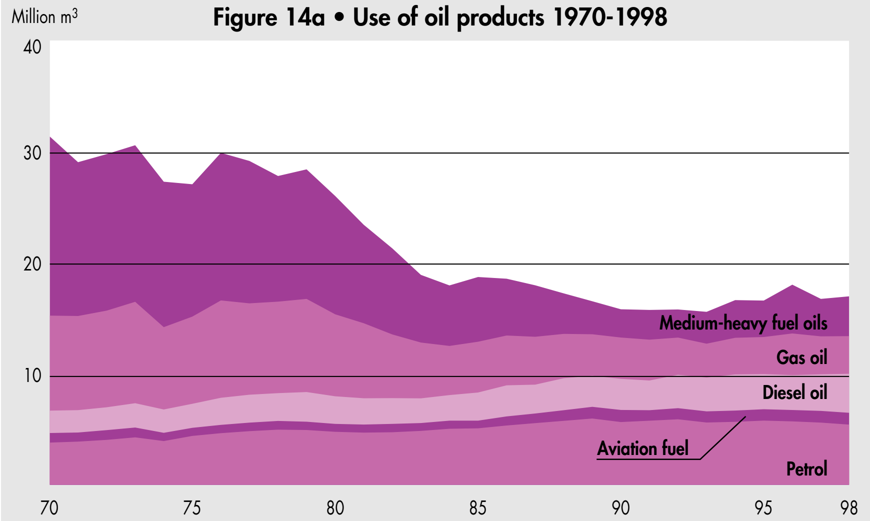
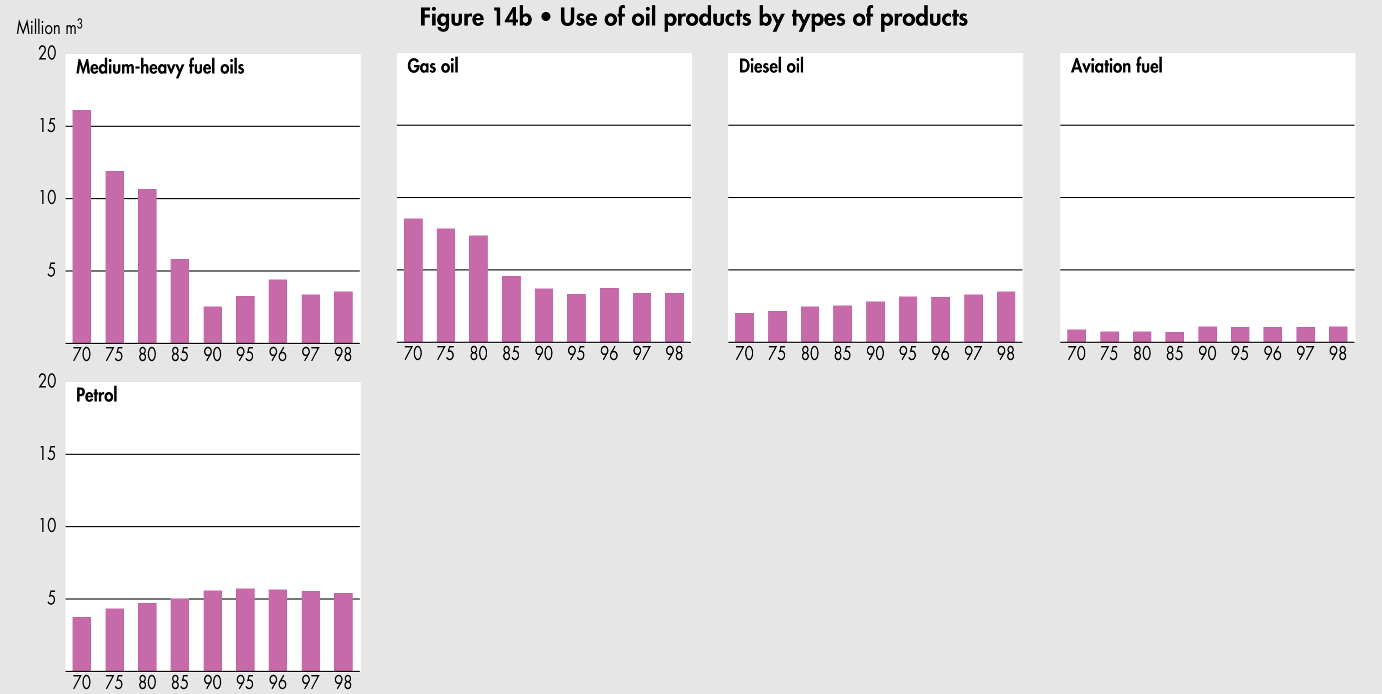


Figure 14b • Use of oil products by types of products



Coal played an important part in Sweden's energy supply up to the 1950s, when it lost ground to the cheaper and more easily handled oil. The troubled oil market during the 1970s contributed to coal again becoming an interesting alternative fuel for reasons of price and security of supply.

The relatively low oil prices of recent years, increasingly stringent environmental standards and rising taxation for heat production in particular have meant that the use of coal has stagnated. In 1987, about 1.9 million tonnes of coal were used for electricity and heat production, but by 1998 this had fallen to about 0.7 million tonnes. However, the structure of the tax system is such that coal is competitive with other fossil fuels for use in industry and for electricity production. Steady advances in combustion technology have matched increasingly stringent environmental requirements.

Swedish imports of coal for energy purposes during 1998 amounted to 1.2 million tonnes, which is a reduction of 25 % on the previous year. Imports came from seven different countries, with Poland, the USA and Australia each supplying over 25 %. Other countries from which Sweden imported coal were Russia, Venezuela, Canada and Estonia.

District heating and CHP production

About 50 % of the coal was used in the district heating sector. Coal is used for heat production in one local authority heating plant, and for combined heat and electricity production in a further eight plants, in which its main use is for electricity production. The plants that produced only heat used about 5 000 tonnes, which was a substantial decrease compared to the use of over 20 000 tonnes in 1997. In 1994, use had amounted to 118 000 tonnes.

Combined heat and power, CHP, stations used about 350 000 tonnes, or slightly less than during the previous year, for heat production. However, the use of 320 000 tonnes of coal for electricity production in these power stations was over 10 % less than during the previous year. The use of coal for electricity production is closely linked to hydro power production, which was higher than normal during 1998. During extremely dry years, such as 1996, the use of coal for electricity production more than doubles. The total energy input in the form of coal to the district heating and CHP sector for heat and electricity production in 1998 amounted to 5.1 TWh.

The use of coal in industry

Industry uses energy coal, coking coal, coke and smaller quantities of other coal products such as graphite and pitch. In 1998, industry's use of energy coal amounted to 720 000 tonnes, equivalent to 5.4 TWh, and representing a small increase over 1997. Industrial use of coal has declined in recent years, from 840 000 tonnes in 1991 to 720 000 tonnes in 1998, as a result of a switch to other fuels, mainly oil and biofuels, which is partly due to the carbon dioxide tax introduced in 1993. 1.7 million tonnes of coking coal were used, primarily for coke production. 1.45 million tonnes of coke were used, which was about the same as during the previous year. The total use of all forms of energy coal, coking coal and imported coke was 3.4 million tonnes, which was 0.1 million tonnes less than in 1997. ■

Figure 15a • Use of energy coal 1985-1998

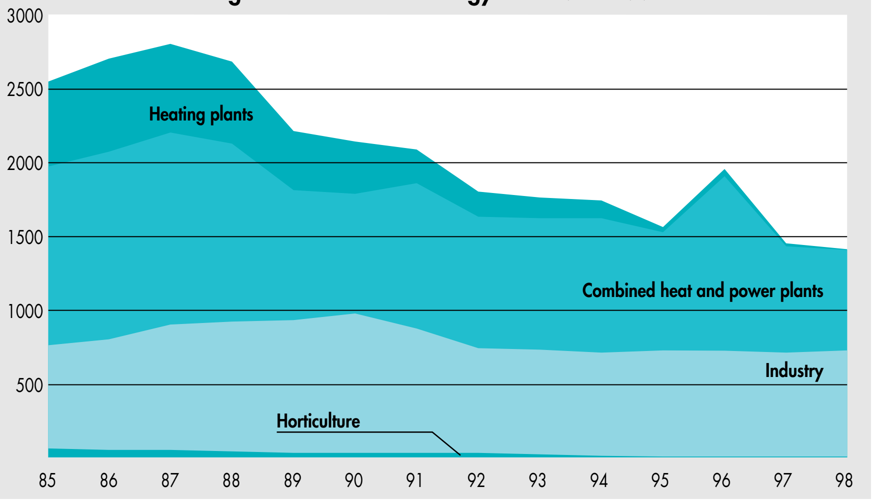
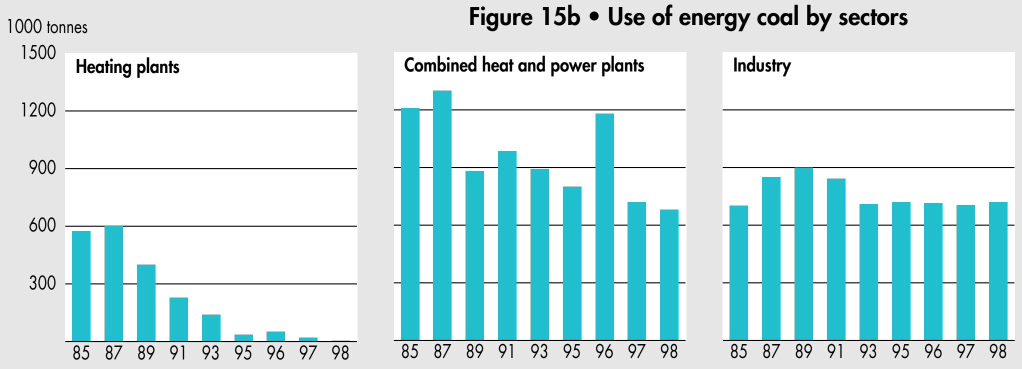


Figure 15b • Use of energy coal by sectors



Natural gas

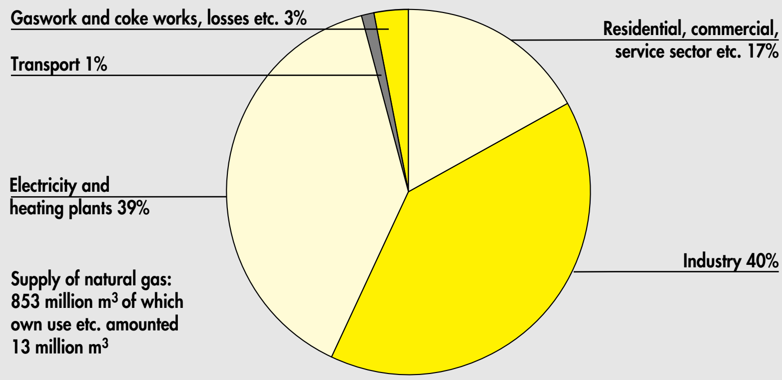
Sweden's interest in natural gas was awakened by the oil crises of the 1970s, and its use has gradually increased since its introduction to Sweden in 1985, stabilising at the present level. Interest in natural gas has reawakened as an alternative, primarily to oil and coal, as a result of the restructuring of the Swedish energy system.

The gas comes from the Tyra field in the Danish sector of the North Sea. After transiting Denmark, a pipeline under Öresund brings the gas ashore at Klagshamn outside Malmö. A 300 km trunk main extends from Trelleborg in the south to Gothenburg. Vattenfall Naturgas AB is responsible for operation of the trunk main and for importation of the gas to southern and western Sweden. Sydgas AB is responsible for the distribution system in southern Sweden. Today, natural gas meets about 20–25 % of energy requirements in most of the areas to which it is supplied, or about 2 % of the country's total energy supply.

Imports of natural gas in 1998 amounted to 853 million m^3, equivalent to about 8.3 TWh[1], a decrease of less than 1 % from the previous year. It is supplied to about 25 towns and 55 000 consumers, made up of a large number of industries and heating plants and about 8–10 000 private customers. A small amount of gas is also used as a motor fuel and for heating greenhouses. Gas has primarily replaced oil in industry and CHP plants, which accounted for 40 % and 39 % of Swedish gas consumption respectively in 1998.

Natural gas is a combustible mixture of gaseous hydrocarbons, consisting mainly of methane, and – unlike coal and oil – is almost completely free of sulphur and heavy metals. Combustion also produces no solid residues such as ash or soot. As the gas contains hydrogen as well as carbon, the quantity of carbon dioxide produced by combustion is 25 % less than that produced by release of the same amount of thermal energy from oil, or 40 % less than from corresponding combustion of coal.

Figure 16 • Supply and use of natural gas by sectors in Sweden 1998



LPG

Imports of LPG to Sweden in 1998 amounted to 759 000 tonnes, while 205 000 tonnes were exported. 628 000 tonnes were supplied to the Swedish energy system, equivalent to 8.1 TWh, representing an increase of 6 % relative to the previous year. It is used mainly in industry, as well as in the restaurant trade and for CHP and heat production, which means that much of its use is interchangeable with that of oil and, to some extent, with that of biofuels. This means that it is therefore sensitive to changes in energy taxation or fuel prices. Nevertheless, for certain industrial processes, such as where cleanliness of the fuel and/or accurate temperature control are important, LPG has qualitative advantages over many other industrial fuels. During 1998, 5.0 TWh were used in industry and 0.6 TWh in district heating.

LPG is a petroleum product consisting of propane, propene, butane or mixtures thereof. It is usually stored in liquid form in rock caverns at low temperatures. Distribution is by rail tank car, road tanker or by direct pipelines. Its environmental characteristics are very similar to those of natural gas, with a very low sulphur content and a complete absence of heavy metals.

Biogas

Biogas consists of methane, formed by the breakdown of organic materials such as sewage sludge, refuse or industrial waste, under anaerobic (oxygen-free) conditions. The process, known as digestion, occurs spontaneously in nature, e.g. in marshes. Today, Sweden has about 100 biogas plants in operation, most of them in sewage treatment plants and landfill sites, producing digester gas and landfill gas respectively. Most biogas is used either for local or district heating, or for electricity production. In 1997, 58 GWh were used for electricity production and 452 GWh for heat production. Biogas can also be cleaned and distributed via the natural gas network as 'green natural gas'. It is also used for powering vehicles: interest in the gas for this application has increased in recent years. Biogas is used primarily in local bus fleets and for urban distribution vehicles. Total production of biogas in 1998 is estimated as about 1.5 TWh.

Town gas

Town gas is produced by cracking naphtha. SE Gas AB in Stockholm is nowadays the only producer of such gas in the country: the town gas used in Malmö and Gothenburg nowadays consists of natural gas mixed with a small proportion of air. Town gas is used for heating detached houses, larger properties and industries, as well as for cooking in restaurants and catering establishments. 0.5 TWh of town gas were used in 1998.

Hydrogen

Pure hydrogen does not occur naturally, but must be produced from sources such as methanol, LPG, natural gas or by electrolysis of water. Production of hydrogen is an energy-intensive process: to produce hydrogen with an energy content equivalent to 100 kWh requires about 125 kWh of electricity. The remainder is converted to heat. Research is in progress, with the aim of improving production technology and of developing effective means of storage. When hydrogen technology has been sufficiently developed, it will be possible to use the existing natural gas network for transportation of hydrogen. Hydrogen can also be used as a fuel in fuel cells, where it is converted to electrical energy and heat.

Today, hydrogen is used as a fuel at sites where it is also produced as part of an industrial process. In 1998, Sweden produced 133 000 tonnes of hydrogen, which were used internally by their respective industries. AkzoNobel operates four of the five largest industrial plants that produce surplus hydrogen. The gas is used internally to produce hydrogen peroxide, which is used for bleaching. ■

[1] In accordance with international practice, Statistics Sweden has used a revised value for the effective calorific value of natural gas, of 9.72 MWh/1000 m^3 instead of 10.8 MWh/1000 m^3, since the fourth quarter of 1998.

In 1998, energy use in this section amounted to 155.7 TWh, or over 40 % of the country's total final energy use. This value is 0.2 TWh higher than that of the previous year.

About 86–87 % of the energy use in this sector is used in space heating, domestic hot water production and the powering of domestic appliances. Energy used in land use applications accounts for about 5 % of total energy use in the sector, while holiday homes account for another 2 % and other service applications for 6–7 % of total energy use. These latter consist of energy use in the building sector, street lighting, waterworks and sewage treatment plants.

Over 60 % of the energy use in the sector is accounted for by space heating and domestic hot water production. This is affected by temperature conditions, which means that there can be considerable random variations in energy demand from one year to another. To enable proper comparisons to be made, it is necessary to correct for climatic conditions. 1998 was 5 % warmer than a statistically average year, which meant that the amount of energy used for space heating was lower than normal. After applying such correction, energy use in the sector in 1998 amounted to 159.2 TWh, representing a slight increase of 0.7 % relative to the figure for 1997.

Figures 17a and 17b show a breakdown of energy use in the sector, classified by types of energy carrier. It can be seen that the temperature-corrected value of total energy use has remained relatively constant from 1970 to 1998, although the relative proportions between the different energy carriers have changed. Oil crises, rising energy process, changes in energy taxation and investment programmes have all affected the move from oil to other energy carriers. Total use of fossil fuels in the sector in 1998 amounted to 35 TWh, as opposed to 113 TWh in 1970. Much of this reduction is due to a move from the use of oil for heating to electricity and district heating.

The number of dwelling units (single-family houses and apartment buildings) in the country has increased by about 30 % from 1970 to 1998. The rate of new building during the 1990s has been very low, amounting on average to 14 300 dwelling units per year. This can partly explain why energy use in the sector has not increased in recent years. The floor areas of commercial premises have increased substantially since 1970, thus accompanied by an associated demand for heating, domestic hot water and electricity for building services systems.

Figures 18a and 18b show the growth of temperature-corrected electricity use, classified by electric heating, domestic electricity and electricity for building services systems. Use of electricity has grown uninterruptedly from 1970 until the middle of the 1990s. In recent years, this electricity use has amounted to over 70 TWh.

Factors that offset greater use of energy

Several factors have helped to offset increased energy use in the sector. On the heating front, there has been a shift from oil to other energy carriers. In detached houses, the change has been mainly to the use of electric heating, while in apartment buildings it has been to district heating. Both these changes have resulted in a reduction in energy use by the end-users through reduced conversion losses.

