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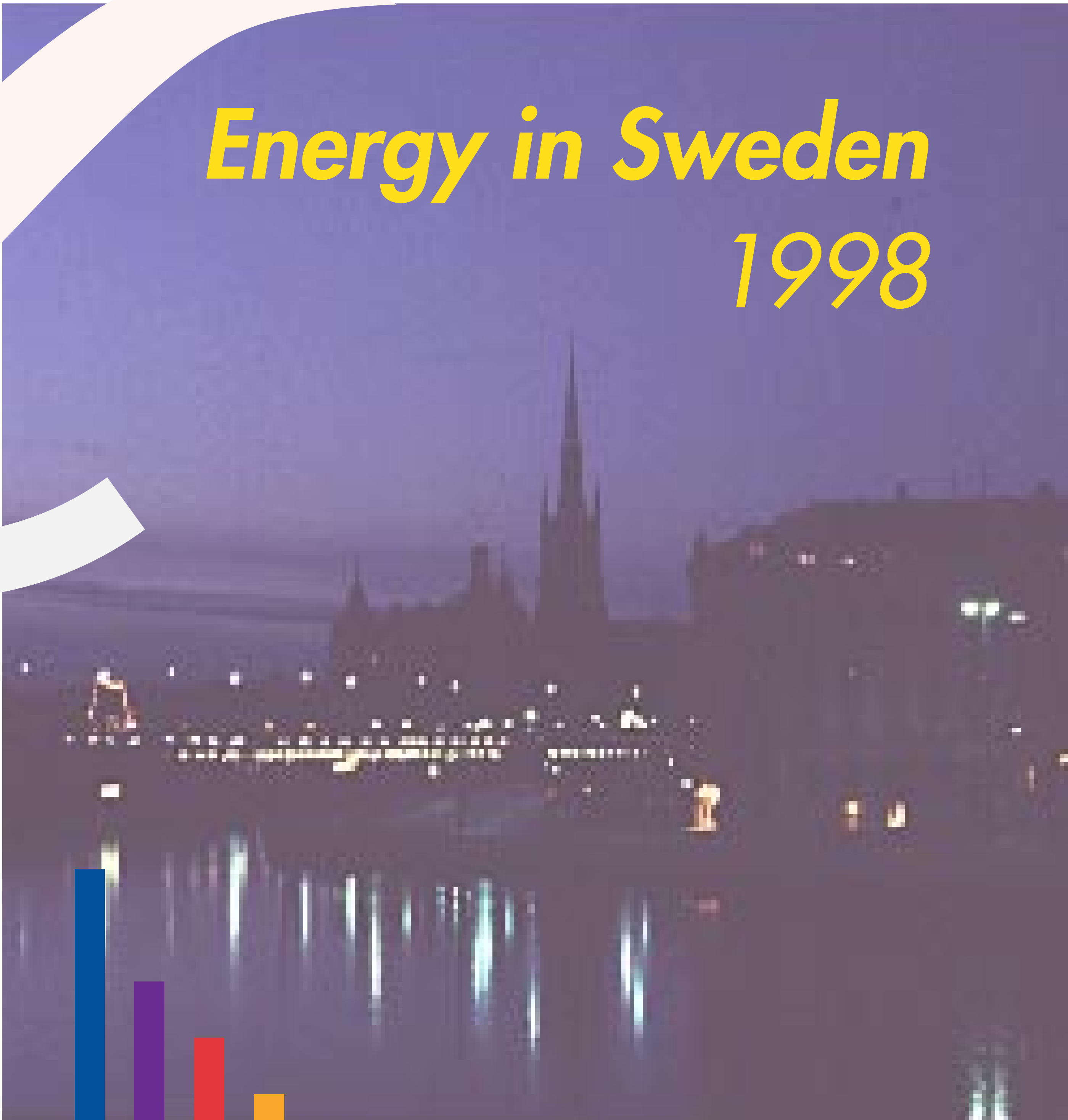

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Further information on the Energy Administration and its publications is available at www.stem.se.

Preface

Conditions governing change in the energy market are in a state of flux, with one of the reasons being the fact that the direction of main emphasis of energy and environmental policy in Sweden and in other countries is changing.

In recent years, Swedish energy and environmental policy has increasingly concentrated on creating or improving the long-term conditions for more efficient energy markets. The restructuring and deregulation of the Swedish electricity market, increasing internationalisation and the effects of the energy system on the environment and on climate, are important factors that influence the direction of policy and so the conditions under which the energy markets operate.

In June 1997, the Swedish Parliament decided, on the basis of the Government´s energy policy bill entitled ´A sustainable energy supply system for Sweden´, that the short-term and long-term objectives of the country´s energy policy should be to ensure an adequate supply of electricity and other necessary forms of energy on competitive terms – competitive, that is, with the rest of the world. The restructuring of the country´s energy system is part of Sweden´s ambition to be a leader in the creation of an ecologically and economically sustainable energy system. One of the points in the energy policy decision is that one of the Barsebäck nuclear reactors will be shut down in 1998, followed by the second one in 2001, provided that the loss of production can be compensated by a reduction in the demand for electricity and greater supply from other sources. However, in May 1988, the Supreme Administrative Court decided to postpone, for the time being, closure of the first Barsebäck reactor in June 1998.

Extensive energy policy programmes have been started in order to facilitate changes in both the supply and use of electricity and other forms of energy. A new public authority, the Swedish National Energy Administration was set up on January 1, 1998, with responsibility for implementing most of the energy policy programs and coordinating the work of restructuring the energy system.

The Energy Administration is also responsible for monitoring developments in the energy and environment fields and to provide 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 coherent and easily available information on developments in the energy sector.

We start with a presentation of developments in the energy system in Sweden, expanding the perspective to an overview of the international situation. We conclude with a presentation of the relationship between energy and the environment. ■

Stockholm, July 1998

Thomas Korsfeldt
Director-General

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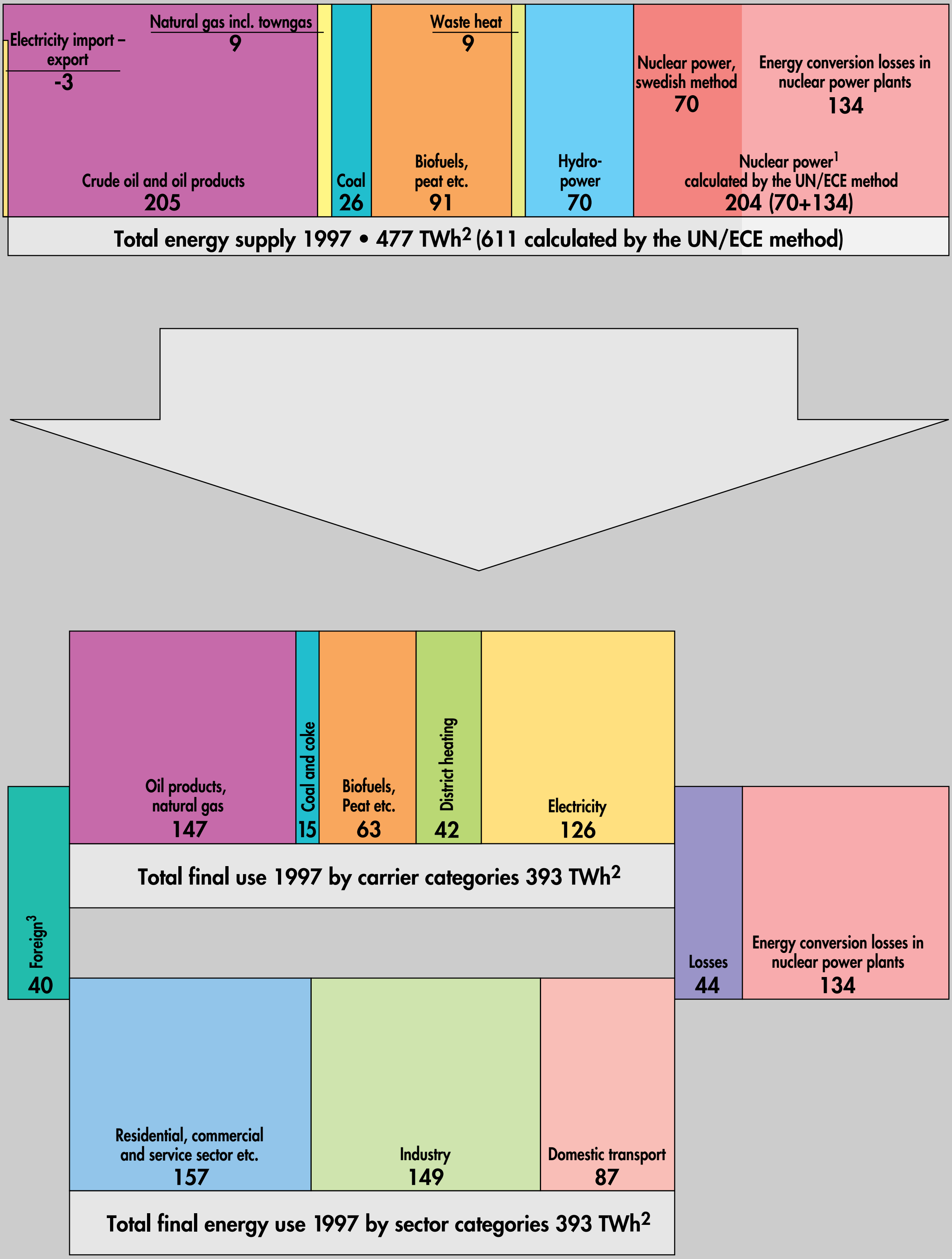
Head of Section, Analysis and Evaluation

Figure 1 • Energy supply and use in Sweden 1997, 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 Swedish way of presenting the figures, the country's energy supply in 1997 amounted to 477 TWh. Average energy supply from 1970 to 1997 has been about 440 TWh/year, with only modest variations. Using the international method, Sweden's energy supply has increased by 34 % between 1970 and 1997, from 457 TWh to 611 TWh.

The constituents making up the total energy supply have changed considerably over these years. In 1970, crude oil and oil products accounted for 77 % of the total energy supply, but had fallen to 43 % by 1997. Nuclear power production started during the period, while hydro power production during a statistically average climatic year has 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 72 TWh/year 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 29 % in 1997, when calculated by the Swedish method. Calculated by the international method, the 1997 proportion is 45 %. 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 1997, these proportions had increased to 5 % (4 %) and 19 % (15 %) 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 7 TWh and 4 TWh higher than would have been the case in a normal year. 1997, on the other hand, was warmer than an average year, and so energy supply was 2.5 TWh less than would otherwise have been the case. ■

[1] *Figures in brackets show the shares of different fuels 1997 according to the international method.*

Figure 2a • Total energy supply in Sweden 1970-1997

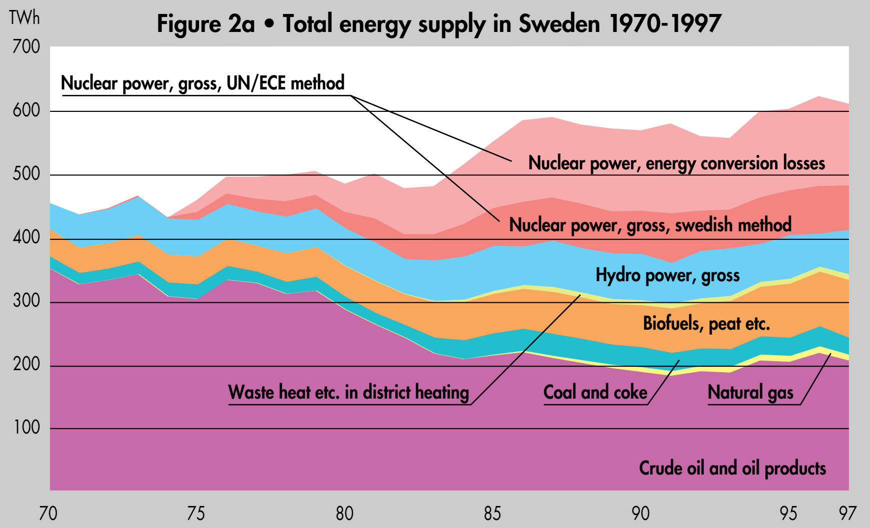
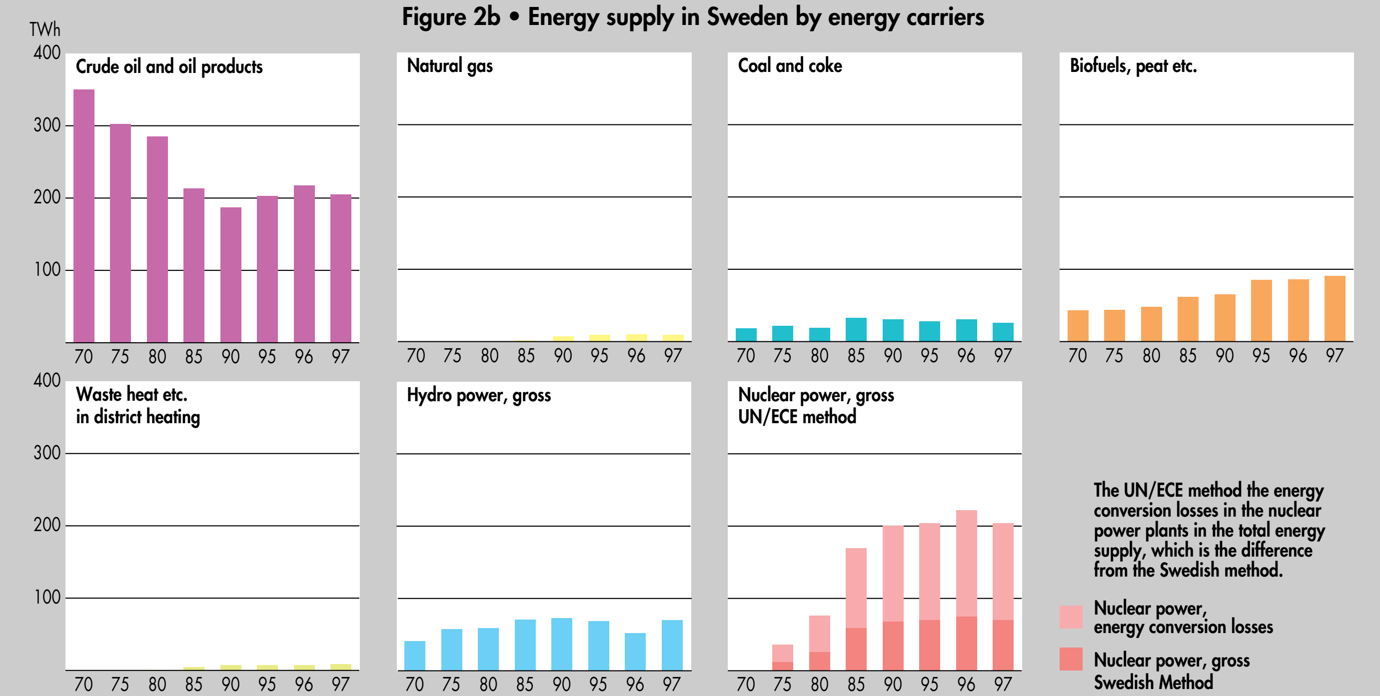


Figure 2b • Energy supply in Sweden by energy carriers



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 by industry and the residential/service sectors etc. have remained more or less stable between 1970 and 1997. 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, for example, were warmer than normal, 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. 1997 swung the other way, and was warmer than normal, resulting in a decline in energy use relative to that of the previous year.

As can be seen from Figure 1, total final energy use in 1997 amounted to 393 TWh. To this must be added 40 TWh for overseas shipping etc. and 44 TWh for losses, giving a total energy balance of 477 TWh for the year. Using the international method of calculating the figures, the losses associated with nuclear power production would be 134 TWh higher, to produce a total loss figure of 177 TWh. ■

Figure 3a • Total energy use in Sweden 1970-1997

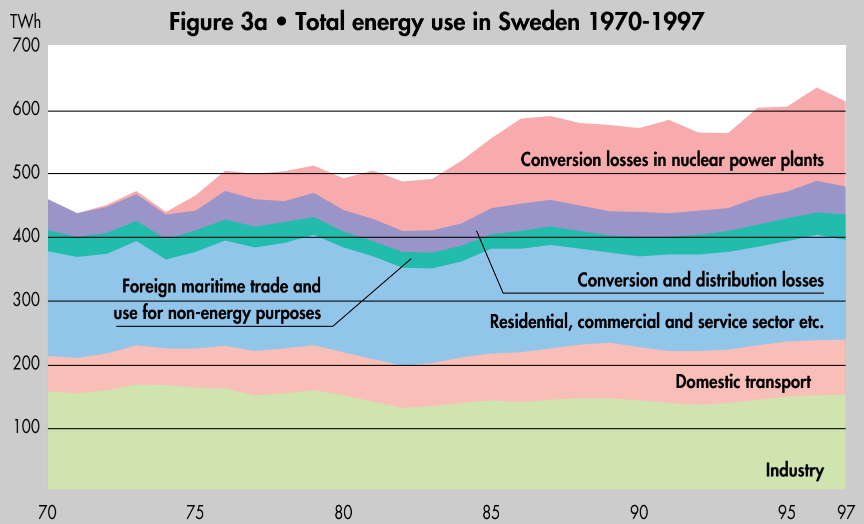
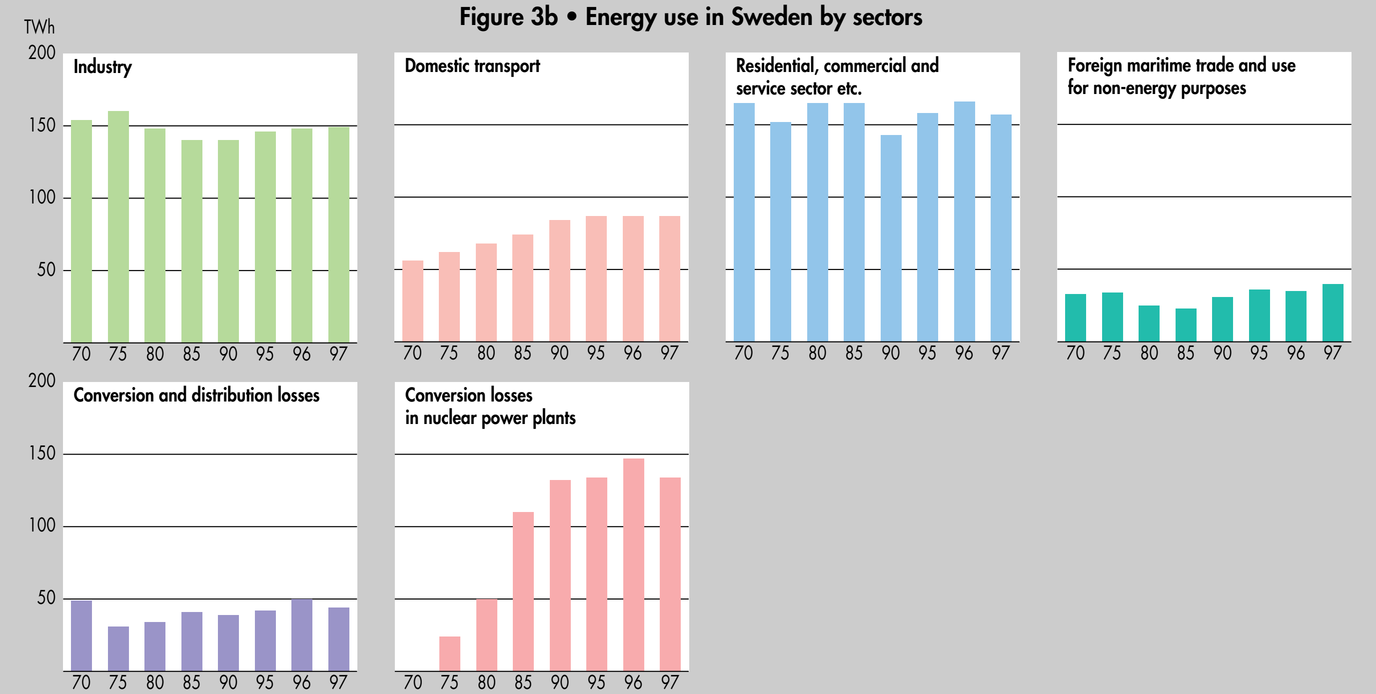


Figure 3b • Energy use in Sweden by sectors



1997 was the second year of the deregulated electricity market in Sweden and Finland: Norway had deregulated its electricity market in 1991. 1997 was characterised by growing competition on the electricity market and good availability of hydro power, which kept prices in the electricity pool down. Several new players, such as oil companies, have established themselves as sellers of electricity. Some concentration of ownership has been noted in the last two 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 forms as takeovers, 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 distribution 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. The first of the three consists of the French EdF and Graninge. The second comprises the Finnish IVO, working with and through Gullspång to form a common company with Stockholm Energi, Birka Kraft. Finally, there is Sydkraft, with the German PreussenElektra and the Norwegian Statkraft.

Electricity use

Figures 4a and 4b show the growth in electricity use in Sweden since 1970. On average, use has increased by 3.1 % per annum since 1970, amounting to about 142 TWh in 1997. Although electricity use increased by about 5 % per annum from 1970 to 1986, there has been a considerable easing off in the rate of growth since then, so that electricity use increased by only 0.3 % per annum from 1987 to 1997.

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 71 TWh in 1997, or 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. 1997 was warmer than an average year, which meant that electricity use decreased. In statistically average temperature conditions, the use of electricity for heating would have been about 0.6 TWh higher.

On average, the use of electricity in industry has increased by 1.7 % per annum since 1970. During 1997, industrial use amounted to 53 TWh, equivalent to 37 % of the country's total use of electricity. The use of electricity by industry is closely linked to industrial output in a few major sectors. The pulp and paper industry, for example, accounts for

Figure 4a • Use of electricity in Sweden 1970-1997

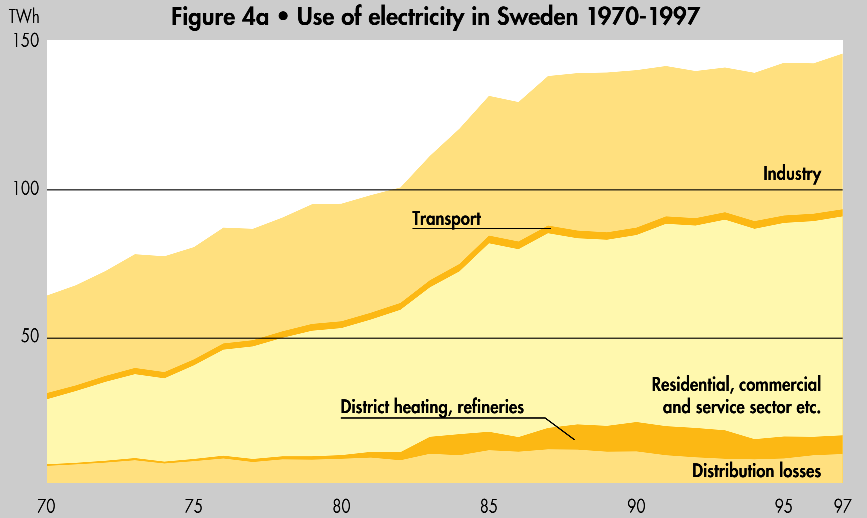
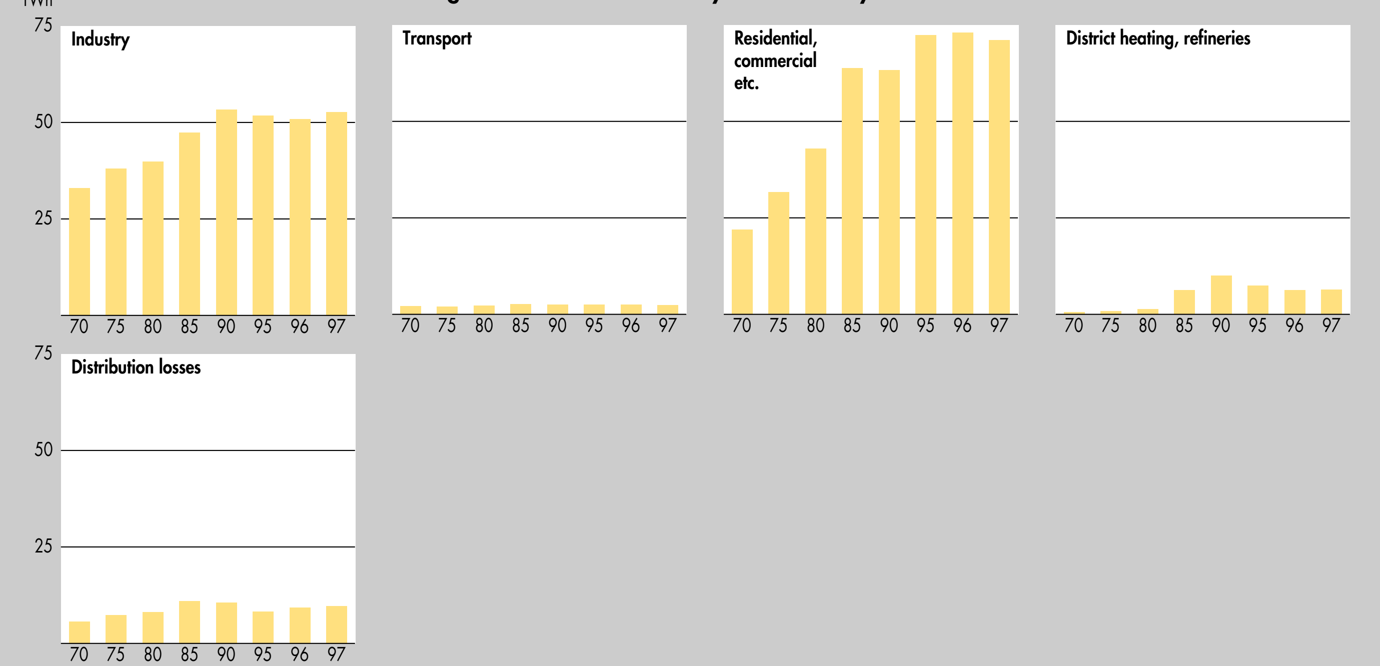


Figure 4b • Use of electricity in Sweden by sectors



about 40 % of the total use of electricity 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 (2.4 TWh in 1997, most of which was for rail-borne transport) and for district heating and refineries (6.4 TWh in 1997). Total electricity use also includes the losses associated with the transmission of electricity, amounting to 9.8 TWh in 1997.

Supplies to interruptible electric boilers are also included in the figures for total electricity use. Until deregulation 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 deregulation, 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 can be owned by the State, by local authorities, by industry or by commercial utilities. Seven larger power companies together produced about 133 TWh, or 92 % of Sweden's total electricity output, in 1997. The country's two largest producers, Vattenfall and Sydkraft, accounted for 70 % of the total production.

Most of the 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 back-pressure generation, oil-fired cold condensing plant, gas turbines or wind power.

Back-pressure plant 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.

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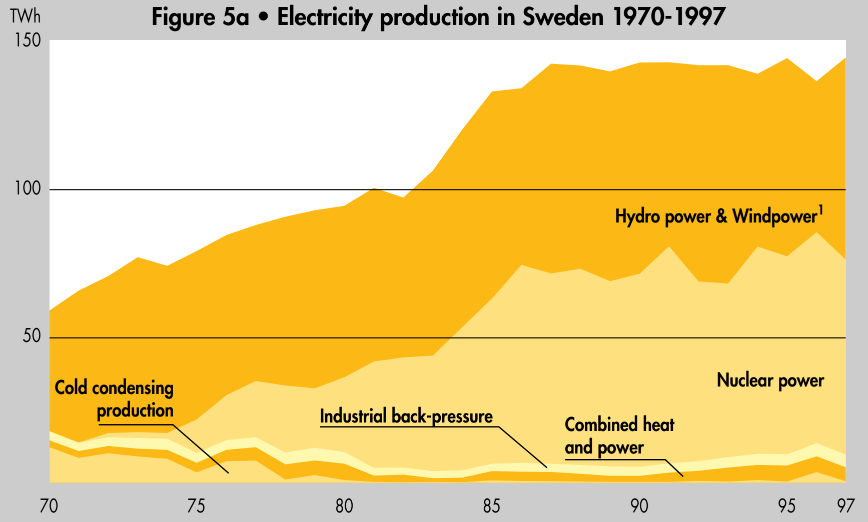
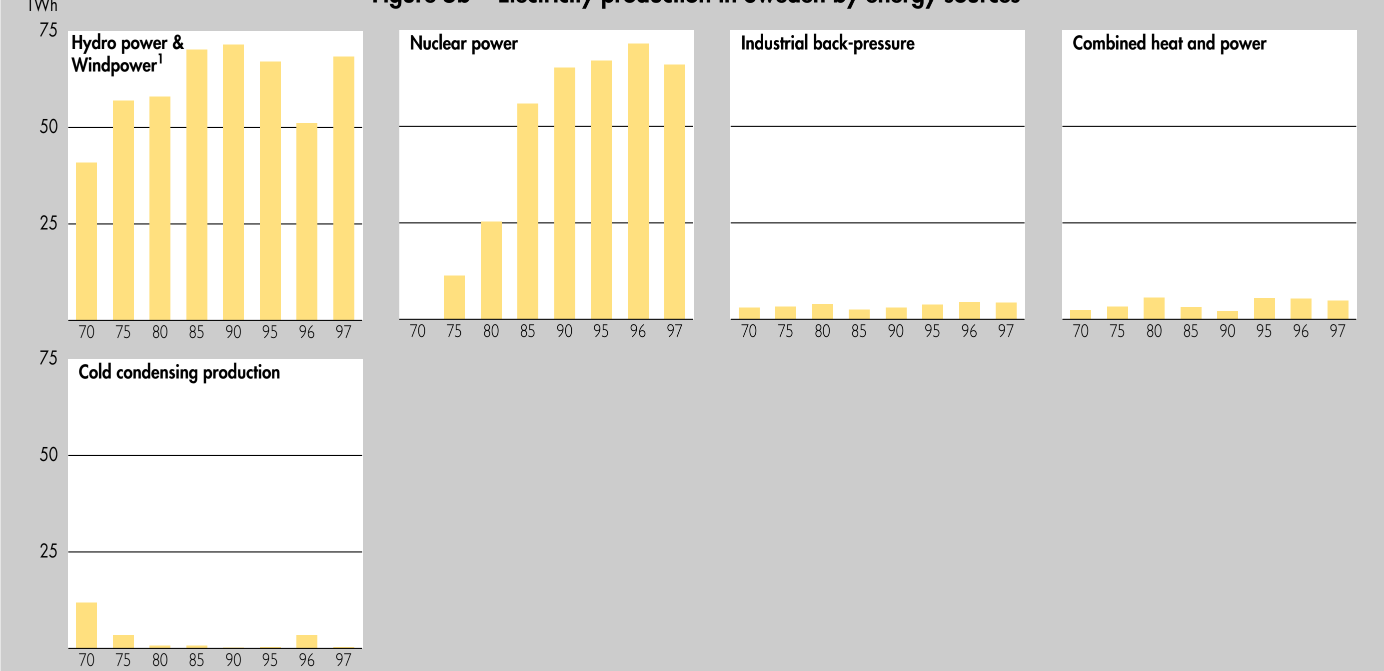
Figure 5a • Electricity production in Sweden 1970-1997



[1] *212 GWh of wind power were produced in 1997.*

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. This capacity may also be needed during economic boom periods, unusually cold years or in the event of unplanned shutdowns of other power production capacity. However, the substantial expansion of nuclear power generation capacity since the beginning of the 1970s has greatly reduced the proportion of electricity supplied from oil. Restructuring of the electricity market coupled with greater internationalisation, has meant that several cold condensing power stations have been mothballed, as it is not economic to keep them ready to start.