Different energy carriers exhibit differences in distribution and conversion losses in the process of final conversion to heat at the consumers' premises, which can be expressed in the form of mean annual efficiencies. The mean annual efficiences indicate how great a proportion of the theoretical energy content of the energy carrier is actually utilised by the consumer in the form of thermal energy. These efficiencies allow for the aggregated effects of the combustion efficiency of the heating system, heat losses, distribution losses and shortcomings in control and adjustment of the heating system. The mean annual efficiencies of electric heating and district heating are assumed to be, on average, higher than the value for oil, which means that replacing oil by electric heating or district heating results in a reduction in final energy use.

The number of small heat pumps in use has increased considerably in recent years, contributing to a reduction in the actual use of energy for space heating and domestic hot water production. Heat pumps abstract heat from rock, earth, air or water and supply it to the building's heating system. Heat pumps can supply 80–90 % of the annual space heating and domestic hot water requirements. Heat pumps normally supply 2–3 times as much thermal energy as is used in the form of electrical energy for running the pumps and generated 3 TWh of heat in 1997.

Other factors that have helped to prevent an increase in energy use for space heating and domestic hot water production in residen-

Figure 17a • Final energy use within the residential, commercial, service sector etc. 1970-1998

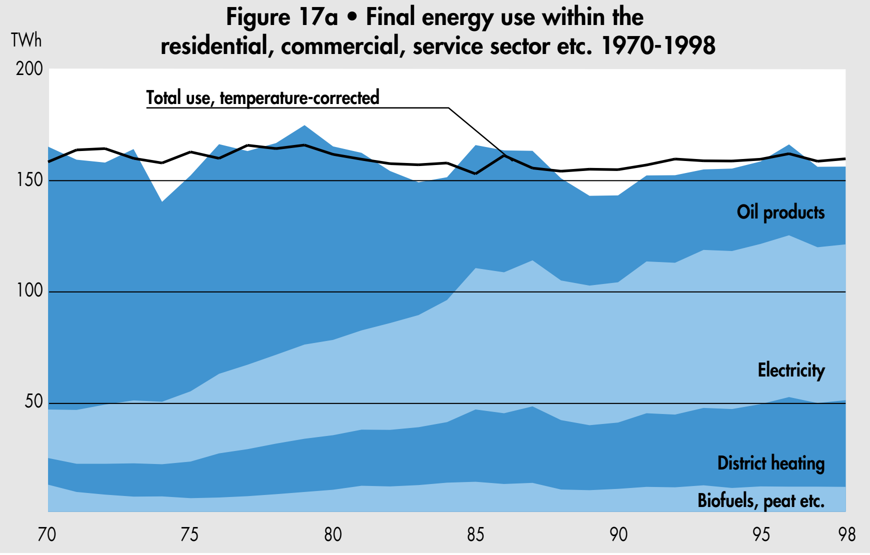
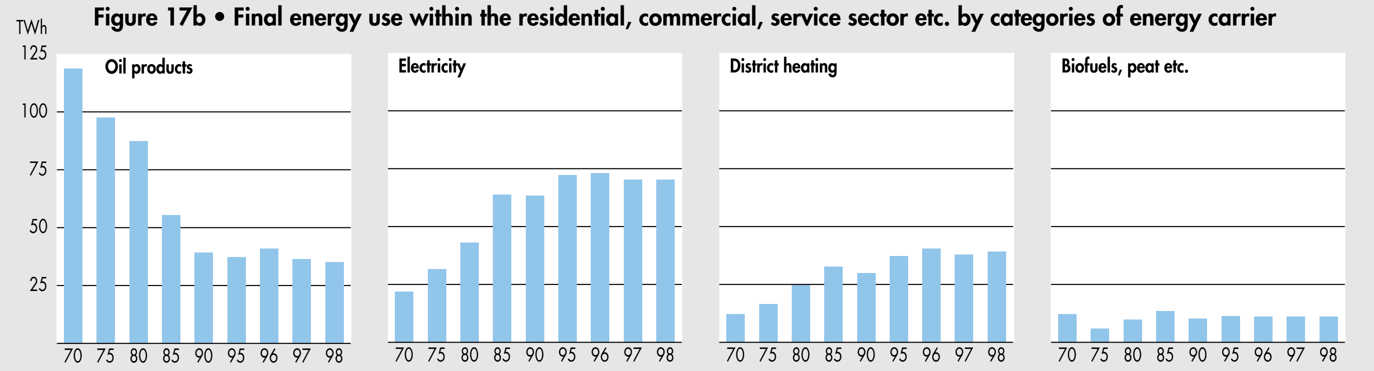


Figure 17b • Final energy use within the residential, commercial, service sector etc. by categories of energy carrier



tial buildings and commercial premises are various types of energy conservation measures, such as retrofitting additional thermal insulation and upgrading of windows in older buildings.

The rate of increase of use of electricity for domestic purposes and operation of building services systems has been limited through greater use of equipment with higher energy efficiencies.

Heating

Of the 98 TWh that were used for space heating and domestic hot water production in 1997, it is estimated that about 46 % were used in detached houses, 29 % in apartment buildings and 25 % in commercial premises.

The most common form of heating in detached houses is electric heating, being the main heating source in about 40 % of such dwellings. Approximately 26 % of detached houses have direct-acting electric heating, with the remaining 14 % having waterborne electric heating. The reason for this high proportion of electric heating is that it is cheap to install and simple to run. Figure 18 clearly shows how the use of electric heating has increased substantially in this sector from 1970 to 1990, with the increase being greatest up to the first half of the 1980s.

Another common heating system in detached houses is electricity in combination with wood and/or oil firing. The proportion of detached houses with such systems has grown constantly, so that almost 30 % of detached houses had such heating systems as their main heat source in 1997.

In 1997, the total use of electricity in detached houses for heating purposes amounted to 19 TWh. In detached houses with electric heating in combination with some other energy carrier, the electric heating can easily be replaced by the other energy carrier. This means that such house heating systems are relatively flexible, with the use of electricity being determined by the relative prices of the various energy carriers. Other households, not having this ability quickly to change their energy carriers, are more vulnerable to changes in the relative prices. About 8 % of detached houses are heated by oil alone, while 7 % have district heating and 4 % are heated by wood.

District heating is the commonest form of heating in apartment buildings, with approximately 73 % of apartments being supplied by it, equivalent to a use of almost 21 TWh of district heating. Oil is used as the sole or main heat source for 14 % of apartments, equivalent to 5 TWh of oil. The use of electric heating in apartment buildings is relatively low, amounting to 2 TWh in 1997.

The main source of heat in commercial premises, too, is district heating, with almost 56 % of them being supplied, equivalent to almost 14 TWh of district heating. Electric heating of commercial premises accounted for 5 TWh, which was also the amount of space heating and domestic hot water product energy supplied by oil.

Domestic electricity

The use of electricity for domestic purposes more than doubled between 1970 and 1998, from 9.2 TWh to 19.1 TWh, due to an increase in the number of households and greater ownership of domestic appliances. However, continued improvement in the efficiency of such appliances in terms of their electricity use of has tended to offset this increase, as old, worn-out appliances are replaced by new, more efficient ones. In particular, new white goods use less electricity than did old ones. The proportion of total temperature-corrected electricity use accounted for by domestic electricity amounted to over 27 % in 1998.

Building services systems

The use of electricity for building services systems has increased substantially since the 1970s, from 8.2 TWh to 24.2 TWh in 1998. The reasons for this increase include rapid growth in the service sector and greater use of office machines. The high growth rate of private and public services has also resulted in a relatively substantial increase in the total floor area of office premises. Lighting and ventilation, which at the beginning of the 1990s accounted for about 70 % of the use of electricity for building services systems, have become more efficient as a result of new and improved light sources, more sophisticated operational control and correct sizing of systems at the time of installation. Nevertheless, the potential for further improvements in the efficiency of electricity use in commercial premises is still regarded as considerable. Although companies constantly replace equipment, which becomes steadily more efficient, there is also a trend towards greater numbers and increased power of items. ■

Figure 18a • Electricity use in the residential, commercial, service sector etc. 1970-1998, temperatur-corrected

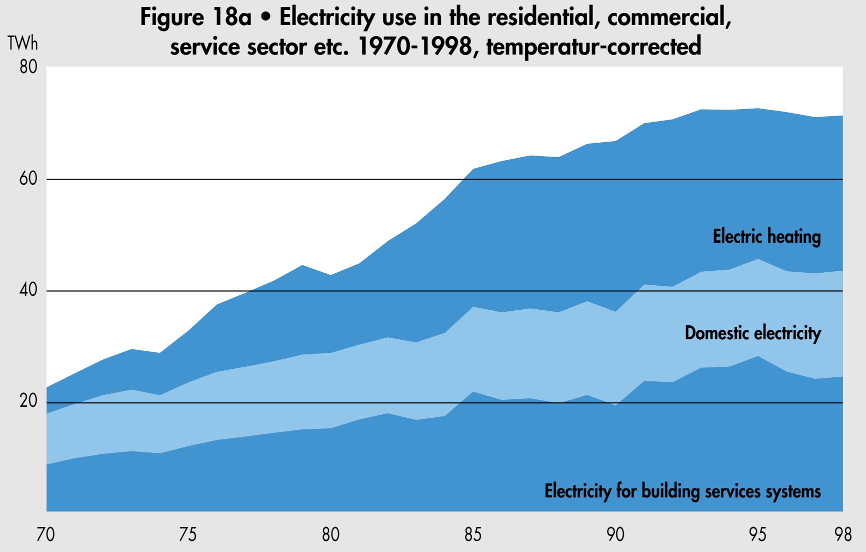
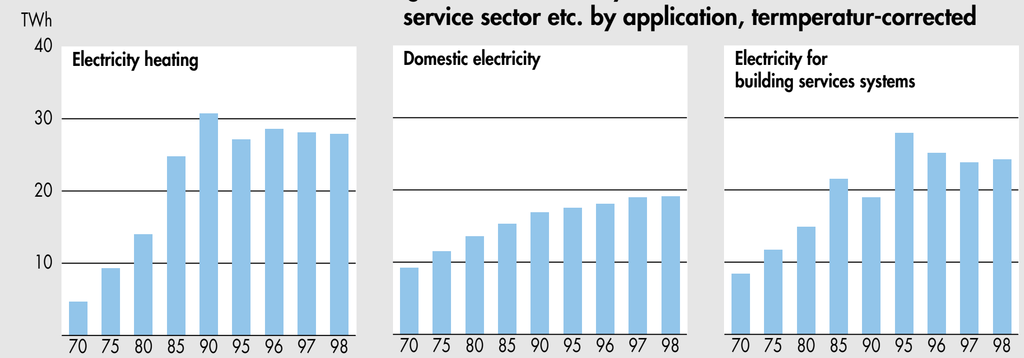


Figure 18b • Electricity use in the residential, commercial, service sector etc. by application, termperatur-corrected



In 1998, industry's use of energy increased by 0.3 TWh over the previous year, amounting to 150.4 TWh, equivalent to 38 % of the country's final energy use.

Classified by energy source/carrier, this consisted of 21.2 TWh of oil products, 15.6 TWh of coal and coke and 53.7 TWh of electricity. Supplies of natural gas amounted to 3.7 TWh, and those of district heating to 4.9 TWh. The use of biomass fuels, peat etc., amounted to 51.3 TWh, of which over 40 TWh were in the pulp industry, mainly in the form of black liquors, manufacturing waste etc. Black liquors, which are a by-product of chemical pulp manufacture, are burned to recover process chemicals and release energy. Final energy use in industry during the year therefore consisted of 27 % fossil energy and 34 % biomass fuels, peat etc., with the rest being in the form of electricity and district heating.

In Sweden, a relatively small number of sectors accounts for the bulk of energy use. The pulp and paper industry uses about 45 %, the iron and steel industry about 14 % and the chemical industry 7 %. Together, these three energy-intensive sectors account for two-thirds of total energy use in industry. The mechanical engineering industry, although not regarded as energy-intensive, nevertheless accounts for almost 8 % of energy use in industry as a result of its high proportion of total industrial output in Sweden.

The relationship between output and energy use

Energy use in industry essentially follows the variations in industrial output. In the short term, it is output volume that determines industry's use of energy: in the longer term, total energy use is also affected by changes in the types of goods produced, technical developments, taxes and energy prices.

Between 1990 and 1992, industrial output fell by 6 %, accompanied by a fall of 5 % in energy use. Electricity use in the sector also fell, but by 6 %, i.e. by more than the fall in total energy use, as the recession tended to hit the electricity-intensive sectors harder.

1993, however, was marked by some recovery in industrial output, and was followed by a substantial rise in 1994 and 1995. Output volume in 1998 increased by over 43 % relative to 1992, while energy use by almost 12 %. During the same period, the use of electricity increased by almost 4 TWh, or over 8 %.

Changes in oil and electricity use

Over a longer time perspective there has been a clear redistribution between the use of different forms of energy, particularly in respect of a move from oil to electricity, as shown in Figures 19a and 19b. Despite rising industrial output, the use of oil has fallen substantially since 1970, resulting from the greater use of

Figure 19a • Final energy use in industry 1970-1998

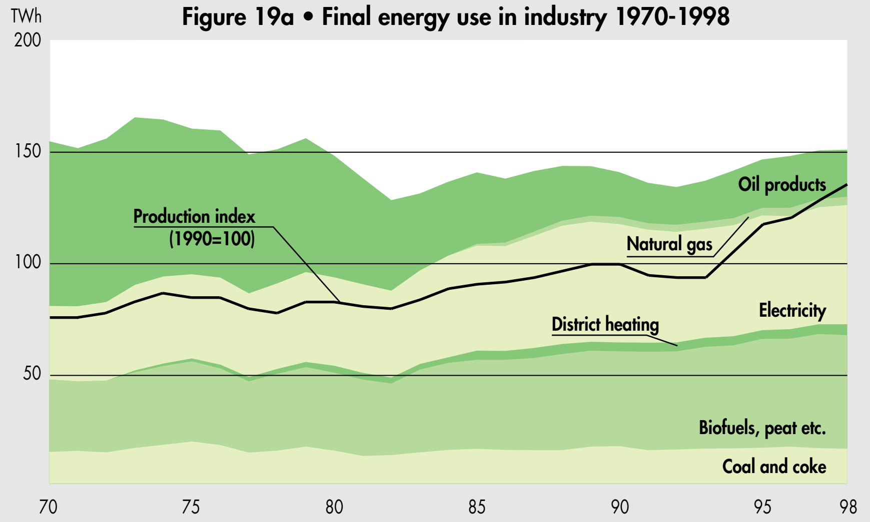
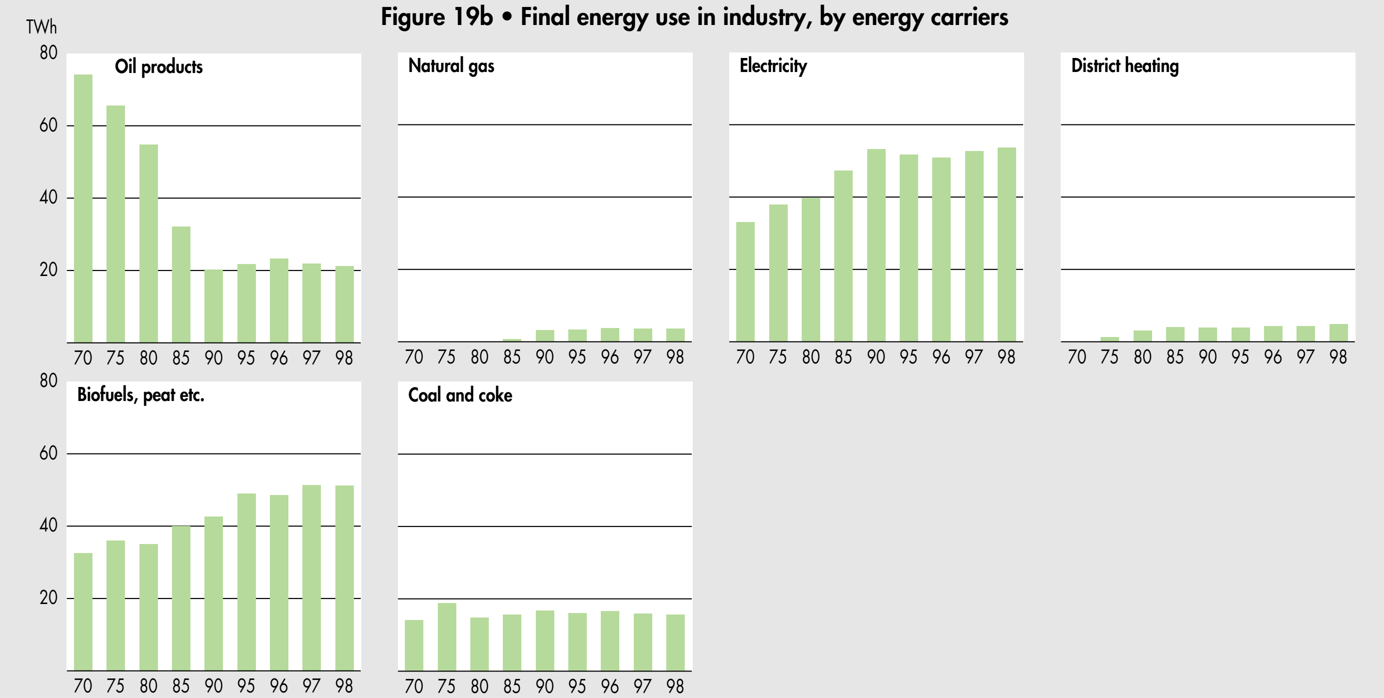


Figure 19b • Final energy use in industry, by energy carriers



electricity and improvements in the efficiency of energy use. This trend started in connection with the oil crises of the 1970s, resulting in intensive work by both State and business aimed at reducing the use of oil. In 1970, electricity use constituted only 21 % of industry's total energy use, which can be compared with the present proportion of 36 %. At the same time, the use of oil has fallen from 48 % to 14 % in terms of industry's energy use. Between 1970 and 1998, the proportion of biofuels, peat etc., has increased from somewhat over 21 % to 34 % of total energy use in the sector. This change from oil to electricity and other fuels has meant that energy use in the sector has fallen, partly because electrical energy often has a considerably higher efficiency than oil for the majority of applications, and partly because the conversion losses associated with electricity production, that were previously booked to the industrial sector, are now booked to the electricity production sector.