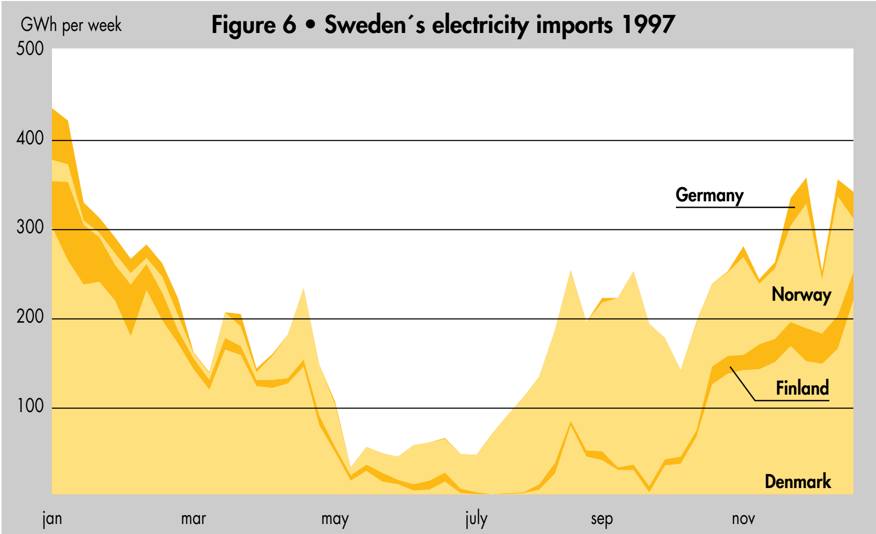
There are also about 330 wind power plants in the country, but their contribution to the total electricity balance is still very small (0.2 TWh in 1997).

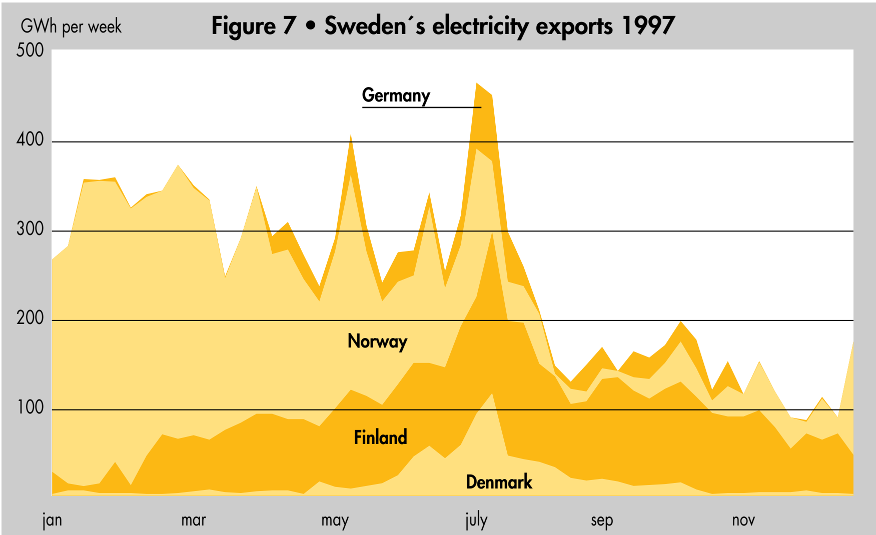
Figures 5a and 5b show the proportions of output from different types of production plant since 1970. In 1997, the country produced 145 TWh of electricity. 1997 was a wet year, with the result that hydro power production amounted to 68 TWh or 47 % of the total electricity production. Nuclear power produced 67 TWh or 46 % of production. Together, hydro power and nuclear power provided 94 % of the country's total electricity supply, with 6 % being produced by back-pressure power plant.

Trade in electricity

Electricity is traded between parties such as producers, distributors and traders. Not only is it bought and sold within Sweden, but also with other countries to which there are transmission links. The Nordic Power Exchange, 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 two 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 – which in principle also includes those in other countries - have been able freely to select their suppliers. Swedish producers are therefore able to sell electricity directly to customers in Denmark, Norway and Finland, and producers in those countries can also sell to customers in Sweden.





Source: Swedish Power Association.

Trade in electricity between the countries varies from year to year, both in terms of quantities and overall (net) 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 therefore of hydro power production, in the Norwegian system, substantially complemented by 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, with Denmark becoming a net exporter to Norway and Sweden, which means that the Danish system provides reserve capacity for the Nordic electricity production system.

Sweden's total import of electricity in 1997 amounted to 10.2 TWh, which is a substantial drop from 1996' import of 15.8 TWh. Somewhat more than half of this electricity (5.2 TWh) was purchased from Denmark, with about 3.8 TWh from Norway, rather less than 1.0 TWh from Finland and 0.4 TWh from Germany.

Total exports of electricity to neighbouring countries in 1997 amounted to 12.8 TWh, which is an increase of 3.2 TWh over the previous year. Sales to Denmark and Finland increased, while those to Norway fell. In total, Sweden was a net exporter of electricity in 1997 (2.6 TWh). Figures 6 and 7 show how the power flows varied during the year. ■

During 1997, use of biofuels, peat etc. amounted to over 90 TWh. Fuels included in this category, and mostly produced in Sweden, are:

- digester 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

For cost reasons, the forest products industry has always used its byproducts for heat and some electricity production. Digester liquors remaining after chemical processing of wood to produce wood pulp are burnt to recover certain chemicals. They can be produced and used only within the cellulose industry, and provided almost 33 TWh of energy (excluding electricity production) in 1997.

Wood fuels in the form of raw materials residues are used in both the cellulose 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 1997, the cellulose industry used a total of 6.9 TWh of such materials for energy production, while sawmills and other woodworking industries used 9.6 TWh.

District heating plants

A total of 25 TWh of indigenous fuels were used in the district heating sector in 1997. Of this, wood fuels accounted for 13.7 TWh, unrefined tall oil for 1.4 TWh, refuse for 4.7 TWh and peat for 3.2 TWh.

The use of wood fuels by the district heating sector has almost tripled over the last five years. In 1997, use rose by 1.3 TWh or 10 % relative to the previous year. The main form of the fuels is felling waste and forest byproducts, although processed fuels such as briquettes and pellets have also been increasingly used in recent years, as has tall oil (a residue from pulp production).

Refuse has been used for district heating production since the 1970s, and has settled fairly steadily at around 4.7 TWh. The problems of removal of dioxin emissions have now been satisfactorily solved. Sorting at source reduces the quantity of domestic refuse that can be burnt, while industry has a potential for 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, vehicle tyres etc., have been imported in recent years, but the quantity is difficult to estimate

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Figure 8a • Use of biofuels, peat etc. in industry 1980-1997

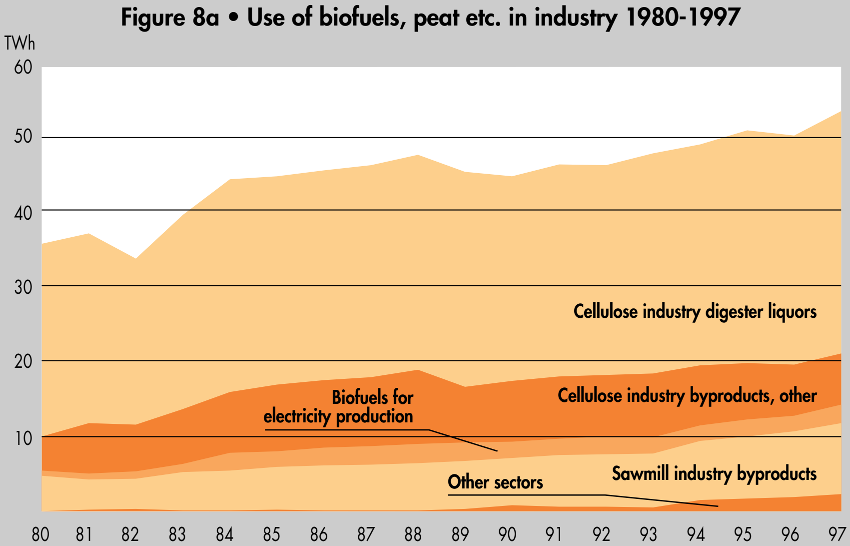
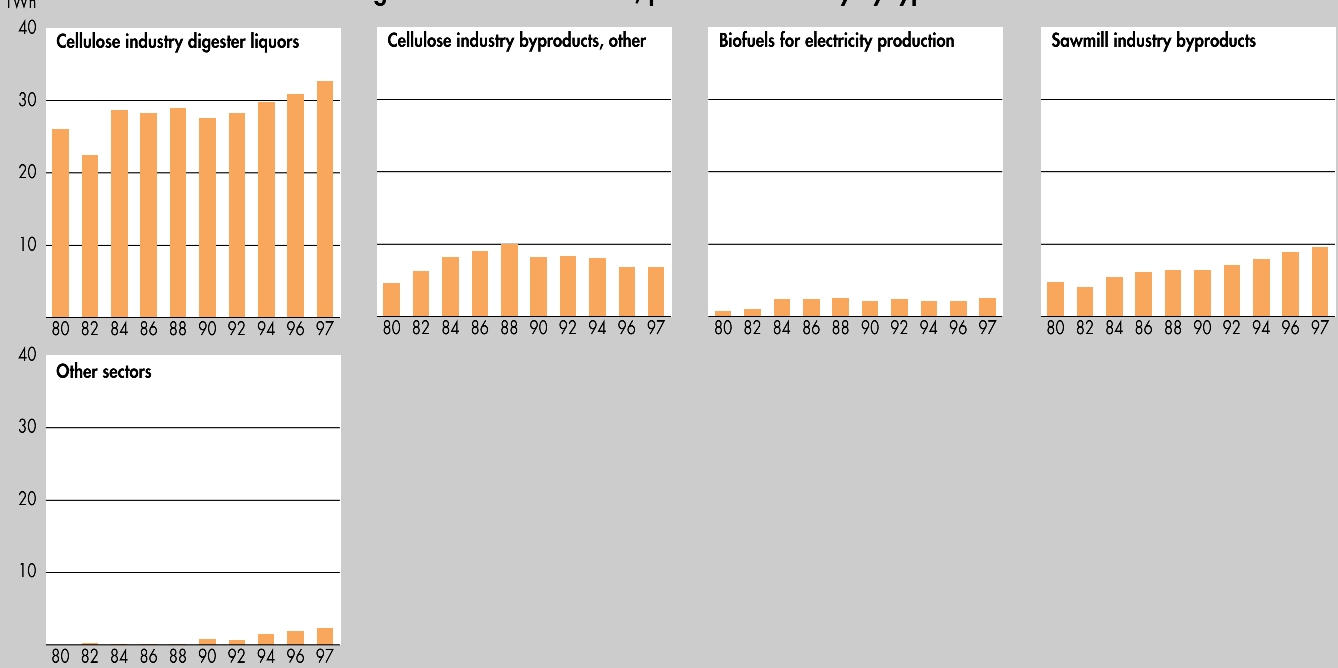


Figure 8b • Use of biofuels, peat etc. in industry by types of fuel



The use of peat in 1997 amounted to 3.2 TWh, which is 0.3 TWh less than during the previous year. Production is dependent on the weather, and can therefore vary from year to year. Production in 1997 amounted to 3.4 million m^3, which was somewhat less than the average for the 1990s. During good years, stocks are built up for use in future years if less should be produced.

Experimental use has been made of energy crops such as energy forests, straw and energy grass since the beginning of the 1990s. About 0.11 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 17 000 hectare that have been planted with energy forest are expected to fall to about 15 000 hectare as land is turned over to the production of more profitable crops, such as cereals, as a result of the EU common agricultural policy

There was a relatively extensive commercial import of biomass fuels during the year, e.g. 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 1997. Imports account for about 35-40 % of the supply of biofuels for district heating plants, which means that they are now a substantial raw materials source. They are imported at prices which are below those on the home market, which means they exert a certain price press on indigenous biofuels. For some individual heating plants, imported fuels form an important part of their fuel supply. The potential of biofuels is considerable, both as a raw material and for its possible use in Sweden and in neighbouring countries, and so an increasingly important international trade in biomass fuels could develop in the future: the magnitude of this trade will depend on market development

The detached house sector

About 12 TWh of biofuels peat etc., mainly in the form of logs and chips, were used in single-family houses in 1997. Wood firing is commonest among property-owners with good access to forests, e.g. in agricultural or rural areas.

Electricity production

Almost 4 TWh of biofuels were used for electricity production. About 1 TWh of this was produced from wood fuels in CHP plants supplying district heating. Of the remainder, about 1.2 TWh was produced from wood fuels in industrial back-pressure plant and the same quantity from digester 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 1980-1997

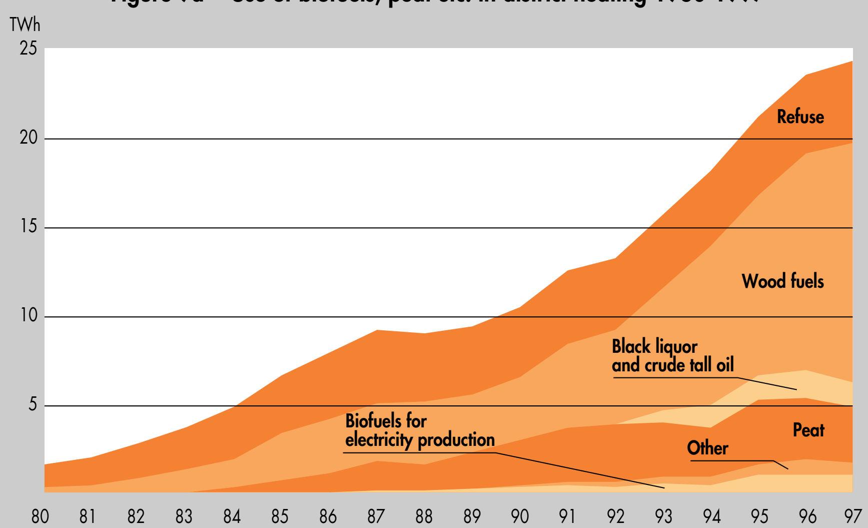
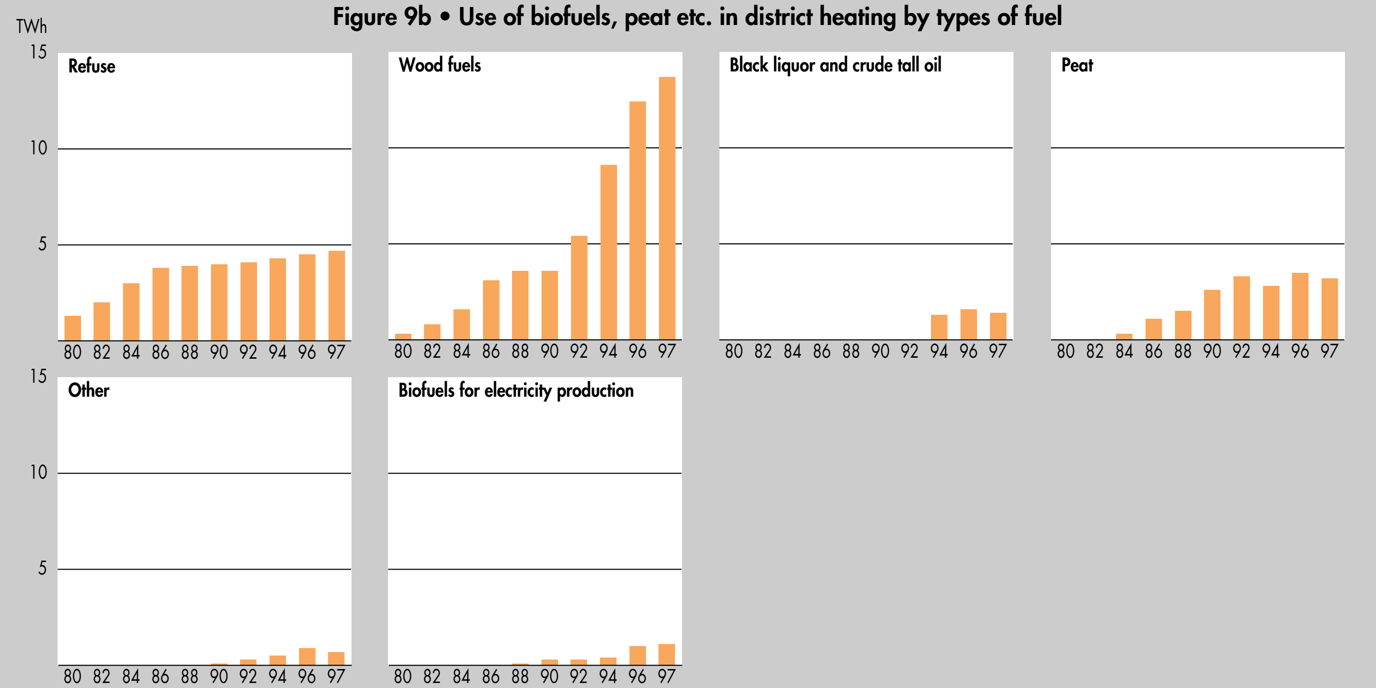


Figure 9b • Use of biofuels, peat etc. in district heating by types of fuel



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. CHP stations produce heat and electricity simultaneously. Some of the district heating utilities also supply district cooling which, instead of supplying 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. The biggest growth in district heating occurred during 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 low-density 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 1997. Of them, about 165 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 directly or indirectly by the State and 9 % were operated as local authority services.

The nominal connected load in 1997 amounted to about 22 GW, supplied through about 9600 km of mains.. During the year, 42.2 TWh of heat were supplied, equivalent to 43.1 TWh after correction for statistically average climatic conditions. 56 % of the heat was supplied to residential users , almost 36 % to the service sector and over 8 % to industry.

A total energy input of 48.6 TWh, made up of 35.9 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. Since then, a wider range of fuels has been used, so that nowadays wood fuels, peat, refuse etc. are the main energy inputs for district heating systems, accounting for 24 TWh, or over 49 %, of the total energy input in 1997. Other energy inputs included oil (5.0 TWh), heat pumps (7.0 TWh), coal and blast furnace gases (3.7 TWh), natural gas and LPG (3.5 TWh), waste heat (3.8 TWh) and electric boilers (1.9 TWh). Over 2 TWh of electricity were used to power the heat pumps, while a further 1 TWh was 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 deregulation 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, with the result that it is therefore cheaper to produce heat using the heat pumps.

The high proportion of electricity as an input energy carrier for district heating systems has meant that losses have been reduced: conversion and distribution losses amounted to 6.4 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.

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Figure 10a • Use of district heating 1970-1997

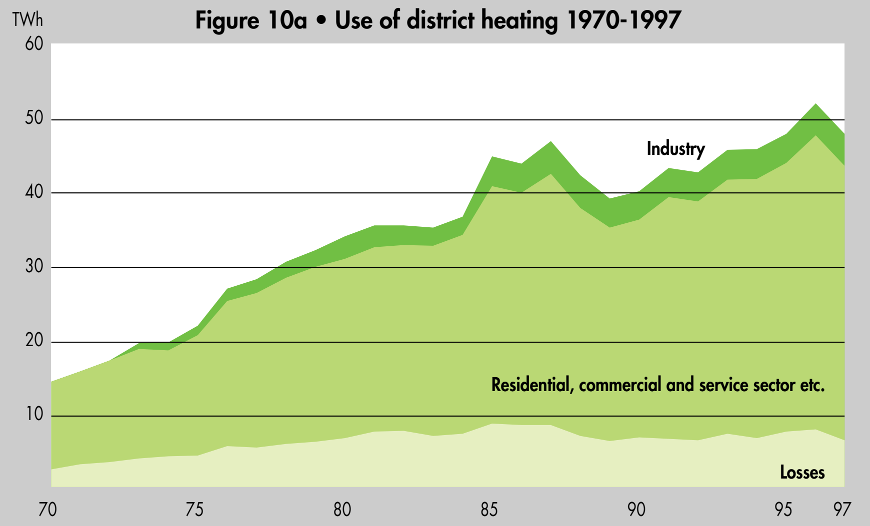
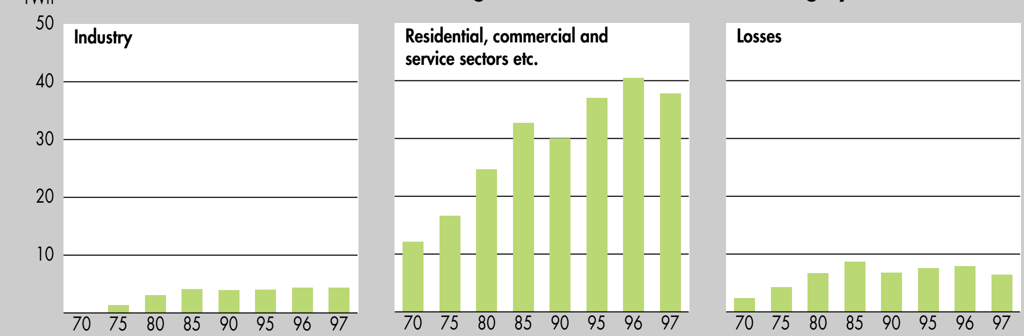


Figure 10b • Use of district heating by sectors



District cooling

District cooling made its appearance in Västerås in 1992, during which year about 1.2 GWh (0.001 TWh) of district cooling were supplied through about 1 km of mains. Stockholm Energi started to supply district cooling to central Stockholm in 1996, taking the cooling from (or, more correctly, discharging the heat to) 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.

The market for district cooling has expanded strongly in the five years since its introduction, caused by such factors as new building regulations, the greater use of computers and more awareness of the importance of good working conditions. District cooling is used primarily by offices and shops, although also for the cooling of various industrial processes.

In 1996, there were eleven producers of district cooling, supplying a nominal load of almost 90 MW through almost 28 km of mains, and meeting a load of about 0.07 TWh (67 GWh). Preliminary calculations indicate that the quantity of district cooling supplied in 1997 has more than doubled, partly as a result of increasing demand and partly as a result of relatively extensive expansion of the supply mains systems and of the entry of new utilities to the market. Demand will 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 1992-1996

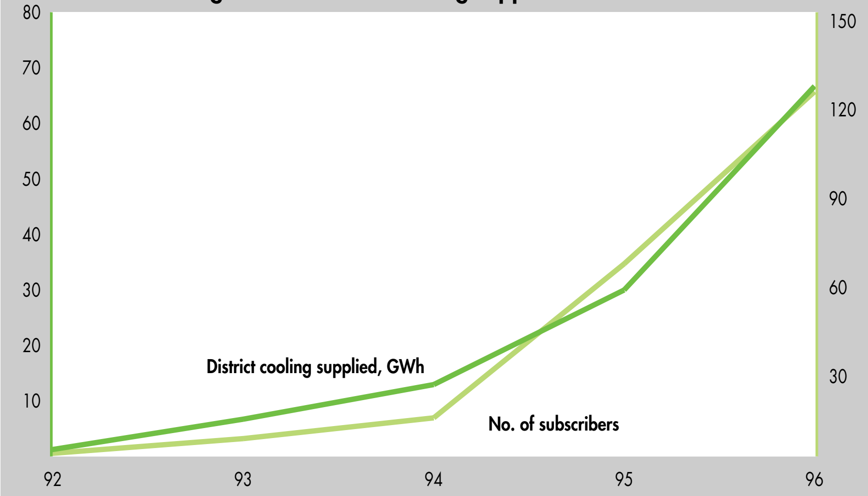


Figure 12a • Energy supplied to district heating 1970-1997

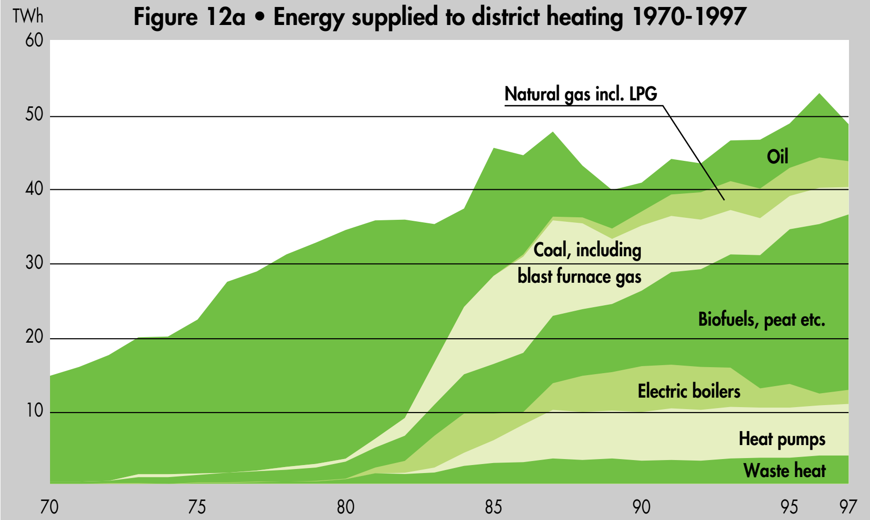
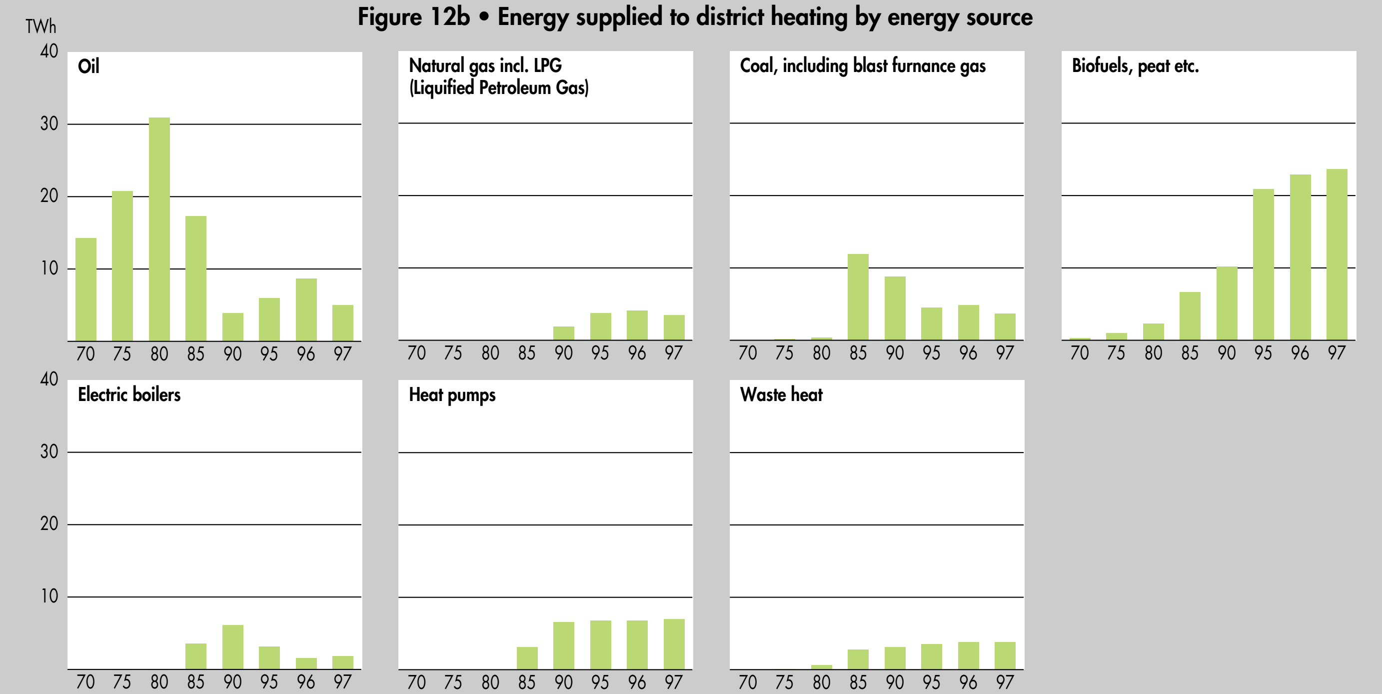


Figure 12b • Energy supplied to district heating by energy source



Sweden used almost 17 million m³ of oil in 1997, 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 use of oil in the country.

During 1997, total import volume decreased by over 7 % relative to the previous year. Much of this decrease was due to the fact that 1997 was a year of normal precipitation, as compared to 1996, which was not only a dry year but also colder than normal. 34 % of the total import volume of over 31 million m³ was imported from Norway.

60 % of the country's crude oil imports in 1997 came from the North Sea and 11 % from Saudi Arabia. Sweden has been a net exporter of refinery products since 1989: exports in 1997 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 heavy fuel oils in 1997, for example, amounted to only 33 % of the volume that was supplied to the Swedish market in 1979. Fuel oils have largely been replaced by electricity and district heating for heating purposes, although the expansion of nuclear power production, district heating and the country's natural gas supply system 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. With effect from 1997, this information has been provided to SCB directly by the oil companies, which means that foreign trade statistics are more accurate than previously. ■

Figure 13 • Swedish imports of crude oil and petroleum products, 1972-1997 by country of origin (million tonnes, net)