Between 1992 and 1998, the use of oil products has increased by 4 TWh, or 22 %. Several factors have contributed to this increase: higher output, lower energy and carbon dioxide taxes and greater use of oil as a replacement for interruptible electric boilers.

Changes in specific energy use

Comparison of energy use in industry with the value of output provides an indicator of the efficiency of energy use and of changes in sector structure and production processes. Energy input per SEK of output value, i.e. specific energy use, has fallen continuously since 1970. Between 1970 and 1998, there was a reduction of 42 %, which shows a clear trend towards less energy intensive products and production processes, together with changes in the types of industries and products. During this period, industrial output has increased by 79 %.

The change from oil to other energy carriers, particularly electricity, is reflected in specific use of oil and of electricity per unit of output value. Specific use of oil fell by 80 % between 1970 and 1992, while specific use of electricity increased by 27 %.

The recent upturn in the economy, coupled with changes in industry's energy taxation structure, is reflected in changes in specific energy use, which continues to fall. Between 1992 and 1998 it fell by 22 %. During the same period, the specific use of oil fell by 15 %, while specific use of electricity fell by 25 %. This recent substantial fall in specific electricity use has been the result primarily of a major increase in mechanical engineering industry output, coupled with almost unchanged electricity use. ■

Figure 20a • Specific use of oil in industry 1970-1998, 1991 price levels

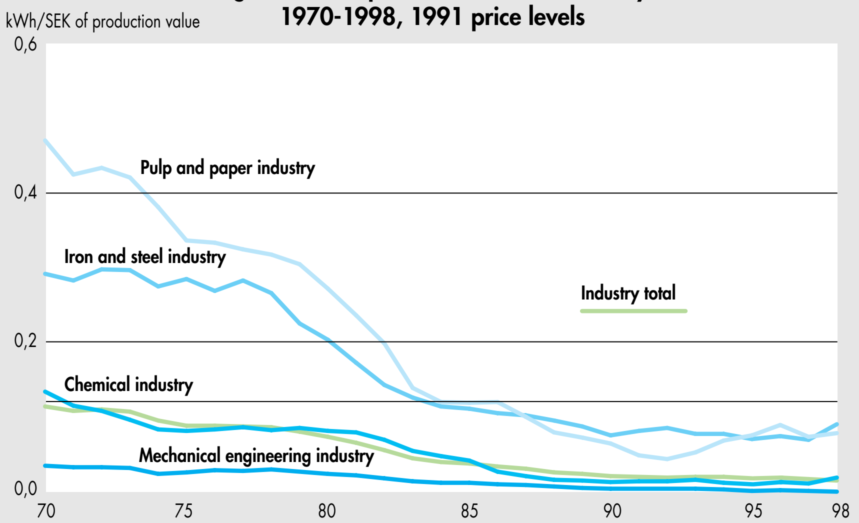


Figure 20b • Specific use of electricity in industry 1970-1998, 1991 price levels

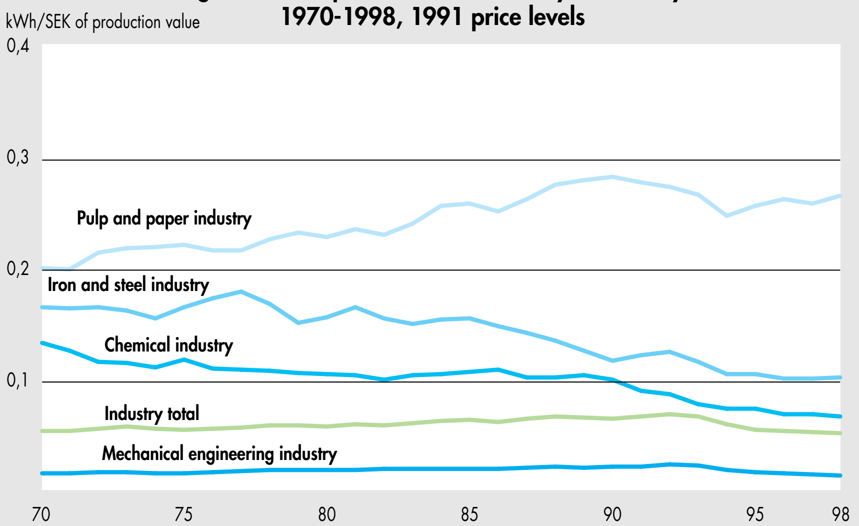
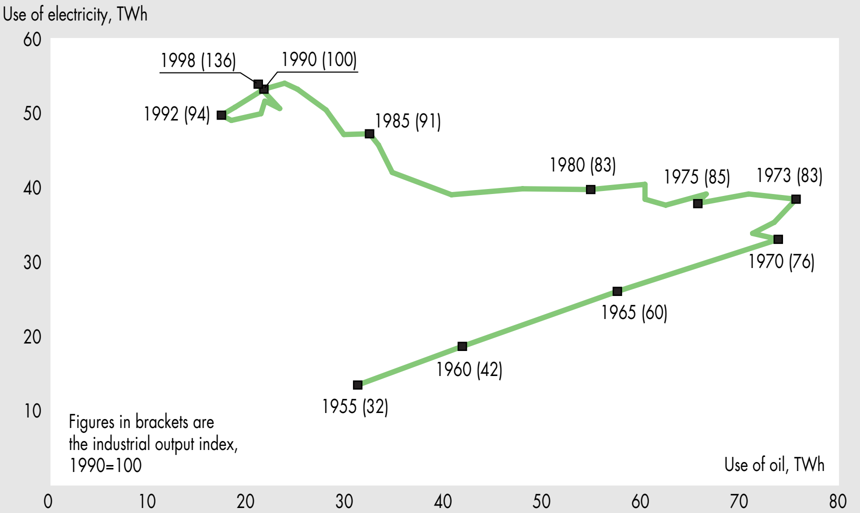


Figure 21 • Use of oil and electricity in industry 1955-1998



Energy use for domestic (internal) transport in 1998 amounted to 88.7 TWh, or over 22 % of the country's total final domestic energy use. Foreign maritime transport used 18.6 TWh of bunker oils.

Energy use in the transport sector is almost entirely in the form of oil products, primarily as petrol and diesel fuel. In 1998, the country used 47 TWh of petrol and 28 TWh of diesel fuel, together making up 70 % of total energy use in the transport sector.

After the very substantial increase in the use of energy for internal transport at the end of the 1980s, a drop of 4 % occurred in 1990. Between 1990 and 1994, energy use in the domestic transport sector varied widely. During 1994, domestic demand increased and business began to expand again, resulting in an increase in energy use of almost 3 % in the transport sector. This trend continued in 1995, with a further increase of 1 %, and remained unchanged in 1996. Domestic energy use increased by almost 2 % in 1998, while foreign maritime transport increased its energy demand by 20 % relative to 1997.

The consumption of petrol fell by 2.1 % from 1997 to 1998, from 48.6 TWh to 47.3 TWh, which was due partly to a reduction in average fuel consumption and to an increase in the proportion of diesel cars.

Traffic and the environment

The use of oil products in the transport sector increased during the 1970s and 1980s as a result of increased traffic. The number of passengerkilometres travelled rose by 54 % between 1970 and 1997. Private cars provide 77 % of passenger transport. Expressed as tonne-kilometres, internal freight transport increased by 52 % between 1970 and 1997, with 55 % being by road, 31 % by rail and 14 % by water. Internal freight transport by road declined by over 1 % during 1998, while freight transport by Swedish trucks in other countries increased by 9 %. Passenger transport by rail increased during the year, although goods transport by rail fell during the same period.

The environmental effect of traffic and its use of oil could be reduced if various measures were introduced, such as stricter emission controls, higher fuel prices, environmental levies, the introduction of alternative fuels and integration of the built environment and infrastructural planning. Over the last few years, the introduction of catalysers has substantially reduced the emission of several hazardous substances. However, carbon dioxide emissions cannot be reduced in this way, which means that they have continued to increase in step with greater use of fossil fuels.

The European automotive industry (ACEA) has entered into a voluntary agreement with the EU Commission to reduce carbon dioxide emissions from new passenger cars by 25 % by 2008, relative to the 1995 level. In addition, the EU has decided to introduce cleaner petrol and diesel fuels, which will be done in two stages, in 2000 and 2005. During 1998, the EU Commission presented a strategy document concerning the introduction of equitable traffic charges throughout the Union.

Alternative motor fuels

Motor alcohols, natural gas, biogases, vegetable oils, hydrogen and various types of electric vehicles offer alternatives to the use of conventional fuels, and generally have less harmful environmental effects. Today, about 300 buses are running on ethanol, with the largest fleet being in Stockholm. About 200 buses and 300 passenger cars are running on natural gas, mainly along the west coast, i.e. where natural gas is available. About another 100 buses and 350 passenger cars are running on biogas, mainly in Linköping, Uppsala and Trollhättan. In addition, there are about a score of mixed fuel buses and 300 Flexible Fuel Vehicles in use elsewhere, complementing almost 800 electric vehicles, made up of over 400 cars, about 350 commercial vehicles and 16 buses.

The costs of producing most of these alternative fuels are at present considerably higher than the costs of supplying equivalent quantities of petrol or diesel fuel. However, this cost differential may fall as the technology is developed and as environmental levies are applied. There are many research projects in progress, concerned with such aspects as production methods, vehicle technologies, environmental and health effects, market introductions and so on. ■

Figure 22a • Final energy use in the transport sector 1970-1998

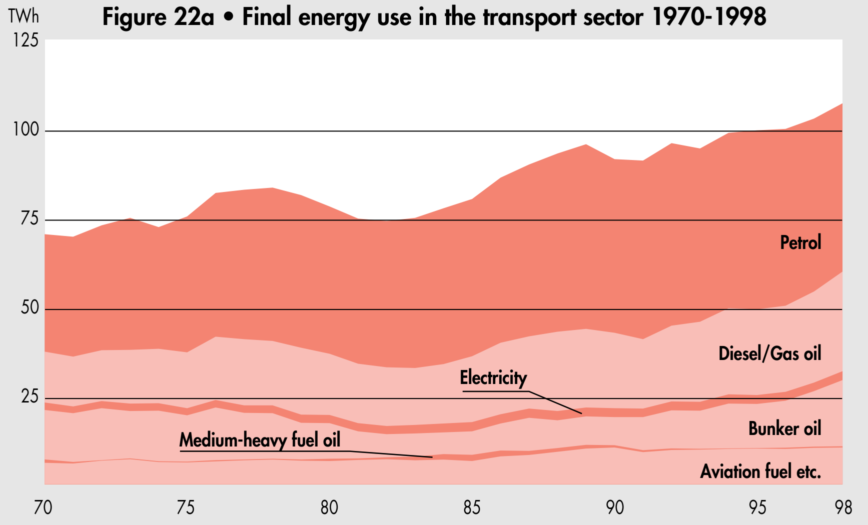
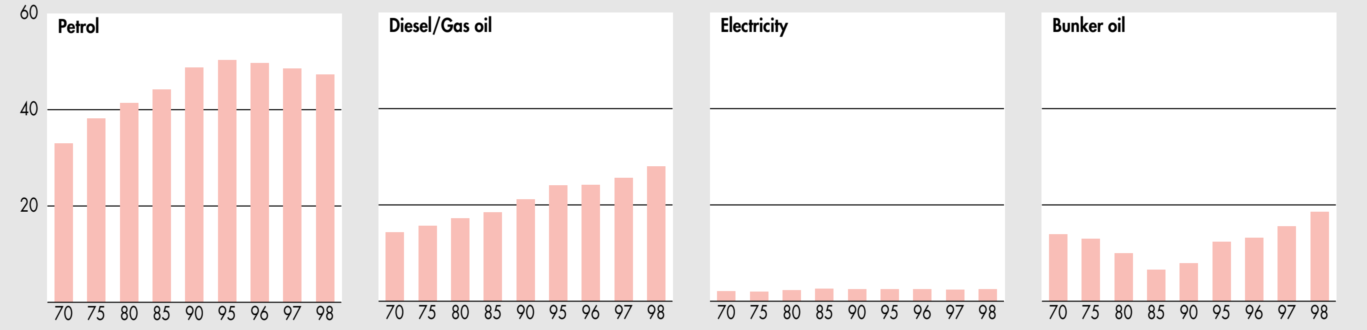


Figure 22b • Final energy use in the transport sector, by energy carriers



The use of energy has been taxed in Sweden since the 1950s. Originally, the objective was to finance the State's public spending requirements, while in later years the emphasis changed to the need to control the use of energy in order to achieve national energy and environmental policy objectives.

The environmental element of taxation was given greater importance at the beginning of the 1990s. Energy supplies were brought within the scope of value-added tax in 1990, while some of the general energy tax was converted into a carbon dioxide tax in the following year. A sulphur tax on fuels was also introduced in the same year, followed a little later by an emission levy on oxides of nitrogen.

Energy and environmental taxes in the present tax system distinguish between types of users and between types of energy carriers. Energy carriers that contain at least 5 % of gaseous or liquid hydrocarbons by weight and that are sold or used for heating purposes are subject to both energy tax and carbon dioxide tax. Fuels that are used for electricity production are exempt from energy and carbon dioxide taxes: instead, these taxes are levied at the point of use. Special rules apply for simultaneous production of heat and electricity in CHP/back-pressure power stations. Biofuels are untaxed for all users, although peat is subject to a sulphur tax, as shown in Table 1. Tall oil, too, has been within the remit of energy and carbon dioxide taxation since 1st January 1999. All energy taxes are at present under review, with the aim of creating a more consistent energy taxation system.

Energy and electricity production taxes

Energy tax is levied on electricity and all fuels other than biofuels and peat, although industry and greenhouse horticulture have been exempt from energy tax since 1993. It is proposed that agriculture should also be relieved from tax from July 2000. Since November 1998, electricity used in electric boilers with a rating of more than 2 MW has been taxed during the winter. The special real estate tax on hydro power production was repealed on 1st January 1999.

Nuclear power is taxed at 2.2 öre/kWh. The budget Bill for 2000 proposes that this should be increased to 2.7 öre/kWh. In addition, the Bill proposes to raise the tax on electricity by 1 öre/kWh. Another Bill proposes that the tax on diesel fuel should be increased, and that on heavy fuel oil should also be changed. In addition, it is proposed that the present differential taxation of LPG, methane and natural gas, depending on whether they are used as motor fuels or for other purposes, should be removed. An EU Directive, necessitating certain adjustments in the existing environmental classification system for petrol and diesel fuels and their associated taxes, is

→

Table 1 • General energy and environmental taxes as at 1 st January 1999, excluding value-added tax

		General energy tax	Carbon dioxide tax[1]	Sulphur tax	Total tax	Tax, öre/kWh
Gas oil SEK/m³						
Environmental class 3	(< 0.1 % sulphur)	736	1 049	-	1 785	18.1
Heavy fuel oil, SEK/m³	(0.4 % sulphur)	736	1 049	108	1 893	17.5
Coal, SEK/tonne	(0.5 % sulphur)	313	912	150	1 375	18.2
LPG, SEK/tonne		144	1 102	-	1 246	9.7
Natural gas, SEK/1 000 m³		239	785	-	1 024	10.5
Peat, SEK/tonne	(0.24 % sulphur)	-	-	40	40	1.5
Petrol, leaded, SEK/litre		4.23	0.85	-	5.08	
Petrol, unleaded, SEK/litre						
Environmental class 2		3.58	0.85	-	4.43	
Environmental class 3		3.65	0.85	-	4.5	
Diesel, SEK/litre						
Environmental class 1		1.61	1.049	-	2.65	
Environmental class 2		1.82	1.049	-	2.87	
Environmental class 3		2.12	1.049	-	3.17	
Electricity, Northern Sweden, öre/kWh		9.5	-	-	9.5	9.5
Electricity, Rest of Sweden, öre/kWh		15.1	-	-	15.1	15.1
Electricity, district heating, Northern Sweden, öre/kWh		11.8	-	-	11.8	11.8
Electricity, district heating, Rest of Sweden, öre/kWh		15.1	-	-	15.1	15.1

A table defining the various environmental classes is included in the tables appendix *Energy in Sweden;* facts and figures.

[1] *Carbon dioxide tax is levied at a rate of about 36.5 öre/kg of carbon dioxide emission.* [2] *All petrol sold in Sweden today is in environmental class 2.*

Table 2 • Industrial energy and environmental taxes as at 1 January 1999, excluding value-added tax

	General energy tax	Carbon dioxide tax	Sulphur tax	Total tax	Tax, öre/kWh
Gas oil, SEK/m³	0	525	-	525	5.3
Heavy fuel oil, SEK/m³	0	525	108	633	5.8
Coal, SEK/ton	0	456	150	606	8.0
LPG, SEK/ton	0	551	-	551	4.3
Natural gas, SEK/1 000 m³	0	393	-	393	4.0

being introduced[1]. The decision will be made in December, and it is expected that the Bill will come into force on 1st January 2000.

Environmental taxes

A carbon dioxide tax was introduced in 1991, applicable to all fuels except biofuels and peat. Fuels for electricity production are exempted from the tax.

From 1993 and until 1st July 1997, industry paid only 25 % of the carbon dioxide tax payable by other users. Since 1997, industry has paid 50 % of the carbon dioxide tax rate. Present tax rates are shown in Tables 1 and 2.

A sulphur tax was also introduced in 1991, and amounts at present to SEK 30/kg of sulphur emission on coal and peat and to SEK 27/m^3 for each tenth of a percent by weight of sulphur in oil. An environmental levy on the emission of oxides of nitrogen (NO_x) was introduced in 1992, at the rate of SEK 40/kg of NO_x emissions from boilers, gas turbines and stationary combustion plant. From 1st January 1997, the NO_x levy has applied to plant with an annual energy production of 25 GWh or more. The system is neutral relative to the national budget, as payments are in proportion to the amount of energy produced and the levels of emission. Repayments are made to operators of plant with the lowest emissions, while those with the highest emissions are net payers.

Prices

The market prices of fuels, electricity and district heating vary with time. Table 3 shows the prices of a number of fuels and electric heating between 1990 and 1998. The prices for crude oil and coal are world market prices, while those for gas oil and unleaded petrol are average end-user prices (excluding tax) in Sweden. Biomass fuels are represented by the price of forest fuel (the main biofuel), which is an average price for forest chips and by-products as paid by heating plants and industry.