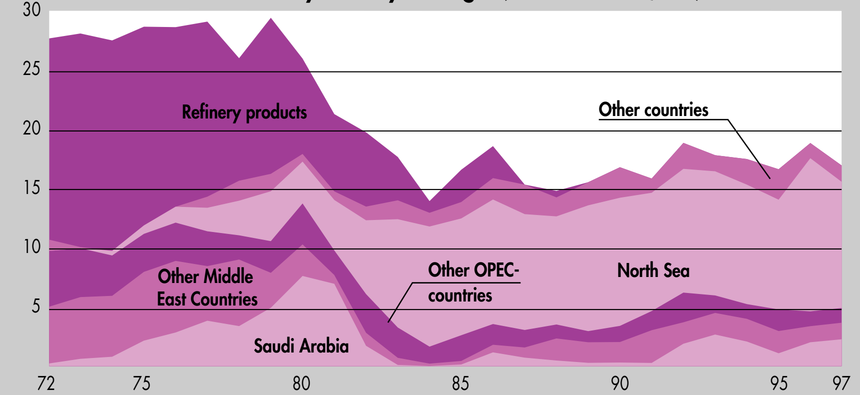


Figure 14a • Use of oil products 1970-1997

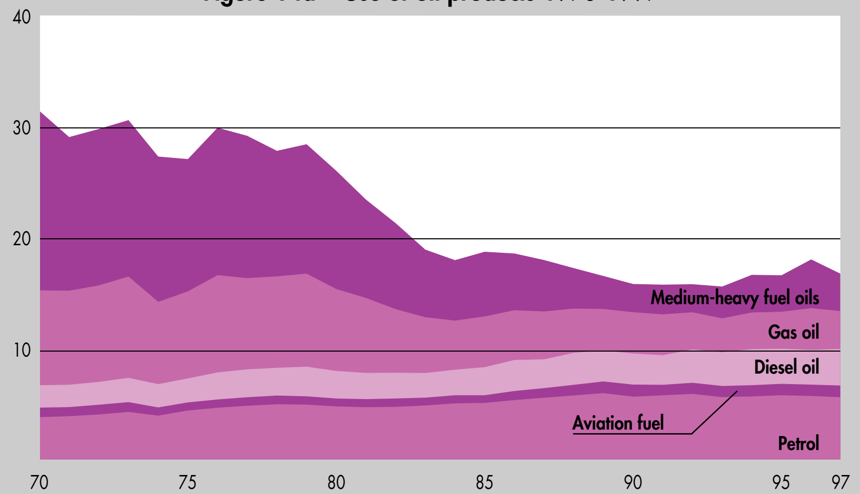
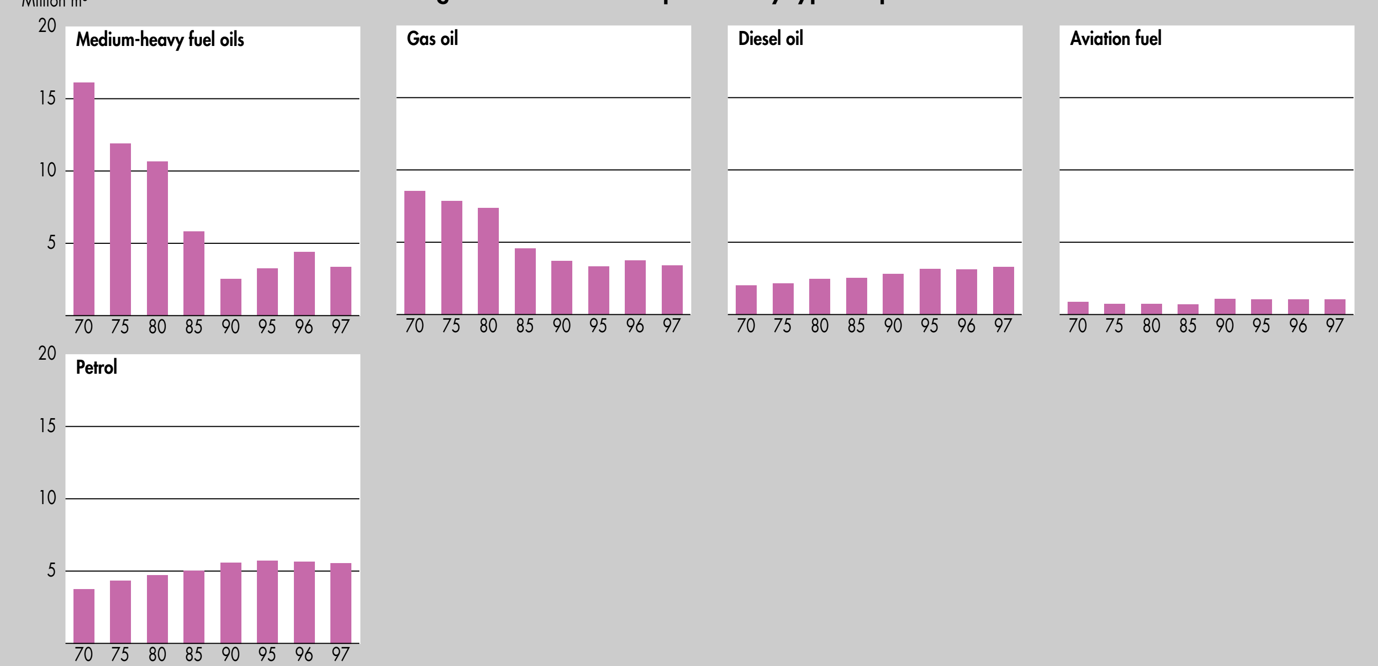


Figure 14b • Use of oil products by types of products



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.

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 1997 this had fallen to 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 1997 amounted to 1.6 million tonnes, which is somewhat less than during the previous year. Imports came from seven different countries, with Poland supplying the greatest proportion (about 32 %). Other countries from which Sweden imported coal were the USA, Australia, 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 two local authority heating plants, and for combined heat and electricity production in a further twelve plants. The plants that produced only heat used about 22 000 tonnes, which was an decrease relative to the previous year's 35 000 tonnes. For comparison, in 1994, use had amounted to 118 000 tonnes. Combined heat and power (CHP) stations used about 360 000 tonnes, or somewhat less than during the previous year, for heat production. The use of coal for electricity production in these power stations was only about half that of the previous year, amounting also to 360 000 tonnes. This was because 1997 was a wet year, with plentiful hydro power production, so that the use of coal for power and heat production fell to a more normal level. The total energy input in the form of coal to the district heating and CHP sector for heat and electricity production in 1997 amounted to 5.5 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. The use of energy coal in 1997 amounted to 704 000 tonnes, equivalent to 5.3 TWh. Industrial use of energy coal has declined in recent years, from 843 000 tonnes in 1991 to 704 000 tonnes in 1997, as a result of a switch to other fuels and a fall in industrial output. 1.7 million tonnes of coking coal were used, primarily for coke production. 1.5 million tonnes of coke were used, which was about the same as during the previous year. The total use of all forms of coal and imported coke was 3.5 million tonnes, which was about 0.5 million tonnes more than in 1996. ■

Figure 15a • Use of energy coal 1985-1997

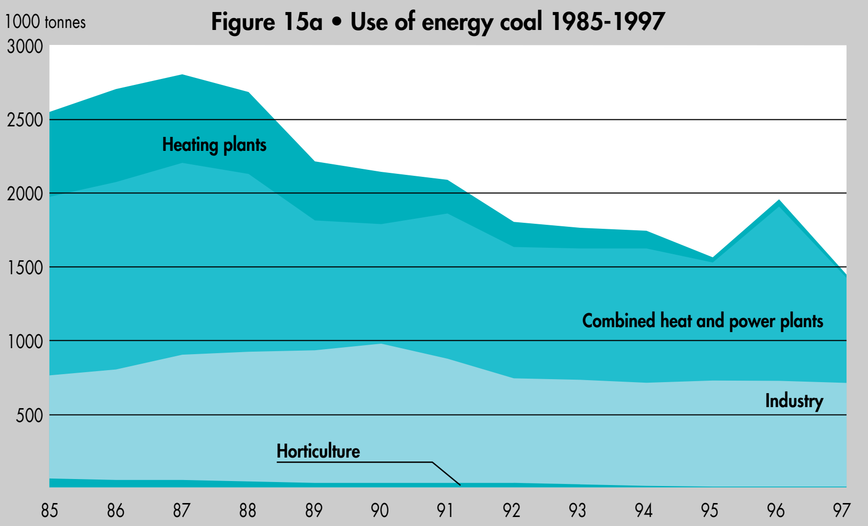


Figure 15b • Use of energy coal by sectors

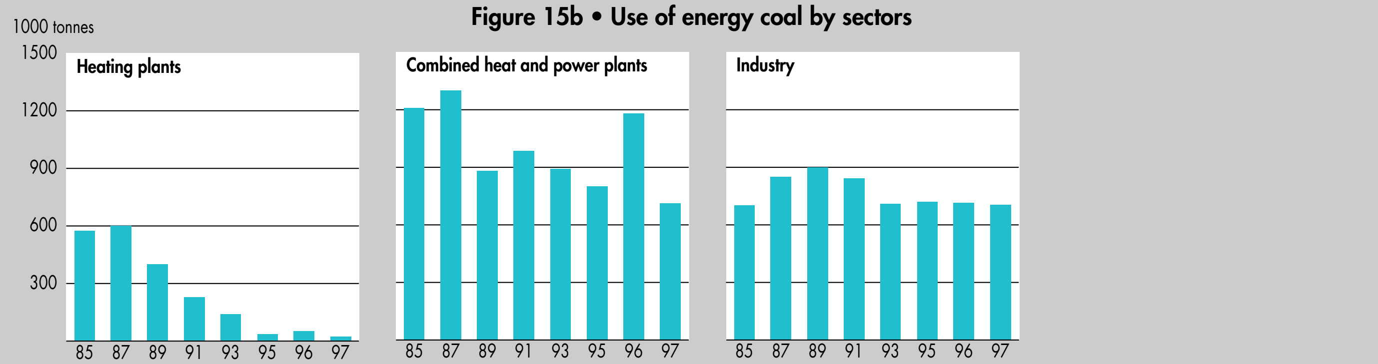
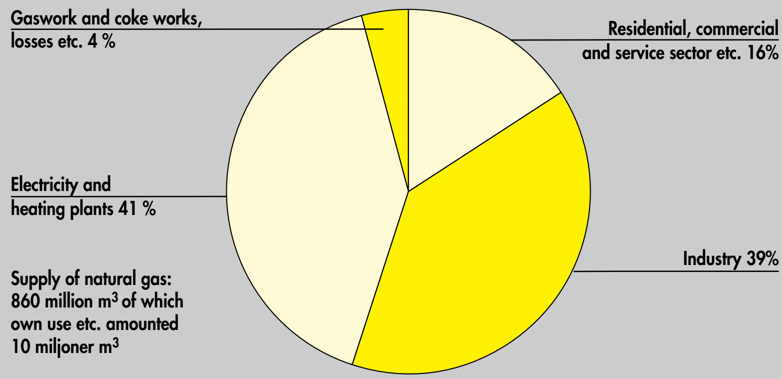


Figure 16 • Supply and use of natural gas by sectors in Sweden 1997



Natural gas

Sweden's interest in natural gas was aroused by the oil crises of the 1970s, and its use has gradually increased, stabilising at its present level, since its introduction to Sweden in 1985. However, interest in natural gas as an alternative fuel, primarily to replace oil and coal, has increased since the deregulation of the Swedish energy system in 1996. Interest has also increased in our neighbouring countries, and the question of a possible Nordic natural gas network is being investigated at present in a joint Nordic project.

The gas comes from 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, while SydGas AB is responsible for the branches in southern Sweden. Today, natural gas meets about 20–25 % of energy demand in several of the towns having a supply, and for about 2 % of the country's total energy supply.

Imports of natural gas in 1997 amounted to 860 million m^3, equivalent to about 9.3 TWh, a reduction of over 1 % relative to 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 8200 private customers. A smaller quantity of natural 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 39 % and 41 % of Swedish gas consumption respectively in 1997.

Natural gas is a combustible mixture of gaseous hydrocarbons, consisting mainly of methane, and 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 or oil.

LPG

Imports of LPG to Sweden in 1997 amounted to 849 000 tonnes, while 230 000 tonnes were exported. 592 000 tonnes were supplied to the Swedish energy system, equivalent to 7.6 TWh, representing an increase of 10 % relative to the previous year.

LPG is used mainly in industry, complemented by use in the restaurant sector and for CHP and heat production. As much of its use is interchangeable with that of oil and, to some extent, with that of biofuels, 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 1997, 4.9 TWh were used in industry and 0.5 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 is produced when organic matter, such as sewage sludge, refuse or industrial waste is decomposed by bacteria under anaerobic (oxygen-free) conditions. The process, called digestion, occurs spontaneously in nature, e.g. in marshes. The gas contains a considerable quantity of energy from the decomposed material. Today, there are about 100 biogas plants in use in the country. Most are in sewage treatment plants, digesting sewage sludge, or on landfill sites, producing landfill gas. Biogas is used primarily for local heating or for district heating or electricity production. It can also be used as a motor fuel: interest in this particular application has been growing over the last ten years. The number of outlets for motor fuel biogas is increasing, and it is often urban bus fleets and distribution vehicles that use it. 1.4 TWh of biogas were produced in 1997.

Town gas

Town gas is produced from naphtha, with SE Gas AB in Stockholm being the country's only producer. Half of the gas is used for space heating of larger properties and by industry in Greater Stockholm, with the remainder being used by detached houses, restaurants and for cooking. 0.4 TWh of town gas were used in 1997.

Hydrogen

Today, hydrogen is used where it occurs as a byproduct of industrial processes, with AkzoNobel operating four of the five largest industrial plants that produce surplus hydrogen. The gas is used internally for the production of hydrogen peroxide, but the quantity is not enough so further hydrogen has to be supplied to the process. About 130 000 tonnes of hydrogen are produced in Sweden each year.

Hydrogen can also be used in fuel cells, where it is converted to electricity and heat. There are at present three demonstration installations in Sweden, producing electricity and supplying heat to district heating systems.

Pure hydrogen does not occur naturally, but has to be produced by an industrial process, such as from LPG or natural gas. To produce a quantity of hydrogen containing 100 kW of energy requires a process input of 125 kW of electrical energy: the 'surplus' is released from the process as heat.

Research is in progress aimed at finding more environmentally sound ways of producing hydrogen and efficient means of storing the gas. When hydrogen technology matures, it may be possible to use the present natural gas distribution network for carrying hydrogen. ■

In 1997, energy use in this sector amounted to 157 TWh, or 40 % of the country's total final energy use. This represents an decrease of 8.6 TWh, or 5.2 %, relative to the previous year. The largest portion of this energy, 107.2 TWh, was used for space heating and domestic hot water production in residential buildings and commercial premises. Other energy use was primarily in the form of electricity for domestic purposes and for the operation of building services systems in residential buildings and commercial premises. The figure also includes energy used in holiday homes, land use applications (agriculture, forestry and fishing) and other service applications. These latter consist of energy use in power stations, waterworks and effluent treatment plants. Street lighting and building and civil engineering construction are also included in this category.

As energy for space heating and domestic hot water production accounts for such a large proportion (about 68 % in 1997) of energy use in the sector, it is necessary to correct for climatic conditions if comparisons are to be made between figures from year to year. After applying such correction, energy use in the sector in 1997, which was warmer than normal, amounted to 159.6 TWh, which is a slight decrease of 1.2 % relative to the figure for 1996.

The proportion of total energy use in the sector supplied by oil products has fallen from about 72 % in 1970 to 23 % in 1997. However, at the same time, there was a substantial increase in the use of electricity. In 1970, electricity supplied about 13 % of the sector's total energy use, while by 1997 this proportion had risen to over 45 %. The proportion of this load supplied by district heating has also increased during the period, from about 7 % to over 24 %.

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 1997, despite the fact that the number of dwelling units in the country (single-family houses and apartment buildings) has increased by about 30 % during the same period. The floor area of commercial premises, too, has also increased substantially, and thus contributed to increasing the demand for electricity for such purposes as office equipment, ventilation and lighting.

Figures 18a and 18b show the growth of temperature-corrected electricity use, classified by electric heating, domestic electricity and electricity for building services systems.

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 through reduced conversion losses by the end users.

In terms of quantity, final energy use is defined as the thermal energy content of the energy carriers supplied to the end users. However, in this respect, different energy carriers exhibit differences in distribution and conversion losses in the process of final conversion to heat at the consumers' premises. It is usual to express performance in the form of mean annual efficiencies of the various energy carriers. These figures 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. Mean annual efficiencies of electric heating and district heating are assumed to be 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.

Other factors that have helped to prevent an increase in energy use for space heating and domestic hot water production in residential buildings and commercial premises are various types of energy conservation measures, such as the use of heat pumps, retrofitting additional thermal insulation and upgrading of windows in older buildings. The use of domestic electricity and electricity for building services systems has also been affected by various measures intended to improve efficiency of electricity use.

Heating

Of the 107.2 TWh that were used for space heating and domestic hot water production in 1997, it is estimated that about 45 % were

Figure 17a • Final energy use within the residential, commercial and service sector etc. 1970-1997

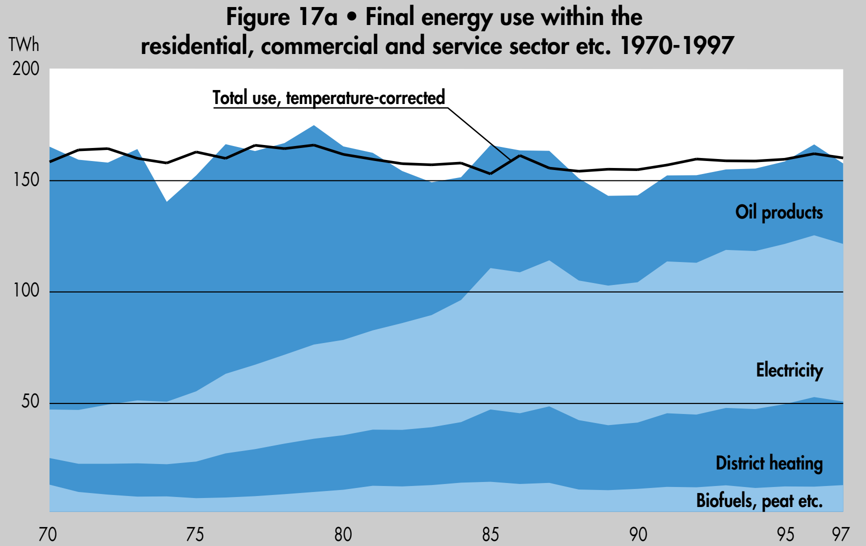
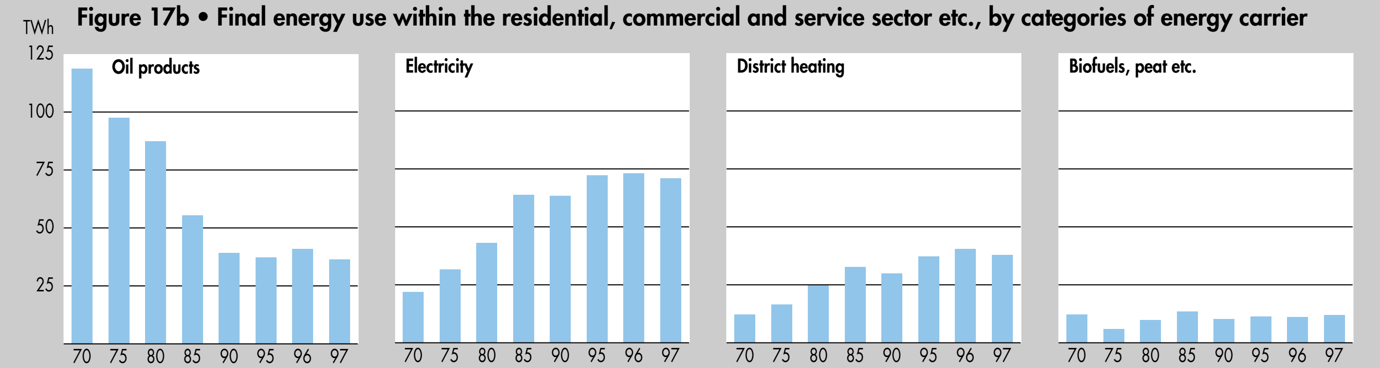


Figure 17b • Final energy use within the residential, commercial and service sector etc., by categories of energy carrier



used in detached houses, 28 % in apartment buildings and 27 % in commercial premises. The most common form of heating in detached houses is electric heating, being the main heating source in over 43 % of such dwellings. Approximately 28 % of detached houses have direct-acting electric heating, with the remaining 15 % 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 during the 1970s and the first half of the 1980s. Another common heating system in detached houses is electricity in combination with wood and/or oil firing, with about 24 % of detached houses having such heating systems as their main heat source.