Until the middle of the 1980s, it was mainly increases in oil prices that caused the rise in energy prices, while since then it is mainly rises in taxation that have increasingly determined prices. ■

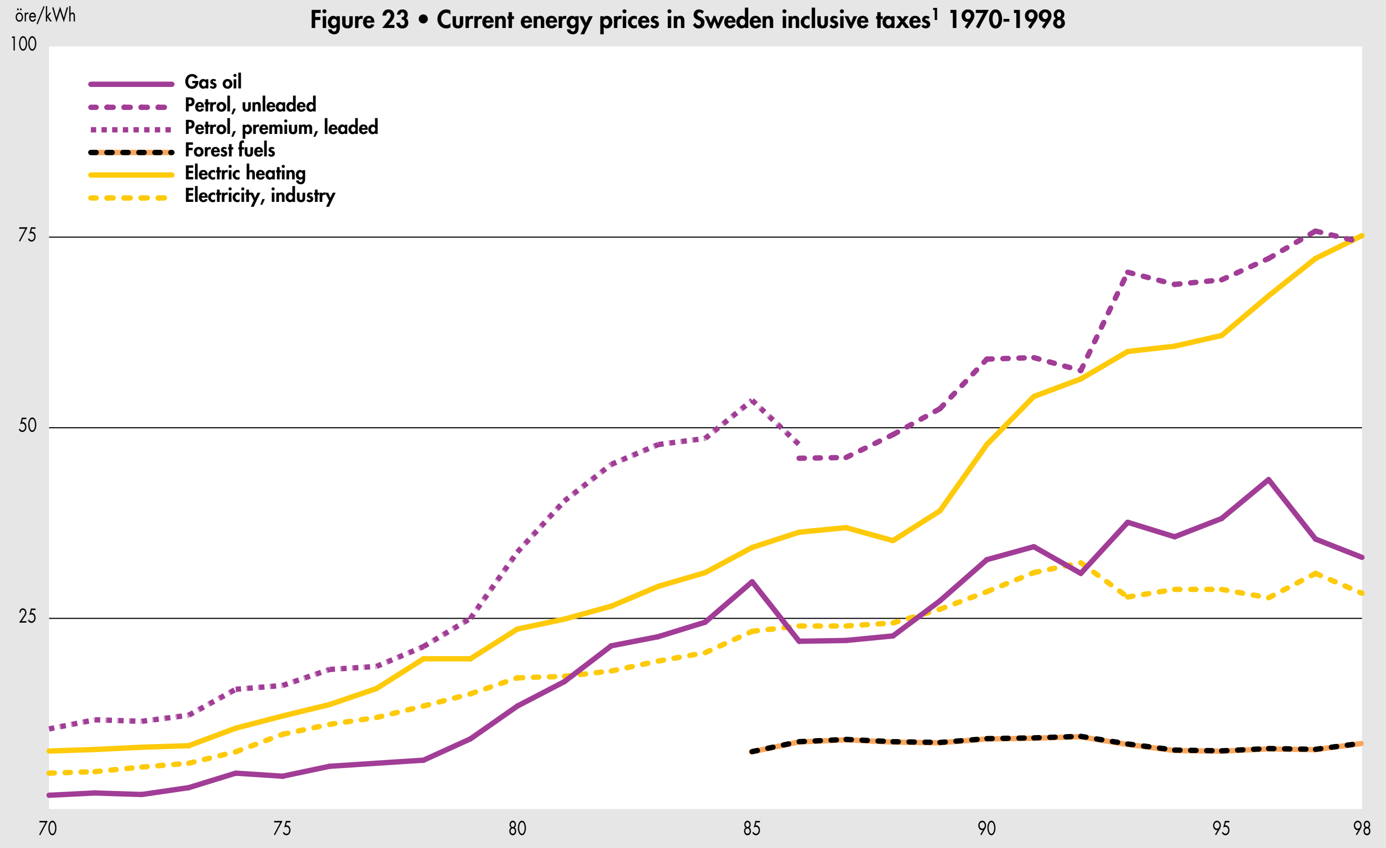
Table 3 • Fuel prices and domestic electricity prices in Sweden,excluding taxes and value-added tax. Current prices

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Crude oil, $/barrel	20.50	16.56	17.21	14.93	14.75	16.10	18.50	18.12	12.16
Gas oil, SEK/m^3	2 146	2 131	1 790	2 207	2 004	2 205	2 603	1 759	1 457
Heavy fuel oil, SEK/m^3	1 702	1 535	1 316	1 652	1 525	1 525	1 526	1 014	853
Petrol, unleaded, SEK/litre	2.23	2.19	2.06	2.23	2.10	2.02	2.10	2.25	2.01
Coal, SEK/tonne	358	366	307	309	317	336	340	367	372
Forest fuels, SEK/m^3	92.70	93.50	95.10	87.05	81.40	79.80	82.22	81.8	87.9
Electric heating, öre/kWh[2]	31.5	36.1	37.9	40.0	39.7	40.7	43.60	45.2	45.0

Note: The tabular version of *Energy in Sweden* shows the consumer price index from 1970 to 1998, enabling the prices shown to be converted to fixed prices.

[1] *A table defining the various environmental classes is included in the tables appendix Energy in Sweden; facts and figures.* [2] *The prices of electric heating also include value-added tax.*

Figure 23 • Current energy prices in Sweden inclusive taxes[1] 1970-1998



Globally, world energy supply is dominated by fossil fuels, which account for about 80 % of the world's total energy supply. Oil is the most important energy source, and its rate of use is still increasing at about 2 % per year. The second most important energy source is coal: its use, too, is increasing, at about 1 % per year. However, it is natural gas of which consumption is increasing most rapidly, at about 2–3 % per year, and it is expected that it will become the second most important fuel in meeting the world's energy supply. Hydro and nuclear power account for about 2 % and 7 % respectively.

Much of the world's energy requirements are still met by individual supplies of wood and other forms of biomass. The statistical details are very unreliable, and estimates vary, but a current view is that traditional energy carriers such as wood, charcoal etc. are probably the world's largest individual energy source outside the OECD countries and the former Soviet Union.

Resources and reserves

Proven resources of fossil fuels – primarily oil, coal and natural gas – are estimates of the quantities that can be viably extracted with present economic and technical conditions. Expressed in relation to present rates of consumption, they amount to:

- 218 years' production of coal
- 41 years' production of oil
- 63 years' production of natural gas.

The proven reserves consist of the known, discovered and developed fraction of the earth's total resources. They can be increased by additional prospecting or by rising prices, which means that new and more expensive methods of recovery become viable.

Energy supplies and international trade

Non-OECD countries hold a significant part of world energy supplies and reserves, and have been able to export their surpluses to the industrialised countries. Over the last two decades, this surplus has fallen from 70 % to 30 % of production. The industrialised countries import almost half of their oil requirements but are, as a group, almost self-sufficient in coal and gas. However, their import requirements for oil are expected to increase over the next 15 years. Production in North America is falling, but Europe is expected to be able to reduce its imports of oil by increasing output from the North Sea, after which dependence on imports is expected to increase.

Developments in the former Eastern bloc countries have been dramatic during the first half of the 1990s, with both production and use of energy carriers falling substantially. However, the situation is now starting to stabilise. Price controls in the former Soviet Union have been removed on coal, crude oil and oil products, with the result that domestic prices of crude oil, lighter products and naturalgas have almost reached world market price levels. In some cases, such as for petrol, prices have even risen above world market levels. Exports to the industrialised countries have largely been maintained.

Figure 24 • World oil reserves 1998 (billion barrels)

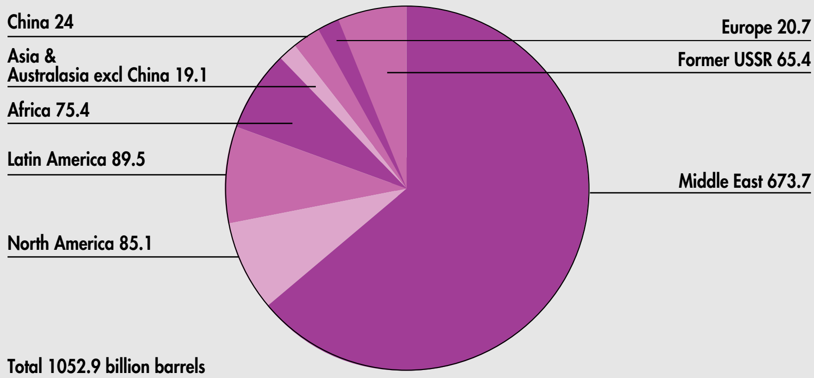
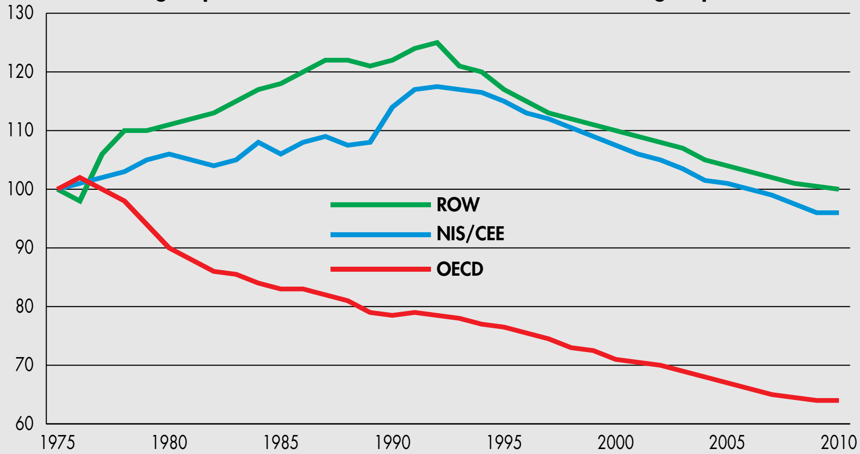


Figure 25 • Energy intensity (energy use/BNP) for the groups of countries. Index 1975 = 100 for each group



The OECD countries comprise the industrialised market economy countries of Western Europe and North America together with Japan, New Zealand and Australia. NIS/CEE (Newly Independent States – Central/Eastern Europe) are those previously having centrally planned economies.

ROW = Rest of World.

Energy use

Since 1990, total world energy use has risen less rapidly than it did during the 1980s. Then, the average rate of increase was 2.6 % per annum: now, during the 1990s, the average rate of increase has fallen to 0.9 % per annum, although demand increased during 1994–96 by 2–3 % per year. However, after this, the rate of increase again fell, so that total energy use during 1998 actually declined by 0.1 %. During the year, energy use in North America increased by 0.1 %, while falling by 0.2 % in the European Union and by 0.3 % in the former Soviet Union. However, this latter fall is a relatively small one in relation to those of previous years. Energy use continues to rise steadily in the developing countries, due primarily to population growth, urbanisation and industrialisation.

Figure 25 illustrates how energy use tends to develop in relation to economic growth. It shows specific energy use per unit of GNP ('energy intensity') for three groups of countries, illustrating historical development since 1975 and a forecast until 2010.

The fact that energy use first increases and then decreases in relation to economic growth is a typical feature of the development of an agricultural society towards an industrial society and, in due course, to a post-industrial service society. This process probably provides a partial explanation for the trends that can be seen for the various groups of countries at different stages of development. The figure does not include the substantial use of biomass in the 'Other Countries' category: if it was included, energy intensity could be assumed to increase by a third.

→

In the case of the former Soviet Union, energy use per unit of GNP is highly inefficient. However, the fact that energy prices have increased, and are now more or less up to world market prices, should bring about improvements. It is assumed that improvements in the efficiency of energy use will continue in China, eastern Asia and Latin America, while the Middle East and southern Asia are expected to develop in the opposite direction. Energy intensity in the Middle East nearly tripled between 1975 and 1993, while that of the OECD countries fell be 21 % over the same period. Some of the differences can be explained by the fact that the two regions are at different stages of development.

Forecasts

World energy demand is expected to continue to increase up to 2010, at which time fossil fuels are expected still to be providing 80–90 % of energy requirements. Energy use in the OECD countries is expected to increase somewhat, but the major increase is expected to occur in non- OECD countries such as Asia and the Pacific Rim. In these countries, use will increase as a result of strong economic growth and industrial expansion, high population growth and urbanisation, coupled with a move away from non-commercial fuels such as wood fuels to fossil fuels. It is expected that the world proportion of energy use by the non-OECD countries will increase, while that of the OECD countries will decrease from about 55 % to below 50 %.

The future is more difficult to foresee for the former planned economy countries, and particularly those of the former Soviet Union. In the shorter term, it is expected that the problems of adjusting to changed circumstances will continue to reduce energy use and the production of (in particular) oil and coal. In the longer term, more stable economic and political situations (if achieved) can result in improved efficiency of energy use and higher production of coal, gas and oil.

World demand for oil is expected to increase from about 70 million barrels/day in 1995 to between 90 and 100 million barrels/day by 2010. This increase is expected to be higher than over the last 20 years due to increased demand for transport in the OECD countries, the lack of any viable alternative energy sources in other sectors and rapid economic growth in other parts of the world. A growing world demand for natural gas can also be expected, due mainly to greater use of gas for electricity production. The use of solid fuels is also expected to increase, although their proportion of the total fuels base is expected to remain the same, while the proportion of energy demand met by nuclear power is expected to decline.

Non-OPEC oil production is expected to increase from about 40 million barrels/day at present to 45 million barrels/day by 2010. OPEC's daily output could rise to about 50 million barrels/day in 2010, which would mean that over 50 % of world oil supply would still be from the OPEC countries.

Forecasts of energy use are very sensitive to the assumptions made in respect of growth of the world economy, as well as to prices of fuels and that of oil in particular. Growing economies use more energy. Despite the efforts of some industrialised countries to encourage the use of biomass fuels, carbon dioxide emissions will probably continue to increase in the future with the increasing use of fossil fuels. ■

Figure 26a • Total world commercial energy use 1960-1998

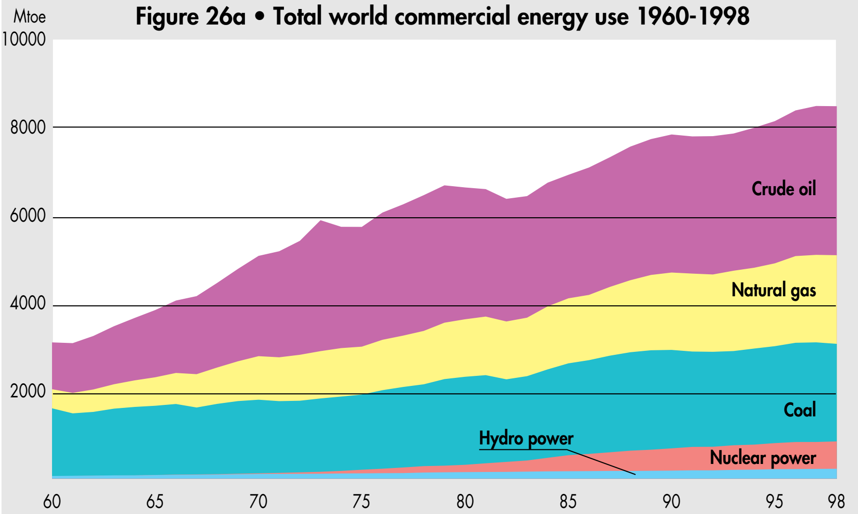


Figure 26b • Total world commercial energy use, by energy carriers

Note: The nuclear power contribution has been calculated using the international method, which includes the energy conversion losses in the process.

Greater competition

The electricity industry is at present undergoing massive changes in many parts of the world in terms of new market conditions, new technology and greater environmental pressures. Northern Europe, and the Nordic countries in particular, are at the forefront of these changes.

The electricity markets in Sweden, Norway and Finland have been restructured, with competition in both production and sales. The effect of the European Union Directive on the electricity market (apart from the UK, where the market is already restructured) will be gradually to open the market to competition. The first stage came into effect in February 1999, and meant that about 25 % of each country's electricity market was opened to competition. The Directive also impinged on other European countries, and particularly on those that have applied for EU membership. Several non-EU countries have already decided to introduce restruction, or are at an advanced stage of planning.

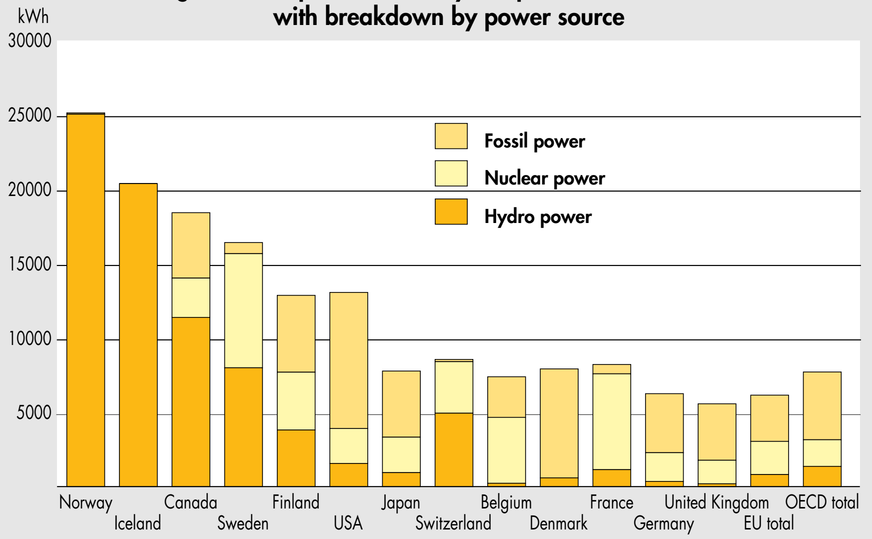
There is also a similar development in other countries, such as in South America, South-east Asia and the Pacific rim countries. Restructuring has started in the USA, with California being the first state to introduce it, in 1998.

Restructuring of the electricity markets involves a change from national monopolies, with central planning, to markets driven by competition. Electricity becomes an energy raw material that can be traded and supplied across national borders.

Some of the most high-profile changes in the electricity market that have occurred in recent years include the take-overs of electricity companies in the Nordic countries. The largest Nordic power utilities are making strategic investments in the Nordic countries and in the rest of Europe, as are companies in other countries such as the German PreussenElektra and the French EDF, both of whom are investing in the Nordic countries.

The companies' strategic purchases of each other will result in greater concentration of ownership; part of a process that will see many electrical utilities expanding from national to European companies, in the same way as has occurred in many other sectors. There is also a trend away from single-product electricity utilities towards more integrated energy companies.