In 1996, the total use of electricity in detached houses for heating purposes amounted to 20 TWh, while in apartment buildings it was 2 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 exposed to changes in the relative prices. Almost 10 % of detached houses are heated by oil alone, while 6 % have district heating and 2.5 % are heated by wood.

District heating is the commonest form of heating in apartment buildings, with approximately 70 % of apartments being supplied by it, equivalent to a use of almost 22 TWh of district heating. Oil is used as the heat source for 12 % of apartments, or to 6 TWh of oil. The main source of heat in commercial premises, too, is district heating, with over 50 % of them being supplied, equivalent to about 16 TWh of district heating.

Domestic electricity

The use of electricity for domestic purposes grew relatively slowly during the 1980s, following a fairly rapid average growth rate of about 4 % per annum during the 1970s. Nevertheless, its use almost doubled between 1970 and 1997, from 9.2 TWh to 17.6 TWh, although the actual rate of growth fell during the 1990s, due to a number of opposing factors. Despite an increase in the number of households and greater ownership of domestic appliances, which resulted in greater use of electricity, continued improvement in the efficiency of such appliances in terms of their use of electricity has tended to offset this increase. Old, worn-out appliances are replaced by new, more efficient ones, while new types of appliances, such as microwave ovens, are inherently more economical and reduce the use of energy-hungry electric cookers. All this explains the levelling off in the use of domestic electricity. The proportion of total temperature-corrected electricity use accounted for by domestic electricity fell from about 41 % in 1970 to just over 24 % in 1997, due primarily to a greater proportion of electric heating.

Building services systems

The use of electricity for building services systems has increased substantially since 1970, when it amounted to 8.4 TWh. By 1980, after rapid growth during the 1970s, it amounted to 14.9 TWh. Growth continued during the first half of the 1980s, reaching 26.6 TWh by 1997. The reasons for this increase included rapid growth in the service sector and greater use of office machines. The high growth rate of private and public services also resulted in a relatively substantial increase in the number and floor area of office premises. At the same time, increasing numbers of electrical appliances and greater use of them resulted in higher specific energy use per m2 of floor area.

The rate of increase fell sharply during the latter half of the 1980s, with the explanation to be found in the greater efficiency of electricity use. Lighting and ventilation, which together account 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. The potential for further improvements in the efficiency of electricity use in commercial premises is still regarded as considerable. ■

Figure 18a • Electricity use in the residential, commercial and service sector etc., 1970-1997, temperatur-corrected

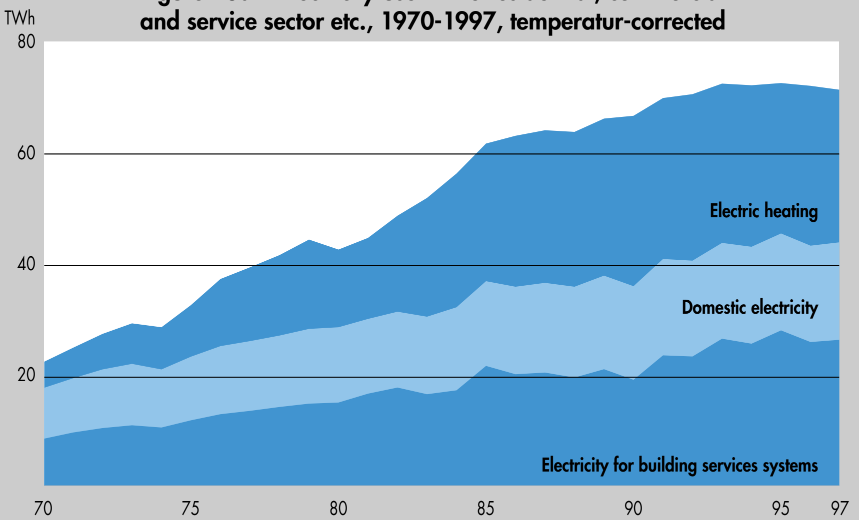
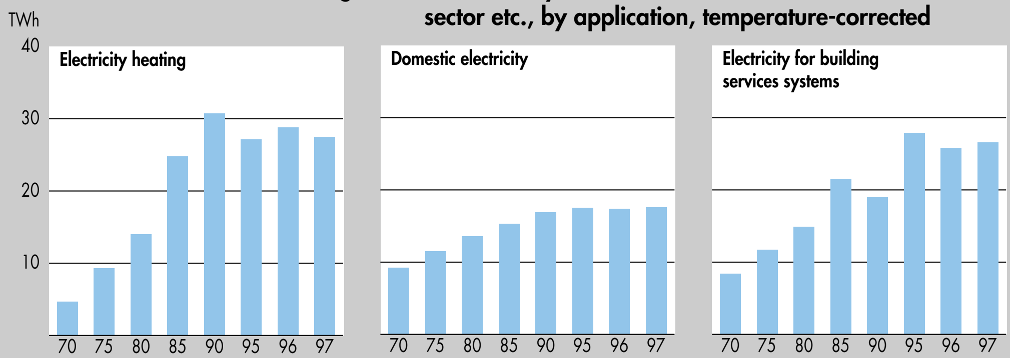


Figure 18b • Electricity use in the residential, commercial and service sector etc., by application, temperature-corrected



In 1997, industry's use of energy increased by 1.3 TWh over the previous year, amounting to 148.9 TWh, equivalent to 38 % of the country's final energy use.

Classified by energy source/carrier, this consisted of 21.9 TWh of oil products, 14.8 TWh of coal and coke and 52.7 TWh of electricity. Supplies of natural gas amounted to 3.7 TWh, and those of district heating to 4.4 TWh. The use of biomass fuels, peat etc., amounted to 51.5 TWh, of which 40 TWh were in the cellulose industry, mainly in the form of digester liquors, manufacturing waste etc. Digester liquors, which are a byproduct of chemical pulp manufacture, are burned to recover process chemicals and release energy, but are not available to other users. Final energy use in industry during the year therefore consisted of 27 % fossil energy and 35 % biomass fuels, peat etc., with the rest being in the form of electricity and district heating.

In Sweden, a relatively small number of sectors – together known as the energyintensive sector – accounts for the bulk of energy use. The pulp and paper industry uses almost 47 %, the iron and steel industry about 15 % and the chemical industry about 6 %. Together, these three account for two-thirds of total energy use in industry. The engineering manufacturing 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 tracks 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 7 %, i.e. by more than the fall in total energy use, as the recession tended to hit the electricity-intensive sectors harder than other sectors.

Figure 19a • Final energy use in industry 1970-1997

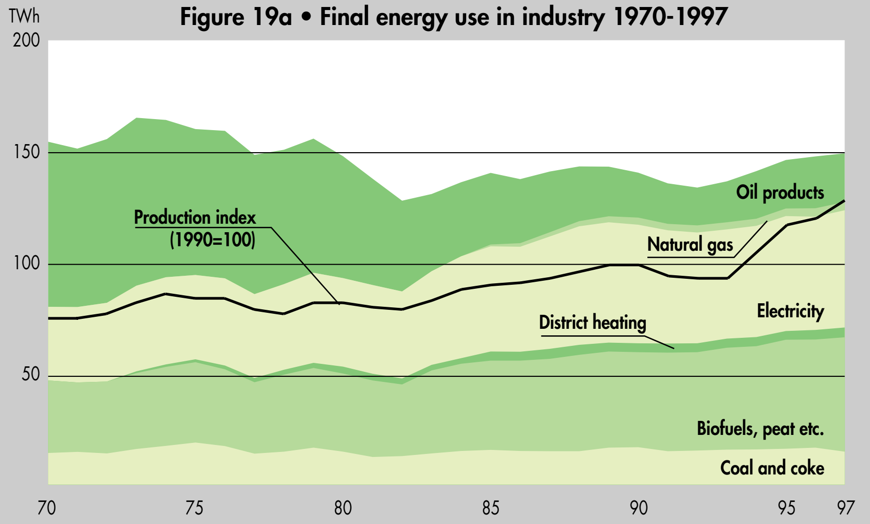
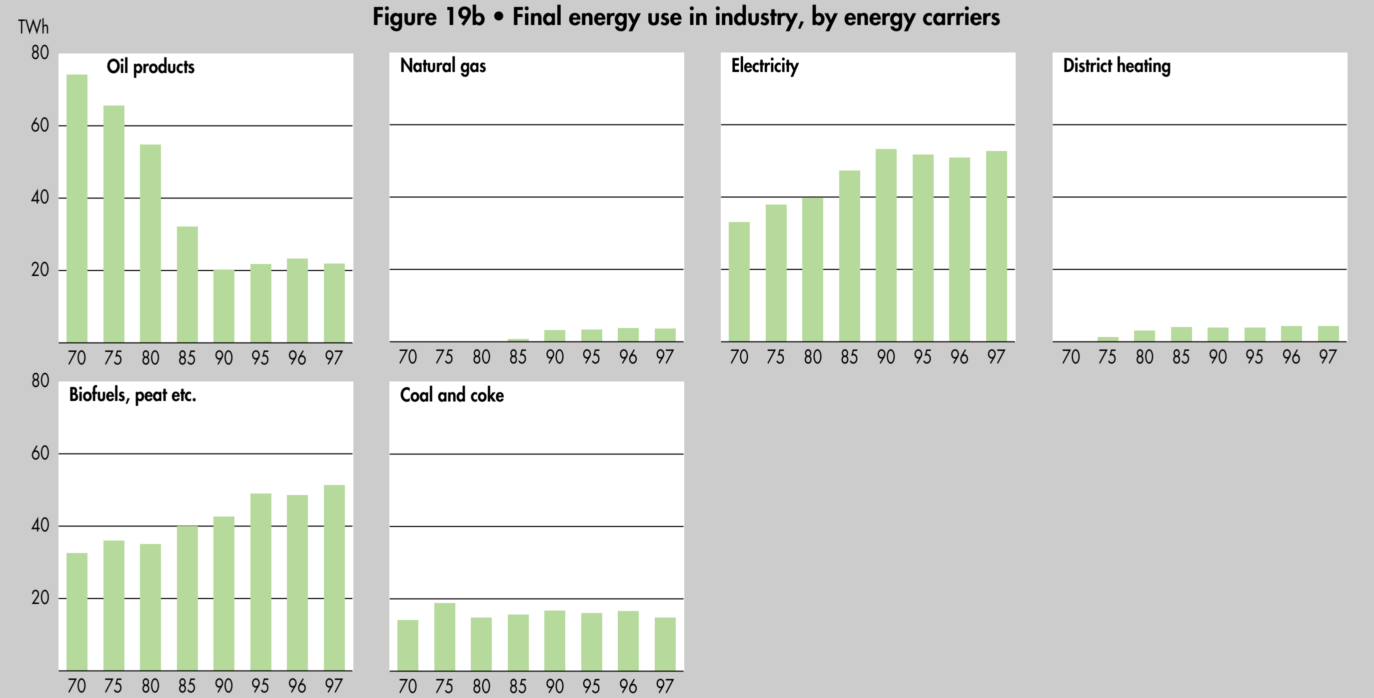


Figure 19b • Final energy use in industry, by energy carriers



1993, however, was marked by some recovery in industrial output, and was followed by s substantial rise in 1994 and 1995. Output volume in 1997 increased by 37 % relative to 1992, and energy use by almost 12 %. During the same period, the use of electricity increased by 3 TWh or almost 6 %.

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 Figure 21. Despite rising industrial output, the use of oil has fallen substantially since 1970, resulting from the greater use of 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 35 %. At the same time, the use of oil fell from 48 % to 15 % in terms of industry's energy use. Between 1970 and 1997, the proportion of biofuels, peat etc., has increased from somewhat over 21 % to 35 % of total energy use in the sector. This change from oil to electricity and other fuels has meant that overall energy use in the sector has fallen, as electrical energy often has a considerably higher efficiency than oil for the majority of applications.

Between 1992 and 1997, the use of oil products has increased by almost 5 TWh, or 29 %. 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 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 1997, there was a reduction of 40 %, which shows a clear trend towards less energyintensive products and production processes, together with changes in the types of industries and products. During this period, industrial output has increased by 70 %.

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 26 %.

The upturn in the economy over the last few years, coupled with changes in industry's energy taxation structure, is reflected in changes in specific energy use, which continues to fall. Between 1992 and 1997 it fell by 19 %. As far as oil and electricity are concerned, the specific use of oil during the same period fell by 9 %, while specific use of electricity fell by 24 %. This recent substantial fall in specific electricity use has been the result primarily of a major increase in engineering industry output (37 % in terms of value), coupled with almost unchanged electricity use. ■

Figure 20a • Specific use of oil in industry 1970-1997, 1991 price levels

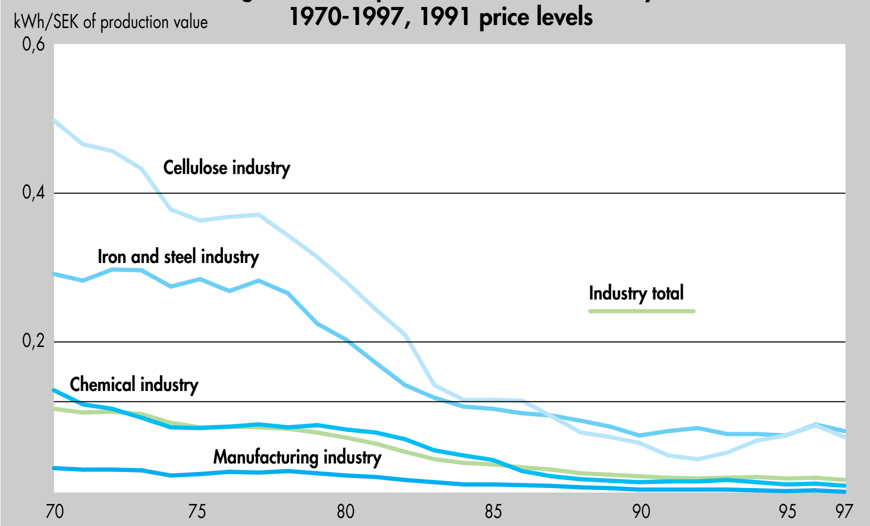


Figure 20b • Specific use of electricity in industry 1970-1997, 1991 price levels

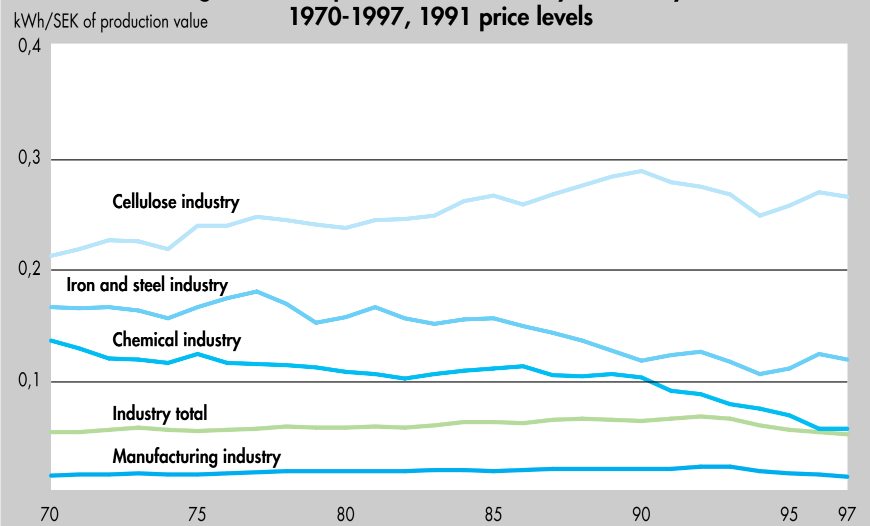
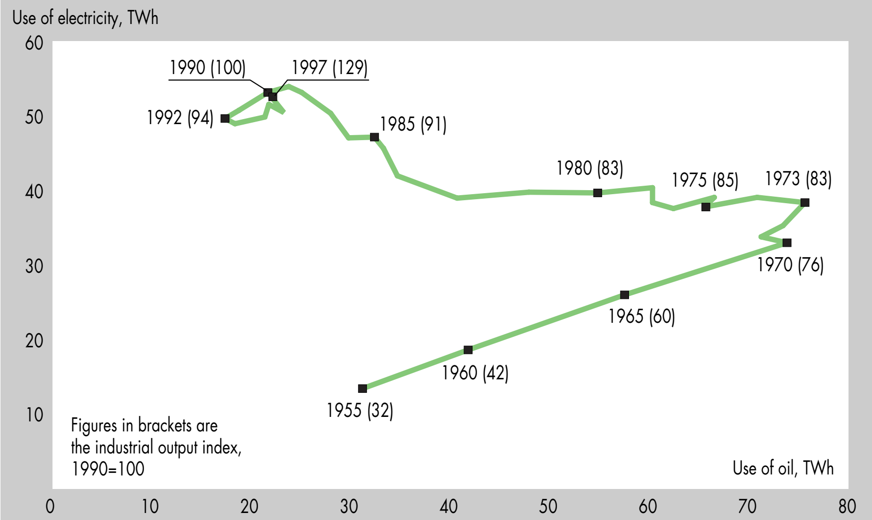


Figure 21 • Use of oil and electricity in industry 1955-1997



Energy use for internal transport in 1997 amounted to 87.2 TWh, or over 22 % of the country's total final energy use. Foreign maritime transport used 15.6 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. The use of these two fuels amounted to 49 TWh and 26 TWh respectively in 1997, together accounting for 72 % 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. Development from 1990 to 1994 has been marked by strong turbulence. During 1994, domestic demand increased and business began to expand again, resulting in an increase in energy use in the transport sector of almost 3 %. This trend continued in 1995 and 1996, with a further increase of 1 % in each year. Domestic energy use rose by 1 % in 1997, while foreign maritime transport increased its energy demand by 18 % relative to the previous year. However, the use of petrol fell by 2.2 % from 1996 to 1997 (49.7 TWh to 48.6 TWh), partly due to the effect of higher prices.

Traffic and the environment

The use of oil products in the transport sector has increased during the 1970s and 1980s, while that in other sectors has decreased, which means that the proportion of pollution ascribable to traffic has increased. This greater use of oil can be explained by a greater demand for transport. The number of passenger-kilometers travelled rose by 60 % between 1970 and 1994. Private cars provide 80 % of passenger transport. Expressed as tonne-kilometers, internal freight transport increased by 45 % between 1970 and 1994, with 50 % being by road, 35 % by rail and 15 % by water. During 1997, there was a slight increase in the amount of goods carried by road and in the overseas transport of goods by air, while passenger and goods transport by rail increased by 1 %.

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. 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.

Specific petrol consumption per vehicle has steadily fallen since 1980, although the use of diesel fuel has increased over the same period as a result of such practices as 'just-in-time' deliveries, which can require more frequent deliveries. Total fuel consumption per vehicle depends on such factors as the annual distance driven, as well as on the specific fuel consumption. Between 1987 and 1991, the average specific fuel consumption of the country's private cars fell from 9.4 litres/100 km to 8.7 litres/100 km. If business cars and light vans are included, the value would be somewhat higher. Between 1978 and 1987, the average specific fuel consumption of the country's new private cars fell from 9.3 litres/100 km to 8.2 litres/100 km. However, this trend towards lower fuel consumption has stagnated in recent years: in 1994, the average specific fuel consumption of new private cars was 8.4 litres/100 km, i.e. about 2 % higher than in 1987.

Alternative 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. In Sweden, these fuels are used primarily for public transport vehicles. About 280 buses are running on ethanol, with the largest fleet being in Stockholm. About 180 buses are running on natural gas, mainly in Malmö, and almost 50 on biogas, mainly in Linköping. In addition, there are about a score of mixed fuel buses and about 16 electric buses, complemented by about 300 electric cars and 200 flexible fuel vehicles on the roads. The number of places at which alternative fuels are available is steadily increasing.

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, and so no large-scale introduction of these fuels to the Swedish market can be expected in the near future. However, this cost differential is falling 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 1970-1997

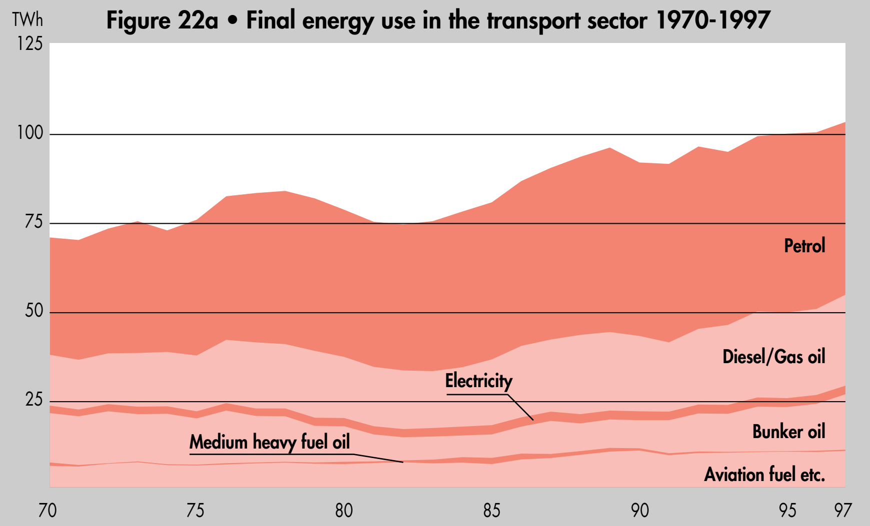
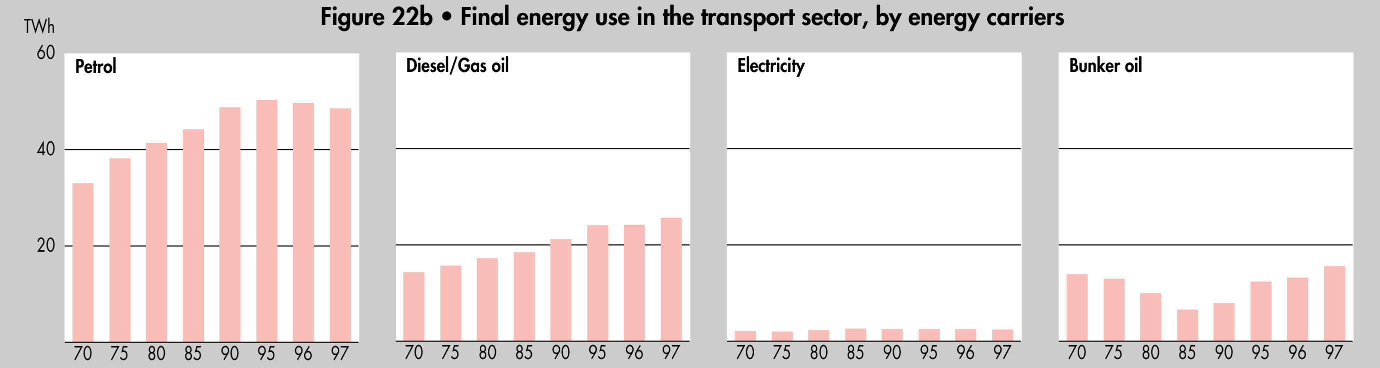


Figure 22b • Final energy use in the transport sector, by energy carriers



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, while sulphur tax is levied on peat.

Energy and electricity production taxes

Energy tax is levied on electricity and all fuels except biofuels and peat, although industry has been exempt from energy tax since 1993. The tax rates for electricity production in Sweden were increased on 1st September 1996. In the spring of 1996, the Swedish Parliament decided that the production tax would be further increased on 1st July 1997. This decision was strongly criticised, as it was feared that the additional tax would impose a severe strain on the competitiveness of manufacturing companies, and particularly on that of the electricity-intensive industries. Although the electricity market is deregulated, most electricity is still sold under the terms of contracts entered into before deregulation. This would mean that the electricity producers could pass on the tax by increasing the price of electricity to consumers, who would not be able to make up this cost increase as the price of their products is determined by the world market. In the autumn of 1996, Parliament therefore decided that the increases in the tax on hydro power and nuclear power that had been due to come into effect on 1st July 1997 should be replaced by higher energy taxes on electricity and fossil fuels not used by industry. It was also decided that the existing hydro power tax should be replaced by a special real estate tax based on the value of the land, at a rate of 3.42 % of the land value. This tax rate was reduced to 2.21 %, with effect from 1st January 1988, in the 1997 spring budget. The 1998 spring budget proposed that the tax should be totally removed with effect from 1st January 1999.

For the time being, the tax on nuclear power production, at the rate of 2.2 öre/kWh, remains, but it is expected that it will be removed.

Environmental taxes

A carbon dioxide tax was introduced in 1991, applicable to all fuels except biofuels and peat.

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Table 1 • General energy and environmental taxes as at 1 st January 1998, excluding value-added tax

		General energy tax	Carbon dioxide tax[1]	Sulphur tax	Total	Tax, öre/kWh
Gas oil SEK/m³						
Environmental class 3	<0.1 % sulphur	743	1 058	-	1 801	18.2
Heavy fuel oil, SEK/m³	0.4 % sulphur	743	1 058	108	1 909	17.6
Coal, SEK/tonne	0.5 % sulphur	316	920	150	1 386	18.3
LPG, SEK/tonne		145	1 112	-	1 257	9.8
Natural gas, SEK/1 000 m³		241	792	-	1 033	9.6
Peat, SEK/tonne	0.2 % sulphur	-	-	40	40	1.5
Petrol, leaded, SEK/litre		4.27	0.86	-	5.13	
Petrol, unleaded, SEK/litre						
Environmental class 2		3.61	0.86	-	4.47	
Environmental class 3		3.68	0.86	-	4.54	
Diesel, SEK/litre						
Environmental class 1		1.61	1.058	-	2.67	
Environmental class 2		1.84	1.058	-	2.90	
Environmental class 3		2.14	1.058	-	3.20	
Electricity, northern Sweden, öre/kWh		9.6	-	-	9.6	9.6
Electricity, elsewhere, öre/kWh		15.2	-	-	15.2	15.2
Electricity, district heating, northern Sweden, öre/kWh		9.6	-	-	9.6	9.6
Electricity, district heating, elsewhere, öre/kWh		12.9	-	-	12.9	12.9

[1] Carbon dioxide tax is levied at a rate of about 36.5 öre/kg of carbon dioxide emission. Value-added tax at a rate of 25 % is also levied in addition to the taxes in the table.
A table defining the various environmental classes is included in the tables appendix *Energy in Sweden;* facts and figures.

Table 2 • Industrial energy and environmental taxes as at 1 January 1998, excluding value-added tax

	General energy tax	Carbon dioxide tax	Sulphur tax	Total	Tax, öre/kWh
Gas oil, SEK/m³	0	529	-	529	5.4
Heavy fuel oil, SEK/m³	0	529	108	637	5.9
Coal, SEK/ton	0	460	150	610	8.1
LPG, SEK/ton	0	556	-	556	4.3
Natural gas, SEK/1 000 m³	0	396	-	396	3.7

Electricity production is exempted from the tax. From 1993 and until 1st July 1997, industry has paid only 25 % of the carbon dioxide tax payable by other users. In 1996, the Government proposed that the carbon dioxide tax payable by industry should be doubled, rising to 50 % with effect from 1st January 1997. However, the implementation date was postponed, as the Government was waiting for a decision from the European Union concerning taxation concessions to energy-intensive industry. The 1996 spring Bill therefore proposed that the higher tax rate should come into force on 1st July 1997. In order to compensate for the resulting revenue shortfall, it was also proposed that the general carbon dioxide tax rate should be increased on 1st July 1997. The new 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/m3 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, motor fuels, electricity and district heating vary with time. Table 3 shows the prices of a number of fuels between 1990 and 1997. 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 byproducts 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 pushed up prices. ■

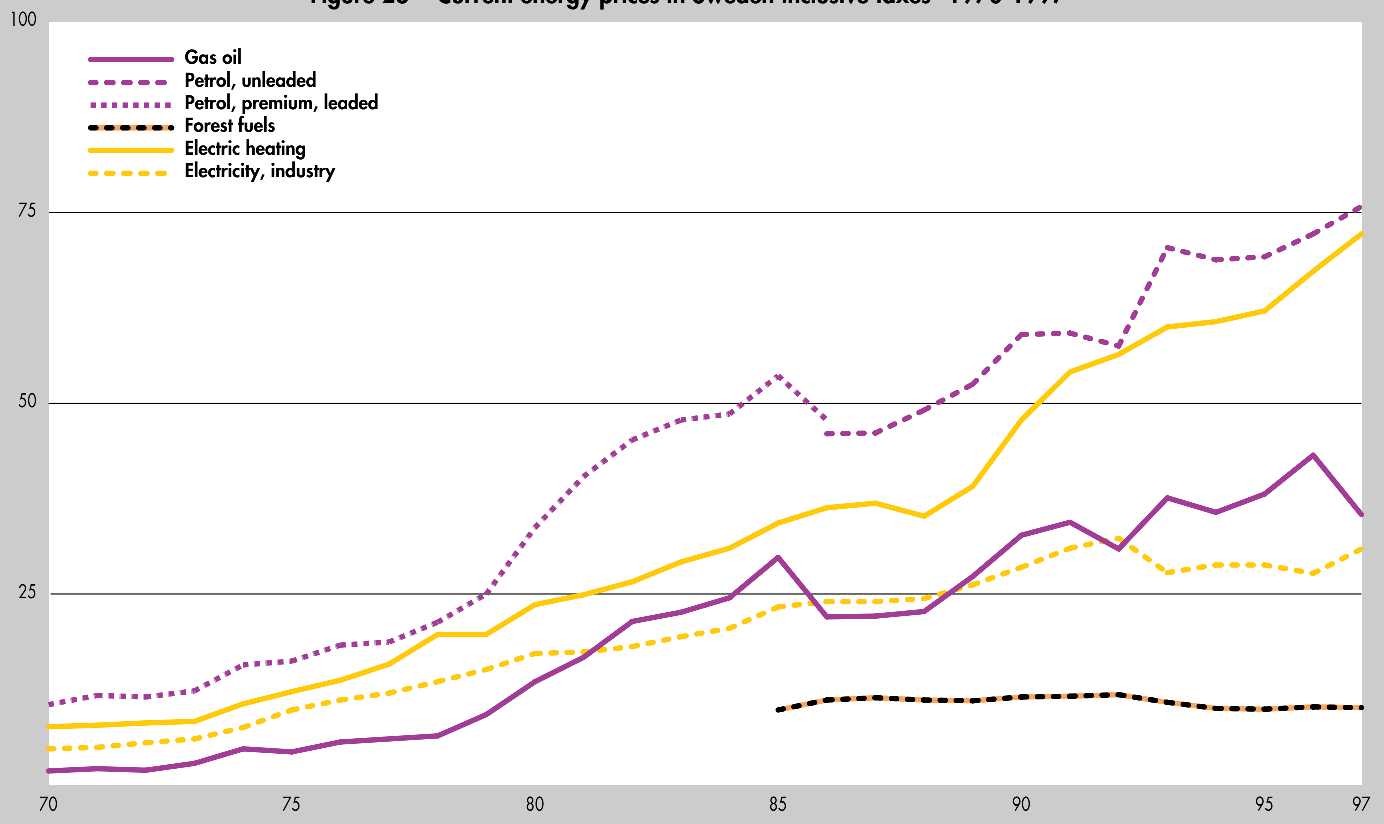
Table 3 • Fuel prices and domestic electricity prices in Sweden, excluding taxes and value-added tax. Current prices

	1990	1991	1992	1993	1994	1995	1996	1997
Crude oil, \$/barrel	20.50	16.56	17.21	14.93	14.75	16.10	18.50	18.12
Gas oil, SEK/m^3	2 146	2 131	1 790	2 207	2 004	2 205	2 603	1 759
Heavy fuel oil, SEK/m^3	1 702	1 535	1 316	1 652	1 525	1 525	1 526	1 014
Petrol, unleaded, SEK/litre	2.23	2.19	2.06	2.23	2.10	2.02	2.10	2.25
Coal, SEK/tonne	358	366	307	309	317	336	340	367
Forest fuels, SEK/m^3	92.70	93.50	95,10	87.05	81.40	79.80	82.22	81.8
Electric heating, öre/kWh[1]	31.5	36.1	37.9	40.0	39.7	40.7	43.60	45.2

[1] *The prices of electric heating also include value-added tax.*

Note: The tabular version of *Energy in Sweden* shows the consumer price index from 1970 to 1997, enabling the prices shown to be converted to fixed prices.