Figure 27 • Specific electricity use per inhabitant, 1997, with breakdown by power source



Note. The diagram does not show imports and exports of electricity, but they are shown in the tabular version of this report.

Import and export of electricity have previously been clear concepts that could be defined in national perspectives. However, as the large companies expand across national borders, it becomes less meaningful to talk of national electricity markets. The large companies buy and sell electricity in many countries other than their original homelands, and the trend is towards a common market in which electricity will be produced wherever it is most physically and economically appropriate.

Electricity use varies between countries

Electricity use per inhabitant in Sweden is relatively high compared with that of other countries. In 1997, Sweden was in fourth place after Norway, Iceland and Canada. Electricity use in the USA was about 20 % less than in Sweden. Among the industrialised European countries, such as Germany, France and the UK, electricity use per inhabitant was about half that in Sweden.

A feature common to all countries with high electricity use per inhabitant is that they have had plentiful supplies of cheap hydro power. In addition, the relatively cold climate in these countries has meant that there has been a substantial use of electricity for heating. In Sweden, it has been other natural resources, such as the forests and iron ore, that have resulted in industry specialising in energy-intensive products. If we remove the electricity demand of these electricity-intensive industries from the statistics, i.e. if we replace the electricity that they use by the amount of electricity that is average for industry as a whole, then the specific electricity use per inhabitant is reduced by about 15 %. Canada, Norway and Finland also have high proportions of energy-intensive industries, and each of them exports a high proportion of the products of these industries.

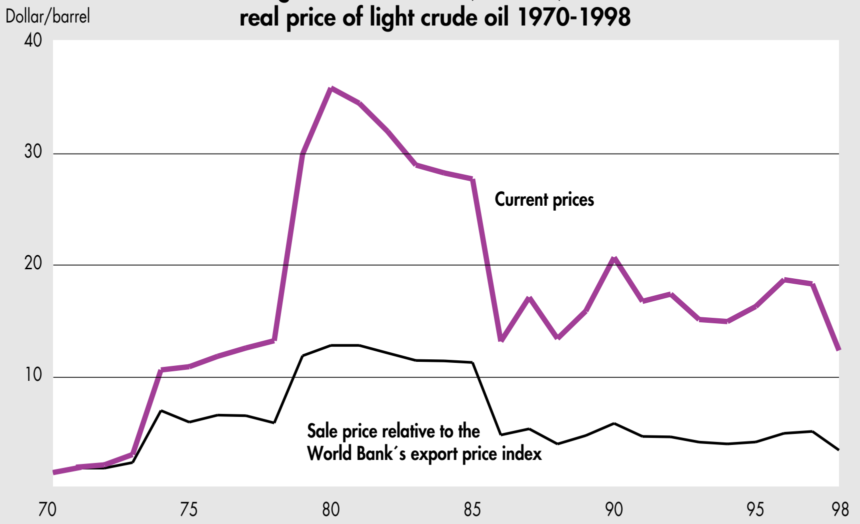
Sweden is one of the world's countries that has a high proportion of hydro and nuclear power in its electricity production. Only Iceland, Switzerland, Norway and Canada have higher proportions of hydro power: France and Belgium have higher proportions of nuclear power. In international terms, the proportion of electricity in Sweden based on fossil fuels is small, amounting to about 4.5 % in 1997. In the EU member states as a whole, over half of electricity production is based on fossil fuels and only 13 % on hydro power etc.

Total electricity production in the European Union amounts to about two-thirds of that in the USA. At the same time, the USA's production constitutes rather less than half of the total production of the OECD countries. Electricity production in Sweden accounts for somewhat less than 2 % of OECD production, and 6 % of EU production. ■

During 1998, the average price of Dubai oil fell from US$ 18 per barrel to just over US$ 12 per barrel. The crisis in Asia had an adverse effect on demand, with the result that the price of oil dropped rapidly at the beginning of 1998. The OPEC countries' difficulties in maintaining their production ceilings meant that the price of oil remained low throughout the year, even continuing to fall at the end of the year. The average price of crude during 1998 was US$ 12 per barrel.

Over production within OPEC, a reduced demand from Asia and a mild winter in the northern hemisphere contributed to a supply surplus, which forced down the price. In addition, the UN allowed Iraq to double its export of oil, which further increased the surplus. In March 1999, the OPEC countries reached agreement on production ceilings. This had an immediate effect on the price of oil, which rose steeply. During the first half of 1999, prices have risen by more than 100 %.

Figure 28 • Current (nominal) and real price of light crude oil 1970-1998



Oil production

Production methods for crude oil have become more efficient. Advanced computer methods have made it simpler to prospect for oil and to bring oil wells on line. New technology has also made it possible to extract more oil from each well. The overall effect has been to reduce the cost for recovering the oil and thus to increase the potential for lower future prices.

Between 1990 and 1998, world oil production increased by 11 %, amounting to over 73 million barrels per day in 1998, with the OPEC member countries supplying about 40 % of total production. The whole of 1998 was marked by disagreement and difficulties in keeping to planned oil quotas among the OPEC member countries. In March 1999, they reached agreement on reducing the agreed production quota to about 23 million barrels a day, representing a reduction of 1.7 million barrels per day in comparison with earlier agreements. In addition, a number of non-OPEC oil-producing countries promised to reduce their production by 0.4 million barrels per day. These cutbacks have not been entirely fulfilled, but nevertheless have managed to maintain the price of oil at a high level after the OPEC meeting in March 1999.

The demand for oil

The demand for oil in Asia fell during 1998 as a result of the economic crisis in the region and adverse exchange rates, although the mild winter in the northern hemisphere also contributed to a reduced demand for oil. The economic position in Asia improved during 1999, so that demand is now almost back to normal levels again.

Future total demand for oil will depend largely on developments in the countries affected by the Asian crisis and on its knock-on effects. It will also be affected by political developments in the region and by weather conditions in the rest of the world.

Two subdued markets...

A contributory reason why there has not been an even greater drop in prices over the last decade has been the break-up of the Soviet Union. In the 1980s, the USSR produced over 12 million barrels per day, equivalent to 20 % of world output. Production halved after the break-up of the Union, falling in 1998 to somewhat over 7 million barrels per day, or about 10 % of world output. Russian exports of oil have been controlled by a combination of licences and quotas, although these have gradually been relaxed in recent years. The same applies for the price ceilings for oil: domestic prices have risen to world market price levels.

The crisis in Iraq, and the resulting disappearance of the country from world markets, has affected the oil market. In 1990, Iraq produced about 2.2 million barrels per day, equivalent to 3.3 % of world output. Immediately after the Gulf War, output fell to 0.3 million barrels per day. Since then, it has progressively increased in step with the withdrawal of UN sanctions and an improvement in the efficiency of oil recovery. In 1998, production exceeded 1.5 million barrels per day, and had risen to 2.5 million barrels per day during the first half of 1999. It is in Iraq's interest to produce more oil, as it can use the resulting revenues to repair its damaged economy, which means that production is expected to continue to increase in the future.

Coal

About half of all the coal that is mined is used as fuel, which means that coal accounts for almost one-third of the world's energy supply. In this context, we are considering relatively high-value black coal, and disregarding the low calorific value brown coal. Coal is divided traditionally into two categories: coking or metallurgical coal, which is suitable for use in the iron and steel industry, and steam coal (also referred to as energy coal).

OPEC – the Organisation of Petroleum Exporting Countries – was founded in 1960 as a counter to the major oil companies and the influence on the market exerted by their home countries. The organisation has 13 member states: Saudi Arabia, Iran, Kuwait, Iraq, the United Arab Emirates, Qatar, Libya, Algeria, Nigeria, Gabon, Equador, Venezuela and Indonesia. Important oil-exporting countries that are not members of OPEC, but which at time have worked together with OPEC, include Mexico and Norway.

Estimates put the amount of coal and brown coal in the earth's crust at about 11 000x10^9 tonnes, although only a smaller fraction of this – about 1 000x10^9 tonnes – can be recovered. If production continues at the present rate of 3 432 million tonnes/year, proven and economically recoverable reserves would last for 218 years. The largest accessible reserves of black coal are in Russia, the Ukraine, China and the USA, while the largest reserves of brown coal are in Russia, the USA, Eastern Europe and Australia.

World coal output in 1998 was less than in 1997. The largest producers of coal are China and the USA: China produced about 28 % of total world output and the USA produced 26 %. Production in the former Soviet Union has been falling for several years, so that today it produces only a little more than 8 % of total world production.

Total world trade in coal in 1997 increased by 5.8 %, to 507 million tonnes. Australia, the USA and South Africa were the largest exporting countries. Coal production in Europe is still declining, while imports are increasing. Poland's exports are rising slowly, after a reduction during the 1980s and the beginning of the 1990s. Russia and other Eastern European countries increased their exports during 1997. The four largest exporting countries, accounting for over half of world trade in coal, are Australia, South Africa, the USA and Indonesia. Since the middle of the 1980s, the entire coal industry has been suffering from surplus capacity, which has resulted in a fall in the price of coal. However, in 1995, the price of coal rose relatively substantially compared to 1994. In 1996, the price of coal was US$ 51.50 per tonne, i.e. unchanged from the price that was established in 1995. By 1997/98, the price of coal had fallen from US$ 46 per tonne to US$ 32 per tonne. However, during the first half of 1999, the price responded to the rising price of oil and began to move upwards.

Figure 29 • World production of coal 1997 (million tonnes)

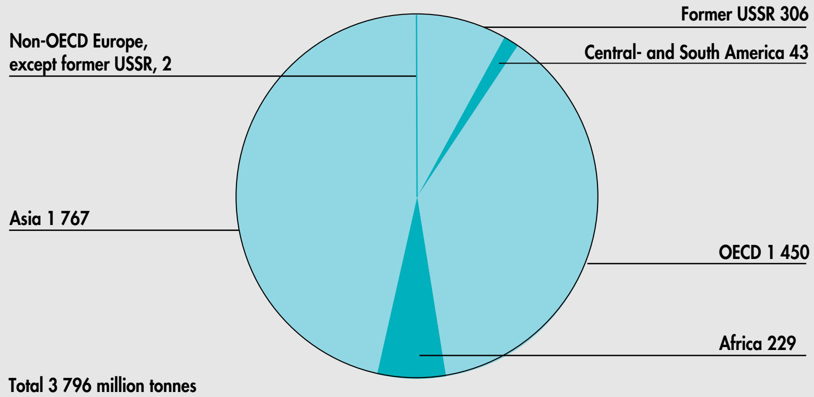
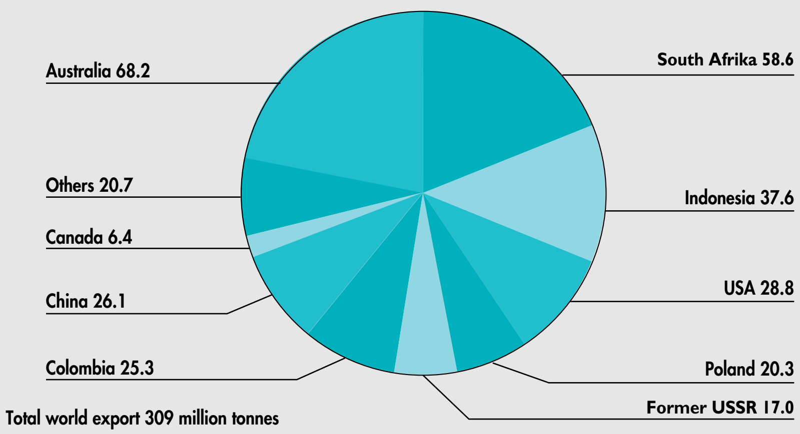


Figure 30 • The major exporters of steam coal 1997 (million tonnes)



The natural gas market

In Sweden, natural gas is a new, and as yet marginal, energy source, meeting less than 2 % of the country's total energy requirements. In the Nordic countries as a whole, this proportion rises to about 11 % of primary energy supplies, while almost a quarter of energy supplies in the European Union and about a fifth of supplies in the world as a whole are met by natural gas.

During the last decade, supplies of natural gas to the EU countries have increasingly been based on production in the North Sea and imports from Russia and Algeria. The natural gas used in Sweden comes from the North Sea.

The world's natural gas reserves are substantial: in 1997, the commercially viable reserves amounted to 144 000x10^9 m^3, which would last for about 63 years at the present rate of use. In the short term, supplies are expected to be uncertain in relation to demand as a result of economic developments in the former Soviet Union. However, in the longer term, large quantities of gas may become available from Russia.

There has been a growing interest in natural gas on the European market in recent years, based on reduced emissions of environmentally hazardous substances relative to that from other fossil fuels, a more reliable and more diversified supply of gas and improved utilisation of resources.

February 1998 saw the issue of the EU's Natural Gas Market Directive, with the aim of increasing competition on the European natural gas market. The directive must be incorporated in national legislation by August 2000. It will be implemented in stages, with at least 20 % of the market being open to competition in 2000.

The European natural gas market is in a state of flux. A substantial growth in demand is forecast within the European Union, accompanied by a reduction in gas production, resulting in a greater dependence on imports. With the objective of creating a competitive market and also of establishing security of supply, there is therefore European interest in a natural gas pipe from Russia to the rest of Europe via the Nordic countries. Sweden therefore plays a central role in the extension of a natural gas system in the Nordic countries and the rest of Europe.

Two studies of a Nordic gas pipe, connecting the Russian gas network with the Western European network, have been carried out. The objective of the first of these, the Nordic Gas Grid, is to create an integrated natural gas network between Denmark, Sweden and Finland, and to provide a reliable supply of natural gas from Russia and the Baltic countries in the east to the European states in the west. The study indicates a good potential market for natural gas in Sweden.

The objective of the second project, North Trans Gas, is to build a gas pipe from Russia to north-western Europe via Finland. From Finland, the pipe would run either via the Baltic or via Sweden. Nine countries participated in the project: Russia, Finland, Sweden, Denmark, the Baltic states, Poland and Germany. The project is under the management of North Trans Gas OY, a Finnish company established in 1997 and owned by the Finnish Neste OY and the Russian Gazprom. ■

The production and use of energy are major sources of damage to the human and natural environment. Examples range from the ecological effects of the construction of hydro power schemes through oil spills from tankers to vehicle exhaust emissions. Although Sweden has taken significant steps to counter these mechanisms, by such means as the imposition of statutory regulations, taxation and encouragement of the development of low-pollution technology, much still remains to be done.

The negative effects on the environment can be classified into three levels:

- local
- regional, or
- global.

Local environmental problems

Examples of local environmental problems include fallout of dust from power production processes, vehicle exhausts, smog and the emission of carcinogenic substances from small-scale wood firing etc. As problems of this type generally have an immediate effect on their surroundings and are easy to detect, it is natural that steps have often been taken at an early stage to counter them.

Regional environmental problems

Regional environmental problems include acidification of the ground and water. This particular problem has been considerably more difficult to identify, as the damage that it causes becomes apparent only after a longer time, akin to the fatigue of metals. This has resulted in countermeasures intended to deal with such problems being applied only at later stages, in many cases when the damage has already been done.

Global environmental problems

Global environmental problems are those that have the same effect on the world's environment, irrespective of where the emissions originate. This common dependence means that the problems cannot be unilaterally solved at national, regional or continental levels, but require international efforts. Other aspects, such as the close relationship between economic development and environmental problems, or between national and international development, also play their parts.

Global environmental problems include the depletion of the ozone layer in the stratosphere and possible effects on the earth's climate caused by anthropogenic emissions of greenhouse gases, i.e. emissions resulting from human activities.

Acidification

Since the beginning of the 1970s, acidification has been one of the environmental problems to which the most attention has been paid. As the ability of the ground and water to neutralize acidity is less in Scandinavia than in most other parts of Europe, it was the Scandinavian countries that first suffered from acidification, with the result that it was long regarded as an essentially Scandinavian problem. Sweden is badly affected, with about 20 % of its lakes and much of its forests in the southern part of the country suffering serious acidification damage. In many areas, drinking water in wells has also been affected by acidification. Together with other air pollutants, and in combination with extreme weather conditions, acidification contributes

Figure 31a • Emissions of sulphur dioxide (SO_2) in Sweden 1980-1997

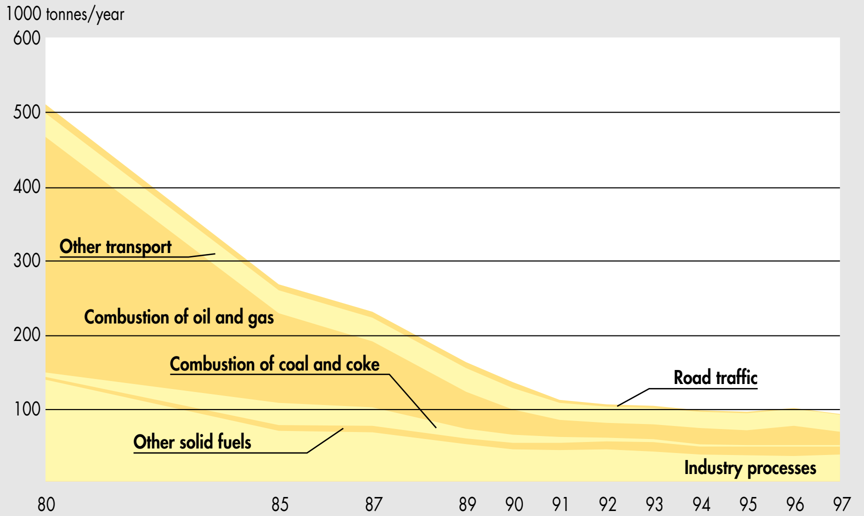
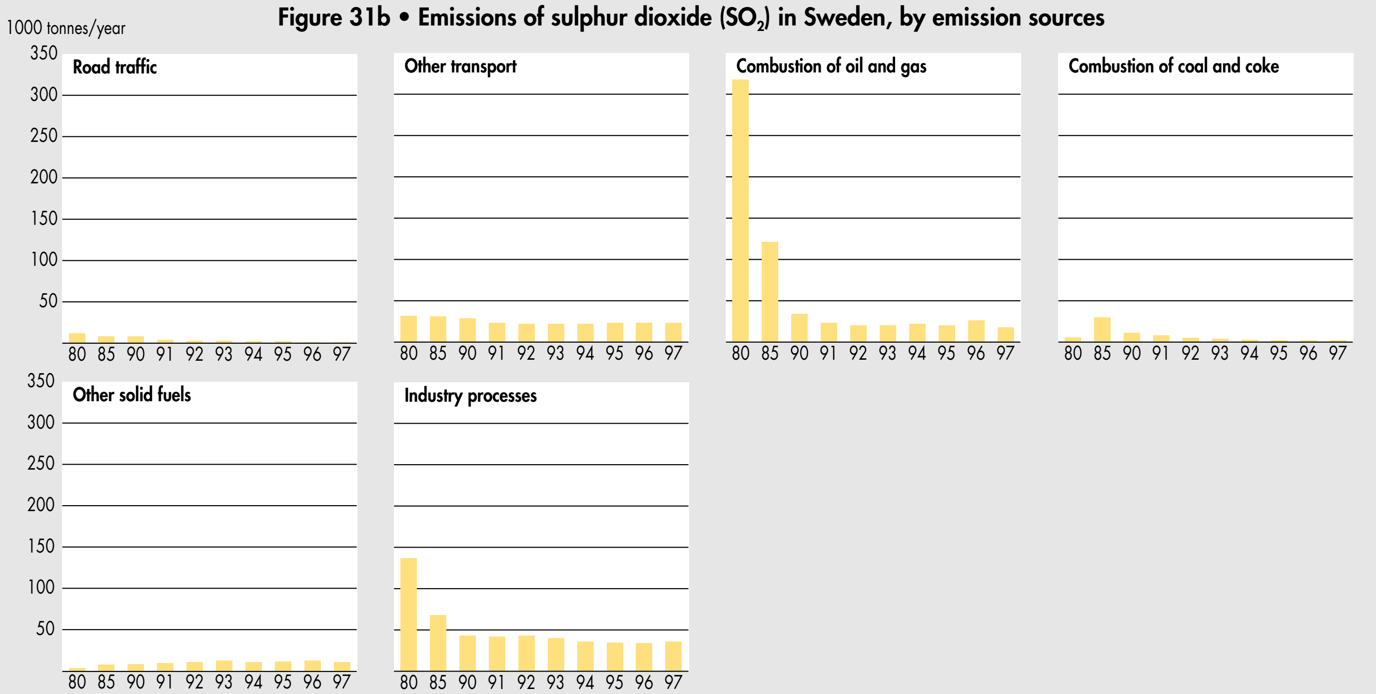


Figure 31b • Emissions of sulphur dioxide (SO_2) in Sweden, by emission sources



to a reduction in the vitality of the country's forests. One of the effects of acidification of the ground is increased corrosion of water pipes and the release of substances such as aluminium and heavy metals.

The main source of this acidification is sulphur dioxide, emissions of which come primarily from the combustion of fossil fuels, such as coal and oil. Other contributory factors in acidification are emissions of oxides of nitrogen – primarily from motor vehicles – and ammonia from agriculture. Modern forestry itself also contributes to the problem, with its clear felling and removal of biomass, resulting in a deterioration of the quality of the soil. In Sweden, the major sources of sulphur dioxide are industrial processes, the combustion of oil and gas and the transport sector. The Swedish Parliament has set an objective for the reduction of sulphur emissions by 80 % by 2000, relative to 1980 emission levels. This objective has already been achieved, with emissions having been reduced by more than 80 %.

As far as emissions of NO_x are concerned, almost 80 % comes from the transport sector. Sweden's objective has been to reduce emissions to 30 % of their 1980 level by 1995. However, between 1980 and 1995, emissions were reduced by only 21 %. Examples of administrative guide measures to achieve this objective are maximum permissible sulphur contents in light fuel oils and requirements or guidelines in respect of maximum emissions of sulphur and nitrogen from fossil-fuelled combustion plant. Financial policy measures include the NO_x levy on combustion plant.

In 1980, over 17 % of sulphur precipitation in Sweden originated from domestic sources. By 1997, this figure had been reduced to about 10 % (see Figure 33a). The countries from which about 20 % of today's precipitation in Sweden comes are primarily Germany and Poland. As far as precipitation of NO_x is concerned, about 19 % at present originates from domestic sources: again, it is Germany, with 11 %, the UK, with 10 %, and Denmark, with 7 %, which are the largest contributors to the rest. However, the proportion of NO_x originating from domestic sources varies from one part of the country to another. In central Stockholm, for example, local emissions account for between 30 and 40 % of sulphur immissions and about 50 % of NO_x immissions, while the local emissions in Gothenburg and Bohuslän account for about 15 % of both sulphur and NO_x immission. In rural areas of northern Sweden, local sources are responsible for even lower levels.

Looking at emissions throughout Europe, it can be noted that the countries that emit the most sulphur dioxide are Germany, Russia, the UK and Poland: fossil fuels are the major energy source in these countries. In total, sulphur emissions in Europe have decreased by almost 50 % since 1980. Most of the NO_x emissions in western Europe are from petrol and diesel vehicles: in central Europe and the former Soviet Union, however, the major contribution is from combustion of coal. In 1995, total emissions of NO_x in Europe as a whole

→

Figure 32a • Emissions of oxides of nitrogen (expressed as NO_2) in Sweden 1980-1997

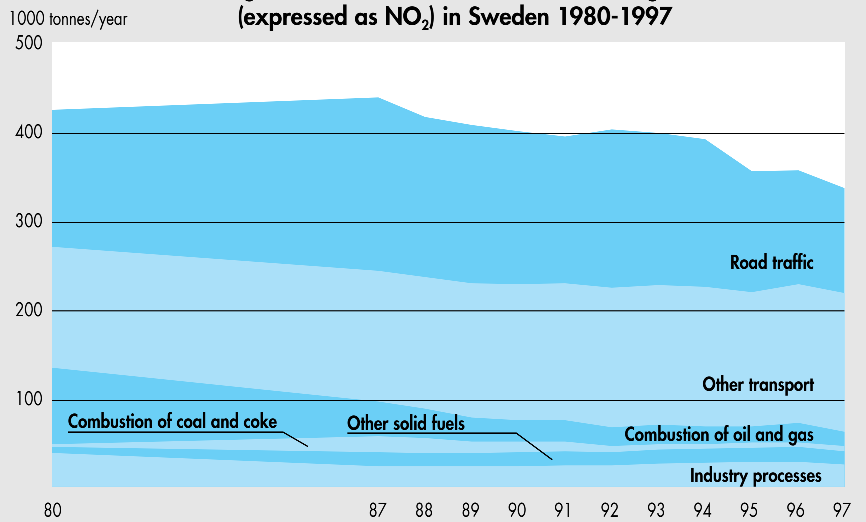
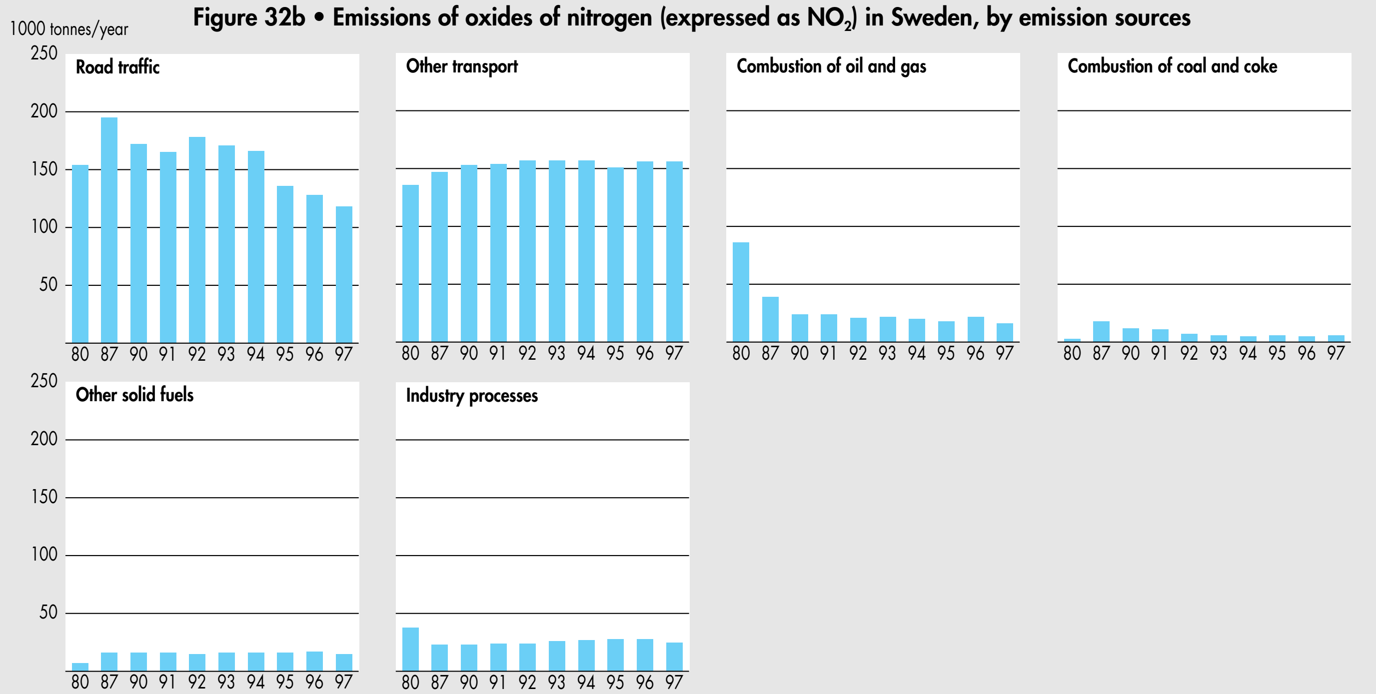


Figure 32b • Emissions of oxides of nitrogen (expressed as NO_2) in Sweden, by emission sources



had been reduced by over 9 % relative to 1980. Several European countries have undertaken to reduce their NO_x emissions so that their 1995 emissions would not exceed their 1987 emissions.

As most of the acidified precipitation in Sweden comes from other countries, Sweden can do little to influence the situation by domestic measures. International cooperation and coordination of policy measures are therefore essential if acidification problems are to be solved. The substantial costs associated with measures attempting to deal with these problems also mean that it is most important that available resources should be properly utilised, i.e. that effective energy and environmental policy instruments are employed.

An important step in the work of reducing acidifying emissions was taken when a new sulphur protocol was produced by the UN Economic Commission for Europe (ECE) in 1994. Under the terms of the protocol, several European countries have undertaken to reduce their SO_2 emissions by between 30 % and 80 % by 2010, relative to 1980 levels. As mentioned above, Sweden has already passed this target. Other countries, such as the UK, Poland and Russia, have so far reduced their emissions by between 40 % and 65 %. The protocol came into force on 5th August 1998, and is legally binding as it has now been ratified by a sufficient number of states.

The European Commission has continued to work on the project, and produced a draft acidification strategy in the spring of 1997. It includes a number of measures intended to reduce the emissions of acidifying substances in Europe. One of the most important elements is the setting of national limits for emissions of three key pollutants; sulphur dioxide, nitrogen dioxide and ammonia. These limits have been set such that the difference between the actual emission levels and the critical load limits, i.e. what the environment can stand, will be reduced by 50 % for each country.

Figure 33a • Deposition of oxides of sulphur in Sweden 1997 from various sources (%)

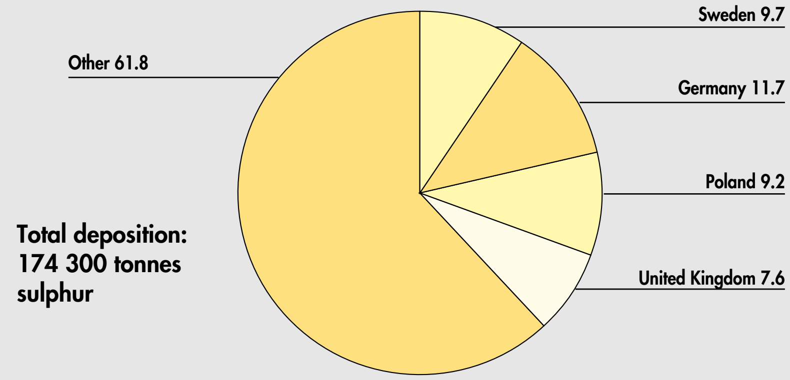


Figure 33b • Deposition of oxides of nitrogen in Sweden 1997 from various sources (%)

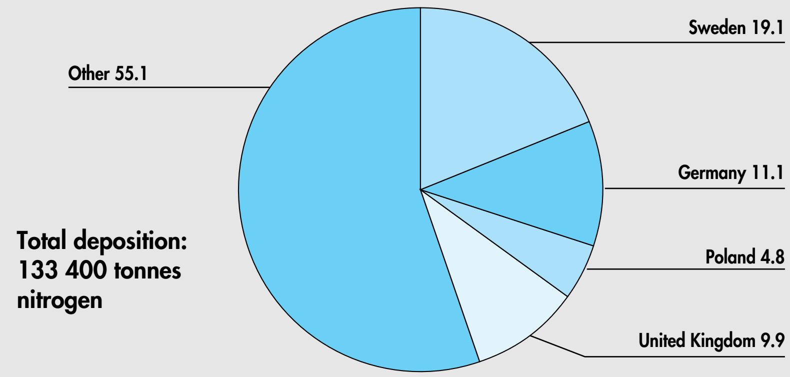
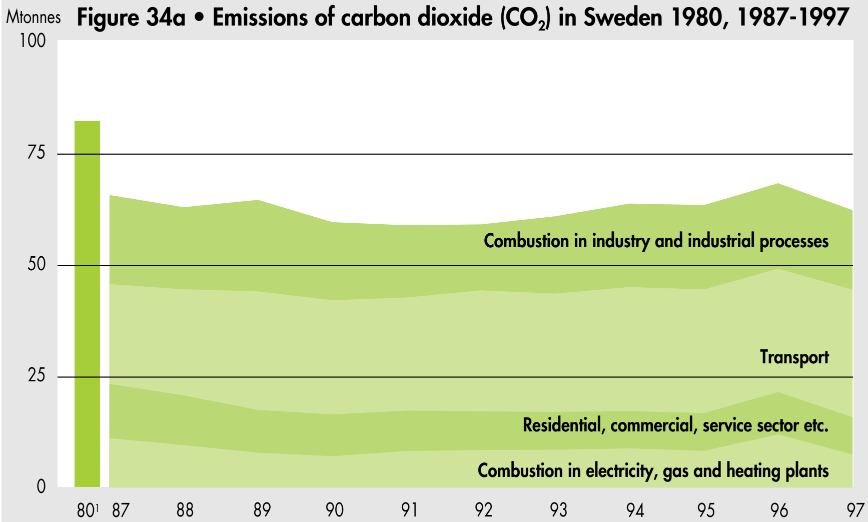
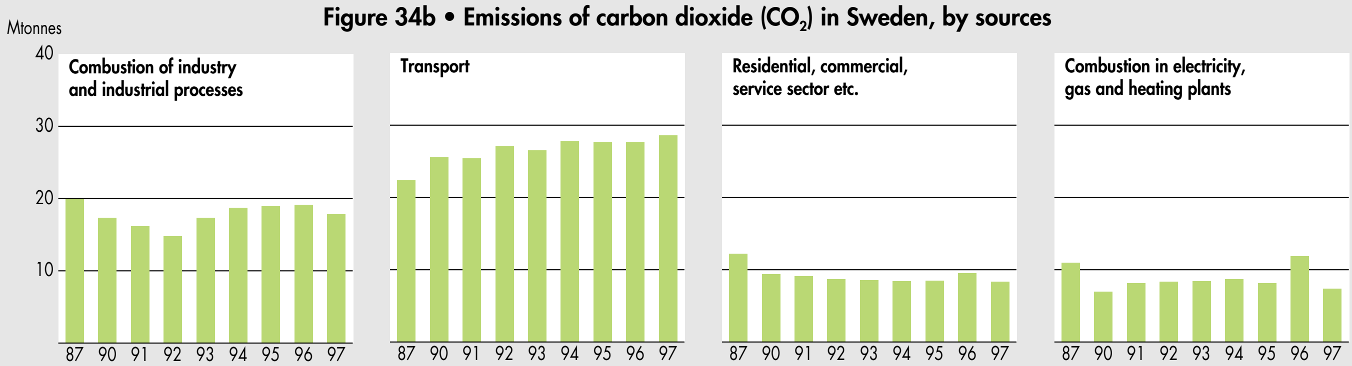


Figure 34a • Emissions of carbon dioxide (CO_2) in Sweden 1980, 1987-1997



[1] *Because of revised emission factors it has not been possible to divide the emissions on sectors.*

Figure 34b • Emissions of carbon dioxide (CO_2) in Sweden, by sources



The greenhouse effect

Carbon dioxide is one of the greenhouse gases in the earth's atmosphere. These gases are responsible for the natural greenhouse effect, by which the atmosphere maintains a balance between insolation to the earth's surface and outward radiation from the surface. Over the last 150 years, anthropogenic activities have increased the concentration of carbon dioxide and other climate gases by atmospheric emissions, thus increasing the natural greenhouse effect. The problem has been identified and discussed in recent years.

OECD countries emit over half of the total global carbon dioxide emissions. In turn, the USA is responsible for by far the greatest amount; almost half of the total OECD emissions. Other countries with high emissions include Japan, Germany and the UK. In terms of highest specific emissions per inhabitant, we find Luxembourg in top place, but with the USA, Canada and Australia following after. These countries also have relatively high emissions in relation to their GNPs (see Figures 37a and 37b).

Sweden contributes a few parts per thousand to the world's emission of carbon dioxide, and its specific emissions per inhabitant are below the average for both the OECD countries and for the European Union. Aggregated emissions from the energy sector have fallen by 30 % between 1980 and 1997, mainly as a result of greater efficiency of energy use and the switch from oil to nuclear power for electricity production. Between 1990 and 1997, carbon dioxide emissions from the energy sector have increased by about 3 %. Emissions from industry and the transport sector have increased by 3 % and 4 % respectively, while those from electricity and district heating production have increased by 8 % over the same period. Emissions from the residential and service sectors, on the other hand, have decreased by 7 % over the period. In 1992, the Swedish Parliament formulated its objectives for carbon dioxide emissions by stating that they should be stabilised at 1990 levels by 2000 in accordance with the Climate Convention, and should thereafter be further reduced[1].

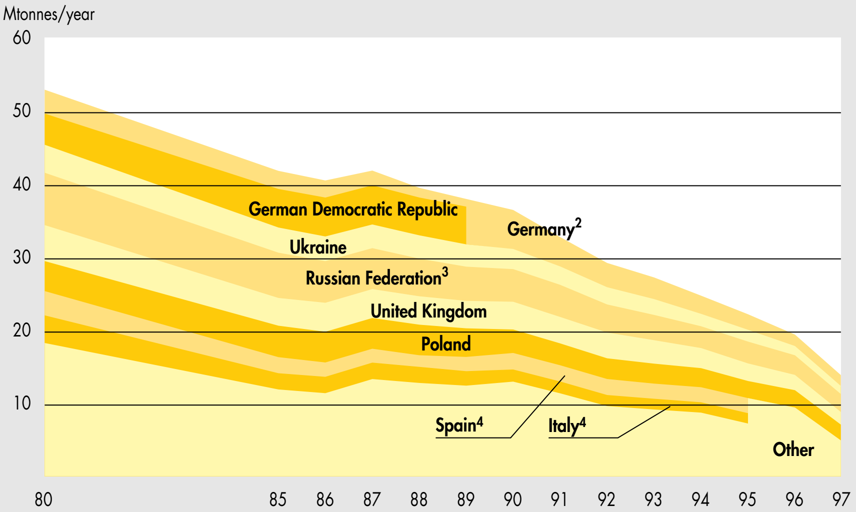
Table 4 • Changes in sulphur emissions in a number of European countries

Country	1997 emission relative to 1980, %
Austria	-86
Sweden[1]	-82
Finland	-83
Norway	-78
France	-70
Denmark	-76
Germany	-54
United Kingdom	-66
Poland	-47

[1] Source: Statistics Sweden.
Sources: EMEP.

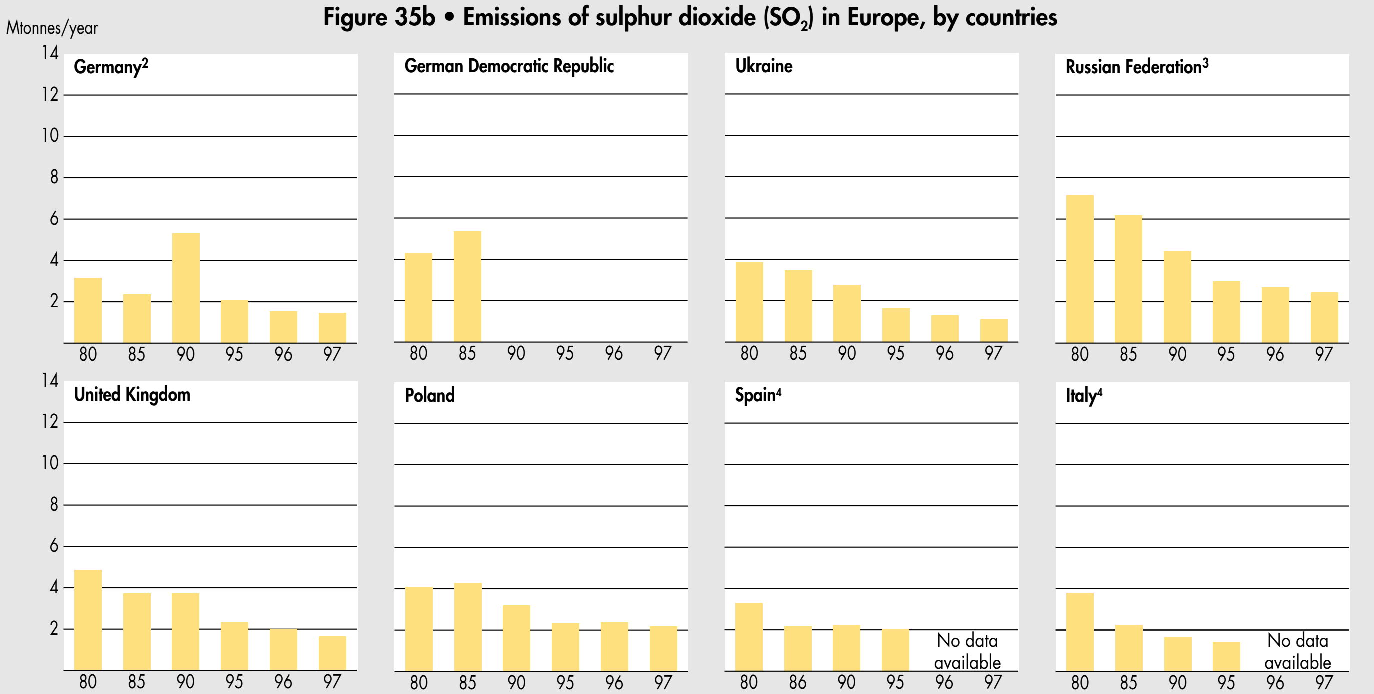
→

Figure 35a • Emissions of sulphur dioxides (SO_2) in Europe 1980-1997



[1] Bill no. 1992/93:179.
[2] West Germany until 1989.
[3] The part included in EMEP's calculations.
[4] No data available for 1996 and 1997.

Figure 35b • Emissions of sulphur dioxide (SO_2) in Europe, by countries



International cooperation

In December 1990, the UN General Assembly decided to start discussions on an outline Convention on Climate Changes, and it was signed at the UN Conference on the Environment and Development in Rio in 1992. The Convention came into force in 1994, when it had been ratified by a sufficiently large number of countries. The Swedish Parliament ratified the Convention in 1993, at which time it also adopted guidelines for Swedish climate policy.[5]

One of the contents of the Convention is that, in summary, it requires all industrial countries to formulate programmes for limiting effects on climate and to prepare measures to reduce the emissions of greenhouse gases. In addition, it states that countries must maintain and increase means for the absorption and retention of greenhouse gases, but does not contain any binding commitments in respect of limitations of emissions. In addition, the industrialised countries must regularly submit detailed information in the form of national reports to the UN concerning the steps that they are taking to achieve this objective.[6]

At the meeting of the parties in Berlin in 1995, it was noted that work to date on reducing the emission of greenhouse gases was inadequate, and a process was started to produce a legally binding document. The third meeting between the parties to the Convention, held in Kyoto in December 1997, started with the parties relatively far from each other. However, after intensive negotiations, a protocol was agreed, regulating not only the emissions of carbon dioxide but also those of five other climate gases.

The agreement includes specified reductions for all the Annex 1 countries, i.e. the OECD countries and the previous Eastern states. The EU, for example must reduce its emissions by 8 %, the USA by 7 % and Japan by 6 %, relative to emission levels in 1990 and expressed as an average over the period 2008–2012.

The protocol includes flexible mechanisms to facilitate more cost-efficient reductions. These mechanisms take the form of emission trading, under which the Annex 1 countries can trade their emission rights, and of joint implementation, by which the Annex 1 countries can carry out projects in a third country intended to reduce that country's emissions, but be credited themselves with the emissions. There is also a mechanism, known as the Clean Development Mechanism (CDM), by which the Annex 1 countries and other countries can cooperate in much the same way as in joint implementation projects, but with the difference that such projects must not only reduce emissions but also help non-Annex 1 countries along the road to sustainable development. A considerable amount of work remains to be done in determining the final form of these flexible mechanisms. For the protocol to come into force, it must be ratified by at least 55 countries, responsible for at least 55 % of the aggregated emissions from the Annex 1 countries in 1990. It is hoped that most of the remaining problems can be re-

Figure 36a • Emissions of oxides of nitrogen (expressed as NO_2) in Europe 1980-1997

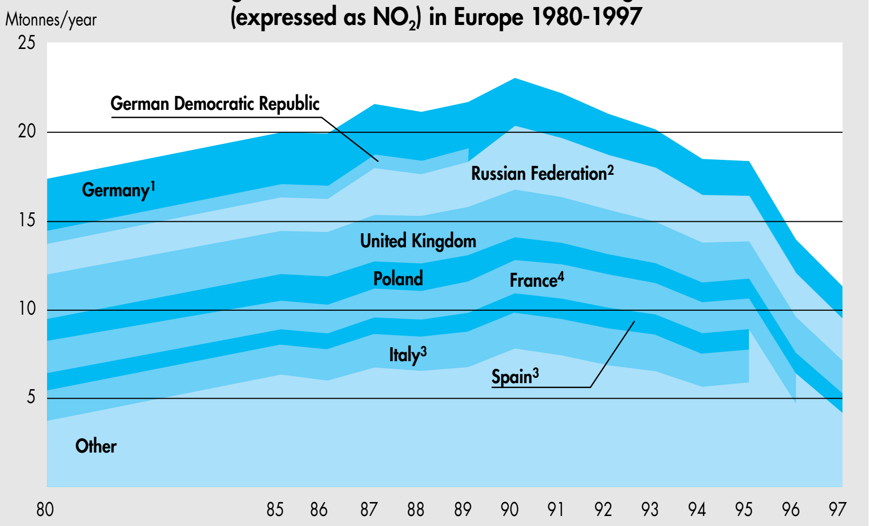
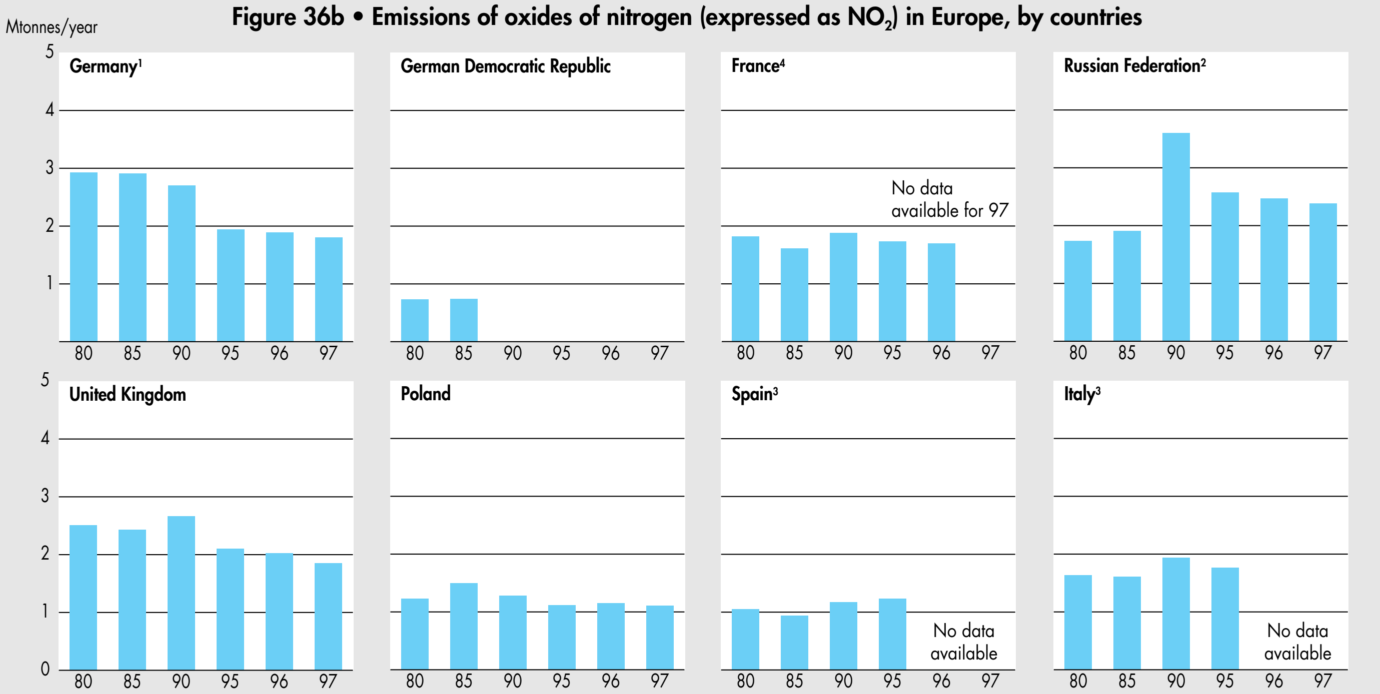


Figure 36b • Emissions of oxides of nitrogen (expressed as NO_2) in Europe, by countries



[1] West Germany until 1989.
[2] The part included in EMEP's calculations.
[3] No data available for 1996 and 1997.
[4] No data available for 1997.
[5] Bill no. 1992/93:179.
[6] Sweden published its second national report on climate change in the spring of 1997 (Ds 1997:26).

solved at the sixth party conference, to be held in the autumn of 2000.

Climate problems and the EU

During the Kyoto negotiations, the EU acted as a single group, with the result that, at the end, the EU states undertook jointly to reduce their emissions by 8 %. Since then, they have reached agreement on the internal breakdown of this aggregate reduction, with some countries reducing their emissions by up to 21 % while others are allowed (to a certain extent) to increase their emissions. Under the terms of the agreement, Sweden is allowed to increase its emissions by 4 % by 2010, relative to the 1990 level.[1] Norway may increase its emissions by 1 %, while Denmark needs to reduce its by 21 %. Finland will stabilise its emissions at its 1990 level. In addition to implementing national measures, the EU states may also employ common actions in order to reduce their carbon dioxide emissions. In the same way as for the Annex 1 countries, the actual formulation and application of the flexible mechanisms will have a considerable effect on how the EU states achieve the agreement emission reductions.

Other current problem areas within EU

Much work is in progress within the EU that will either directly or indirectly affect the energy and environmental sectors. The planned eastward expansion, for example, will have a very considerable effect on both these areas. In general, the environmental standards and performance of the Eastern European countries is poorer than is the case within the EU. When they become members of the EU, they will have to tighten up their environmental requirements in order to comply with the EU rules. This cannot, of course, be done overnight but, in the longer perspective of a few years, will improve the environmental situation in Europe.

The question of renewable energy sources is being approached within the EU in a number of ways. Several programmes are being operated with the aim of supporting the development of renewable energy sources and increasing the proportion of energy supplied by them. The EU Commission has also published a White Paper on renewable energy sources.

The EU has published directives concerning both the electricity and the natural gas markets. The Electricity Market Directive was adopted at the end of 1996, and the Natural Gas Directive in February 1998, both with the aim of improving operation of their respective markets under the aegis of common rules in all member states. Implementation of the directives is being phased in progressively, at different rates in the various member states, which means that it will be some time before the single market for electricity and natural gas is fully developed. ■

[1] *In most contexts, 2010 is taken as representative of the average for the period 2008–2012.*

Figure 37a • Emissions of carbon dioxide (CO_2) per inhabitant and BNP in EU and OECD-countries, 1997

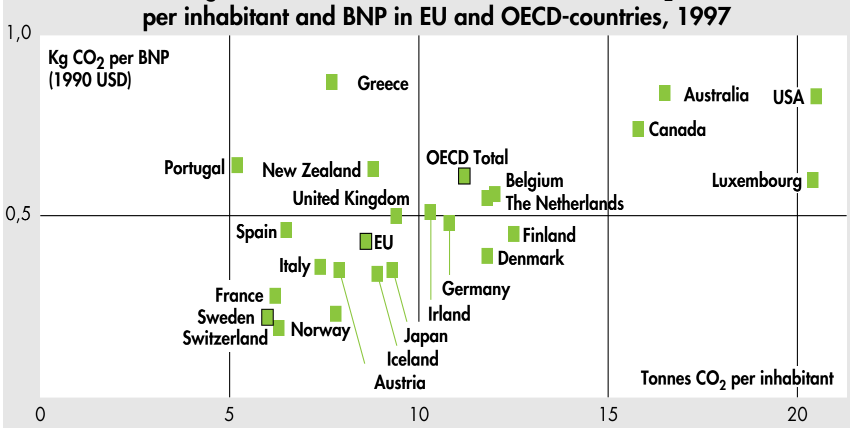
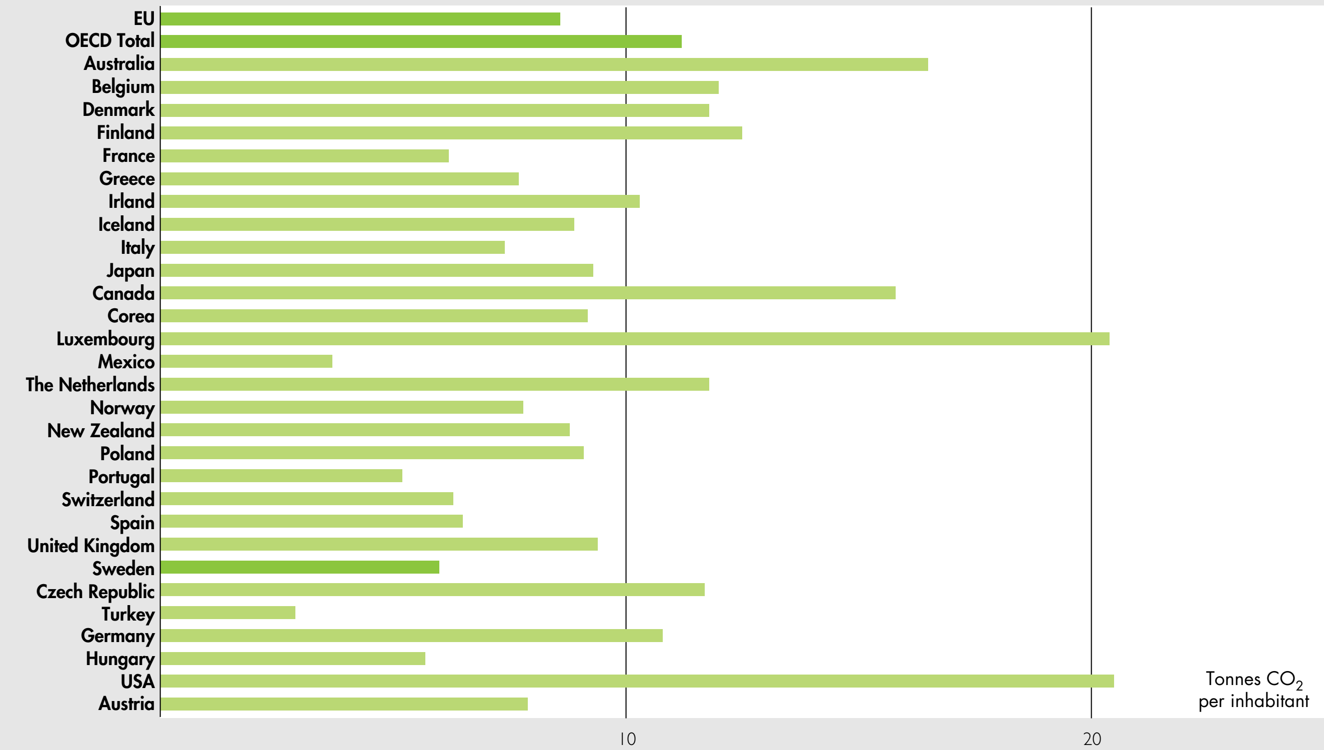


Figure 37b • Emissions of carbon dioxide (CO_2) per inhabitant in EU and OECD-countries, 1997



Alternating current (AC)
Electric current in which the direction of flow of the electrons is constantly reversing.

Automotive petrol
Petrol intended for use in spark ignition internal combustion engines.

Biofuels
Fuels consisting of biomass.

Biogas
Gas produced from biomass as the raw material, e.g. by fermentation.

Biomass
Material of biological origin, and which has not been processed, or processed to only a very limited extent.

Blast furnace gas
Flammable gas consisting of a mixture of nitrogen, carbon monoxide and hydrogen, produced by the reduction of iron ore in a blast furnace.

Brown coal
Combustible solid containing about 70–75 % by weight of carbon. Brown coal can be likened to compacted peat, and is at an early stage in the conversion to coal.

Carbon dioxide, CO_2
Carbon dioxide, CO_2, is a gaseous oxide of carbon, formed by complete combustion of substances containing carbon, e.g. hydrocarbons.

Chemical energy
Energy released or absorbed when the bonds between atoms or molecules are changed.

Coal
Combustible rock-like substance with a high content of carbon. Coal is an intermediate stage in the geological conversion from brown coal to anthracite.

Cold condensing power station
A power plant that produces only electricity, using a steam turbine cycle. Efficiency is 35–45 %: the remainder of the thermal energy in the fuel is removed by the cooling water to the sea, lake, river or atmosphere.

Coke
The solid residue from the pyrolysis of coal.

Coke oven gas
Flammable gas produced by the coking of coal.

Coking plant
Plant for the production of coke and the cleaning of coke oven gas.

Combined heat and power plant
A power plant that produces both electricity and heat, supplying the heat to a district heating system.

Conversion losses
Energy loss in a conversion plant or process, resulting from the less than 100 % efficiency of the process.

Cracking
Chemical modification of heavy hydrocarbons in petroleum to lighter hydrocarbons.

Crude oil
Petroleum from oil wells that has not been processed other than the possible removal of dissolved gases and solids, and which is in transport or being stored or is used as a raw material.

Degree of energy utilisation
The relationship between the amount of (electrical) energy actually produced and that which is theoretically possible over a given period of time.

Diesel engine
Internal combustion engine of piston type, in which the heat of compression is sufficient to ignite the combustible mixture of fuel and air.

Diesel fuel
A light oil for use in diesel engines.

Digester gas, sludge gas
Flammable gas formed by anaerobic bacterial action on biological material.

Digestion
Controlled biodegradation of organic substances under anaerobic conditions, by which the substances are transformed without air change in water-filled pores and in which evil-smelling are produced, such as hydrocarbons, ammonia, hydrogen sulphide etc.

Direct current (DC)
Electric current of which the electron flow is always in the same direction, e.g. from a battery.

Direct electric heating
Electric heating that supplies heat to the heated area without intervening heat storage or heat carrier other than air.

District heating
The provision of a public heating supply, delivered by means of hot water in supply and return pipes. After supplying heat to a building's own space heating and domestic hot water heating system, the cooled district heating water is pumped back for reheating.

Efficiency
A measure of how efficiently a power station or heating plant works. It indicates that proportion of the energy in the fuel or input that is converted to useful electricity and/or heat.

Electrical energy
Energy released or absorbed when electrons move through a solid, a liquid, a gas or a vacuum.

Energy
A measure of work performed in a given time: the product of power and time. Energy is expressed in watt-hours (Wh).

Energy balance
1 The balance of energy supplied and energy used.
2 A presentation of energy supplied and energy used.

Energy carrier
A substance, material or service used to carry energy, e.g. water, air, electricity, battery cells, or fuels such as coal, crude oil, logs etc.

Rational use of energy
Making the best use of energy supplied to a system.

Energy conversion
A process that converts one form of energy to another form.

Energy crops
Crops grown for use as energy raw materials.

Energy forest
Trees or bushes grown for use as energy raw materials.

Energy saving
Reduction in the use of energy by refraining from the use of services etc.

Energy system
A system of plant, equipment etc. that meets a need for energy, e.g. for a house, a factory or a town.

Energy use
Utilisation of electrical energy, heat or some other form of energy.

Ethanol
Ethyl alcohol, normally produced by fermentation of sugar or some other biomass.

Exergy
That part of a quantity of energy in some particular form that can be completely converted into work. The terms energy and exergy describe the suitability of a form of energy for energy conversion. The less the proportion of exergy, the greater the amount of energy that is lost as heat.

Fossil fuel
Fuel formed from biological materials during earlier geological periods, e.g. coal and petroleum.

Fuel
A substance containing substances having chemically or otherwise bound energy that can be utilised for conversion to heat or other form of energy.

Fuel cell
A cell for direct conversion of chemical energy to electrical energy.

Fuel oil
Combustible oil intended for oil burners, consisting of low or high viscosity or semi-solid mixture of hydrocarbons, produced from crude oil by distillation or cracking.

Gasification
The conversion of solid materials, e.g. coal or peat, to a gaseous form, with or without chemical change of the substances involved.

Gas turbine
Power plant for the production of electric energy. A gas turbine consists of an air compressor, combustion chambers and a power turbine driven by the exhaust gases. In turn, the power turbine drives the generator.

Gasworks
A facility for the production gas by means of gas generators.

Geothermal heat
Heat flowing from the interior of the earth to the surface.

Greenhouse effect
Accumulation of heat in the lower atmosphere through a reduction in cooling that is caused by outward radiation from the earth to space, caused primarily by the ability of carbon dioxide to absorb thermal radiation.

Heat pump
A device for raising the temperature of energy from a low-temperature source such as water, air, etc., to a higher temperature. To do this, it requires a certain input of some other form of energy, usually electricity.

Hydro power plant
A power station that converts the potential energy of water to electrical energy.

Kinetic energy
Energy released or absorbed as a result of the change in velocity of a moving object.

Mechanical energy
The sum of kinetic energy and potential energy that is not electrical energy.

Motor fuel
Gaseous, liquid or solid fuel intended for starting, running or heating a machine, a vehicle engine etc.

Natural gas
Flammable, non-volcanic gas found in porous rock strata, often together with and/or partly dissolved in, petroleum.

Natural gas combination plant/cycle
A combined gas turbine/steam turbine plant, fuelled by natural gas.

Normal year
To enable fair comparisons to be made between the use of electricity, heating etc. from one year to another, the climatic conditions of the years concerned must first be converted to equivalent conditions of a statistically average year.

Nuclear energy
Energy released in nuclear reactions or by radioactive decay.

Nuclear power plant
A power plant that utilises nuclear energy for the production of electrical energy.

Oil equivalent
The quantity of fuel oil that, in practical use, is regarded as providing the same quantity of energy as some quantity of other fuel.

Paraffin (Am.: kerosene)
A clear, colourless and low viscosity liquid, consisting of hydrocarbons, produced by distillation with or without refining.

Peat
Organic earth-like material formed in wet and oxygen-deficient conditions by the degradation of dead plant and animal material by bacterial and chemical action.

Petrol (Am.: gasoline)
A clear, colourless and low viscosity liquid, consisting of hydrocarbons, produced by distillation of crude oil, by cracking of gaseous or liquid petroleum fractions or by synthesis.

Petroleum product
Gaseous, liquid or solid mixture of hydrocarbons, produced from crude oil by distillation, cracking or some other process.

Potential energy
Energy released or absorbed by changing the position of an object.

Power
The rate of doing work, given by the quotient of energy and time (= energy per unit time)

Power balance
1. The balance of power input and output.
2. A presentation of input and output power.

Power shortage
The state of an energy system, e.g. an electricity supply system, not having sufficient capacity immediately to supply the power demand.

Pumped storage power station
Hydro power station which, when not producing power from water falling through the turbine, can be used to pump water from a lower level to a higher level for later production of power from it.

Refining
To clean or purify a raw material by wholly or partly removing pollutants or hazardous constituents.

Renewable energy source
An energy source that can be renewed or replaced at the same rate as it is used.

Sludge gas
See: digester gas

Speed control
Control of the speed of, say, a fan, in order to control some other quantity, e.g. an air flow.

Statistically average year
A year for which the meteorological conditions are the average of those over a period of years.

Steam coal
Coal that is used primarily for burning.

Thermal power plant
A power station in which heat is converted to electricity.

Tonne-kilometer
Unit of transport work, calculated as the product of the aggregated distance in kilometer over which a number of tonnes have been carried and the number of tonnes.

Toe (tonnes of oil equivalent)
See Oil equivalent

Town gas
Gas of a medium calorific value, containing methane, nitrogen, butane and (in low concentration) carbon monoxide, with the addition of a substance to provide a tracer smell.

Useful energy
Energy used for its intended purpose within a defined system.

Waste heat
Heat released from processes.

Wind power plant
A power plant that converts wind energy into electrical energy.

The international standard unit for measurement of energy is the joule (J), although the watt-hour (Wh) is often used in Sweden. One joule is equal to one watt-second, which means that one watt-hour is equal to 3600 J. International comparisons often use the tonne of oil equivalent (*toe*), which represents the energy obtained by burning one tonne of oil, i.e. 11.6 million Wh.

When measuring larger quantities of energy, the joule, watt-hour and even toe are inconveniently small units. Instead, multiples such as thousands or millions are used, indicated by the following abbreviations:

k	(kilo)	10^3	thousand
M	(mega)	10^6	million
G	(giga)	10^9	thousand million
T	(tera)	10^{12}	million million
P	(peta)	10^{15}	thousand million million

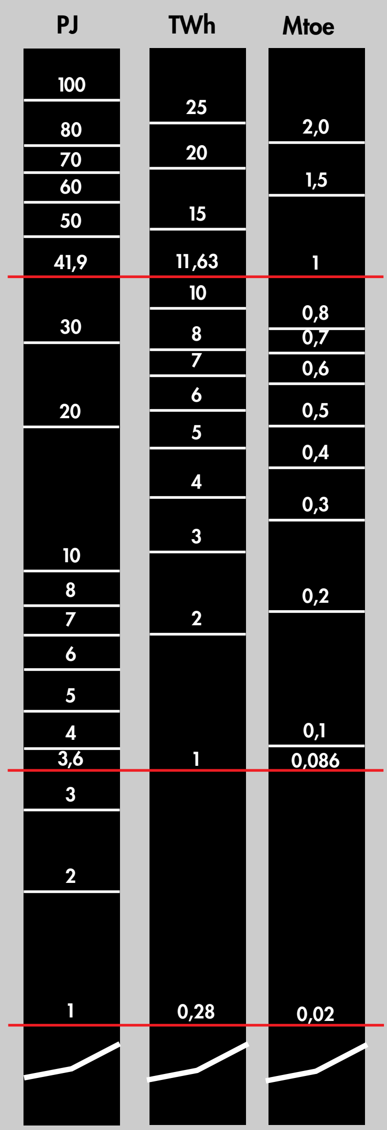
Units commonly used for comparison are the PJ, TWh and Mtoe. See the diagram on the right for conversions between them.

Practical terms

What are these various energy units, expressed in practical terms? A rough guide is as follows:

- 1 kWh can run a cooker hotplate for one hour.
- 1 MWh can power a private car for 1000 km (= 621 miles).
- 1 GWh represents the energy used by a medium-sized town in one day.
- 1 TWh is the quantity of energy supplied by a large nuclear power plant in about two months' full-load operation.

Conversion scales, energy units (logarithmic scales).



Conversion factors for energy carriers:

Crude oil	1 Mtonnes	=	11 TWh	=	42 PJ
Gas oil	1 Mtonnes	=	12 TWh	=	43 PJ
Heavy fuel oil	1 Mtonnes	=	11 TWh	=	41 PJ
Natural gas	1 Gm^3	=	10.8 TWh	=	39 PJ
Coal	1 Mtonnes	=	7–8 TWh	=	25–30 PJ
Forest fuels	1 Mton TS*	=	5–5.5 TWh	=	18–20 PJ
Forest fuels (40% moisture content)	1 Mtonnes	=	3 TWh	=	11 PJ
Peat (50% moisture content)	1 Mtonnes	=	2.5–3 TWh	=	9–11 PJ
Automotive petrol	1 Mtonnes	=	12 TWh	=	43 PJ
Methanol	1 Mtonnes	=	6.35 TWh	=	23 PJ

*Dry solids

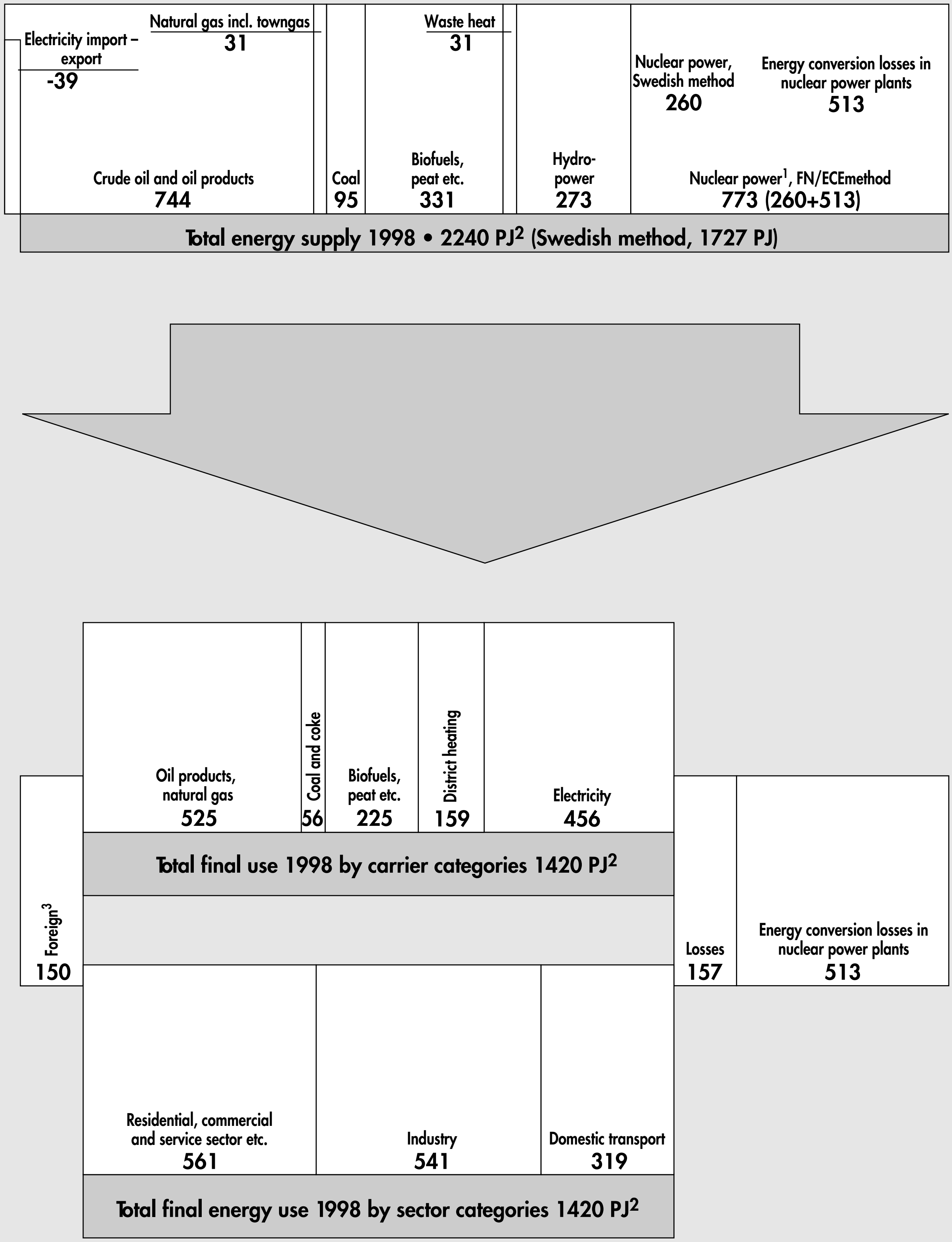
Domestic energy use

A family of four persons in a detached house uses about 5500 kWh per annum of domestic electricity. Average breakdown of domestic electricity is as follows:

Refrigerators and freezers	1 400 kWh
Food preparation	1 000 kWh
Clothes care	1 000 kWh
Lighting	900 kWh
Dishwashing	500 kWh
Other appliances	700 kWh
Total	**5 500 kWh**

A modern, energy-efficient washing machine in such a household should not use more than about 350 kWh/year, and a tumble dryer should not use more than about 560 kWh/year. Similarly, a new, larger, energy-efficient refrigerator should not use more than about 130 kWh/year, and a new energy-efficient medium-sized chest freezer should not use more than about 350 kWh/year.

Figure 1 • Energy supply and use in Sweden 1998, PJ



[1] The UN/ECE method includes the energy conversion losses in the nuclear power plants in the total energy supply which is the difference from the Swedish method.
[2] Preliminary figures. Due to rounding up or down of these figures, total figures may not always agree exactly with the sums of the individual items.
[3] Foreign maritime trade and energy for non-energy purposes.

Swedish National Energy Administration

The Swedish National Energy Administration was established on January 1, 1998, and is Sweden´s national authority on issues regarding the supply and use of energy.

The main task of the Administration is to implement the energy policy programme approved by the Riksdag in the spring of 1997. The aim of the programme is to establish an ecologically as well as economically sustainable energy system.

We work to promote a safe, efficient and environmentally sustainable supply and use of energy. We do so by supporting research on renewable energy sources and technology procurement of energy-efficient products and by providing investment support for the development of renewable energy.

The Administration also serves a supervising function as monitoring authority of the recently deregulated electricity market. The Department for Structural and Market Analysis provides analyses of the linkages between energy, the environment and economic growth.

Swedish National Energy Administration

Swedish National Energy Administration • Box 310 • SE-631 04 Eskilstuna • Sweden
Tel +46 16 544 20 00 • Fax +46 16 544 20 99 • www.stem.se

ET 82:1999/5.000 copies. November 1999. Ordförrådet. Alfa Print, Sundbyberg. Price: 40 SEK excl. VAT.