Figure 23 • Current energy prices in Sweden inclusive taxes[1] 1970-1997



Globally, world energy supply is dominated by fossil fuels, which account for about 90 % of the world's total energy supply. Hydro and nuclear power account for about 3 % 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. However, a significant move from biomass fuels to fossil fuels has become apparent in recent years, partly due to substantial economic growth in certain regions and to urbanisation.

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. In 1996, expressed in relation to present rates of consumption, they amounted to:

- 224 years' production of coal
- 42 years' production of oil
- 62 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 planned economy countries have been dramatic during the first half of the 1990s, with both production and use of oil 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. The prices of electricity and gas have risen, but payment discipline among users is poor, with the result that many energy utilities are in financial difficulties.

Figure 24 • World oil reserves 1996 (billion barrels)

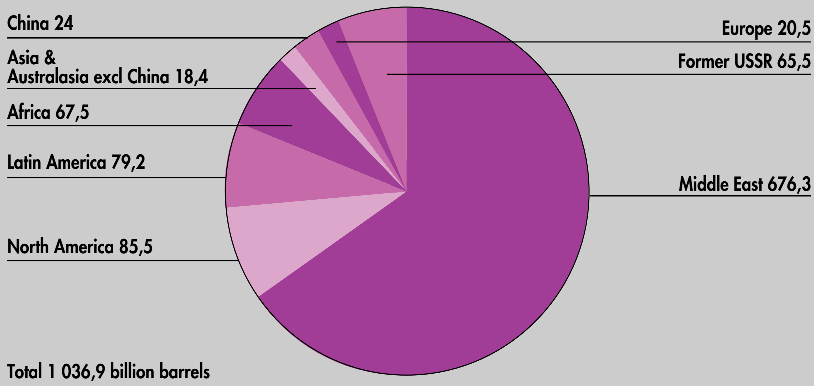
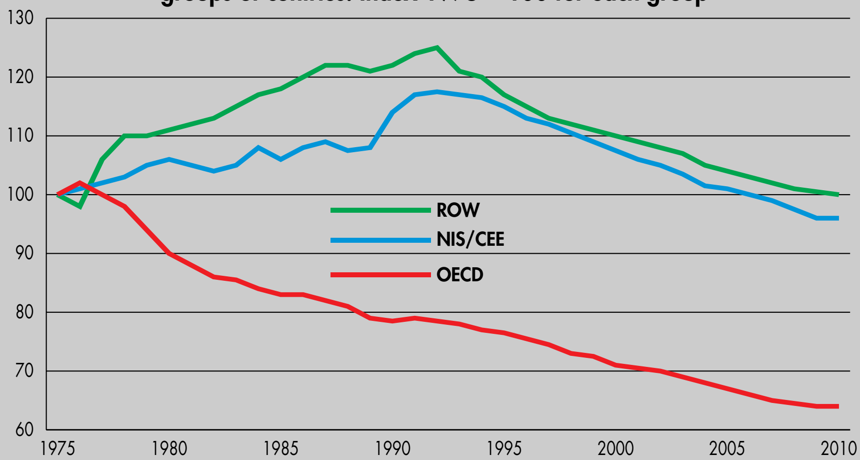


Figure 25 • Energy intensity (energy use/BNP) for the groups of contries. Index 1975 = 100 for each group



The OECD countries comprise the industrialised market economy countries of Wstern 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.

Oil is the most important energy source for world energy supplies, and production rose by 3 % in 1996 relative to 1995, bringing it to 69.7 million barrels/day. Production of natural gas increased by 5 %, to 2008 Mtoe, and that of coal by 2 %, to 4607 Mtoe, in 1996.

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: after three years of a very low rate of increase, global demand rose by about 1 % in 1994, 1.8 % in 1995 and by 3 % in 1996. One of the reasons for this rise in recent years is that the decline in energy demand in the former Soviet Union has eased off. However, in other parts of the world, energy use continues to increase: efficiency improvements in the OECD countries, which use half of all the world's energy, are not sufficient to offset the substantial increase in energy use in other countries. Energy use in North America rose by 3 % in 1996, and in Europe by over 3 %. It continued 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 con-

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tinue 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 has nearly tripled between 1975 and 1993: during the same period, the OECD countries reduced their energy intensity by 21 %. Some of the differences can be explained by the fact that the two regions are at different stages of development. In the Middle East, for example, the service sector plays a considerably less important role than it does in the OECD countries, while energy-intensive industries such as the aluminium and chemical industries have been encouraged. In the OECD countries, the industrial sector is responsible for a declining proportion of output relative to the service sector.

Forecasts

Total energy use is expected to continue to increase up to 2010, at which time fossil fuels are expected still to be providing 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.

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 - over the next few years – 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 just under 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 and rapid economic growth in other parts of the world. A growing world demand for natural gas can also be expected, particularly 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 about 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 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. As the economy grows, so more energy is used. 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 1960-1996

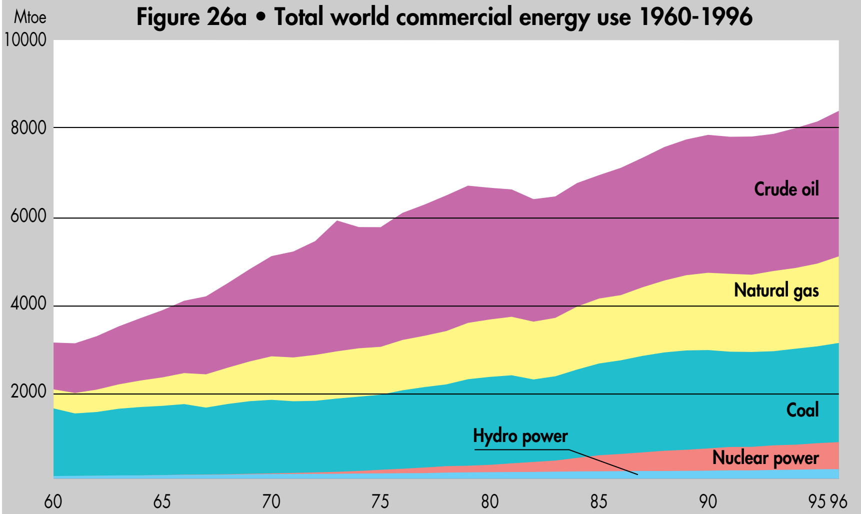
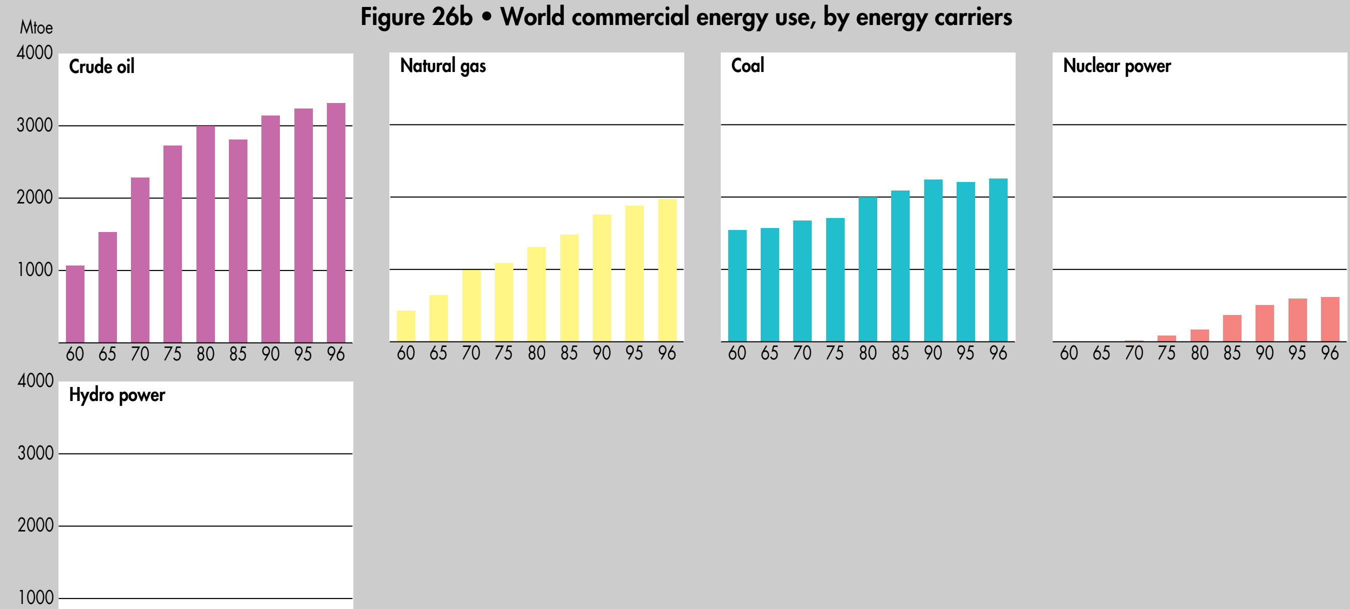


Figure 26b • World commercial energy use, by energy carriers



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 change in many parts of the world in terms of new market conditions, new technology and greater environmental pressure. 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 deregulated, with competition in both production and sales. The effect of the European Union directive on the electricity market (apart from the UK, where the electricity market is already deregulated) will be gradually to open the market to competition. The first stage, to come into effect in 1999, will mean that about 25 % of each country's electricity market will be open to competition. The directive will also impinge on other European countries, and particularly on those that have applied for EU membership. Poland, the Czech Republic and Hungary, for example, have drawn up advanced plans for deregulation.

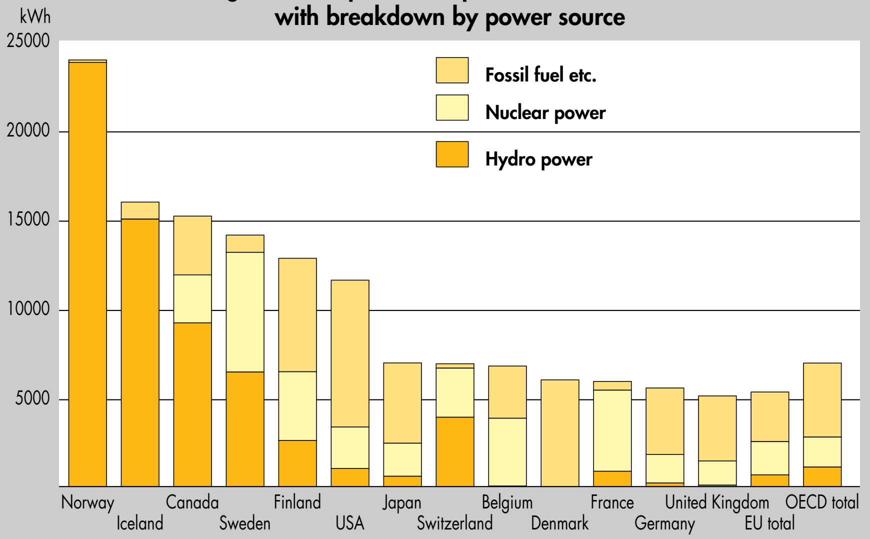
There is also a similar development in other countries, such as in South America, southeast Asia and the Pacific rim countries. Similar deregulation is likely to occur in the USA, now that California has decided to start extensive deregulation.

Deregulation of the electricity markets will result in a change from national monopolies, with central planning, to markets driven by competition. Electricity will become 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 takeovers of electricity companies in the Nordic countries. The largest Nordic power utilities are making strategic investments, although companies in other countries such as the German Preussen-Elektra and the French EdF are also playing.

The companies strategic purchases of each other will result in a 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 use per inhabitant, 1995, with breakdown by power source



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 nominal homeland, 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 1995, 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.

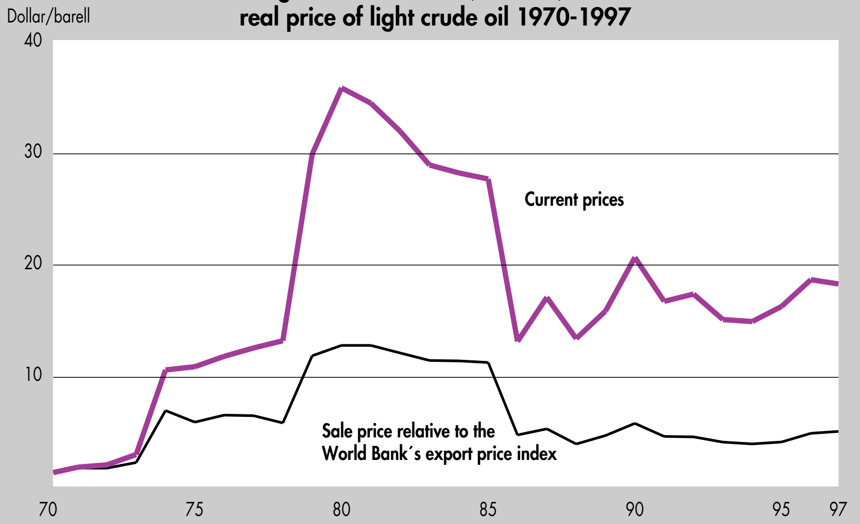
Sweden is one of the world's countries that has a high proportion of hydro and nuclear power in its electricity production. Only Iceland, Switzerland, Norway and Canada have higher proportions of hydro power: France and Belgium have higher proportions of nuclear power. In international terms, the proportion of electricity in Sweden based on fossil fuels is small, amounting to about 7 % in 1995. In the EU member states as a whole, over half of electricity production is based on fossil fuels and only 12 % on hydro power.

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 constituted 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 1997, the price of Brent crude fell from US$ 24 per barrel to just over US$ 17 per barrel. In the autumn, the rising military tension in the Persian Gulf drove up oil prices: in October, they were at their highest for eight months. However, the rise was only temporary, and prices had fallen considerably by the end of the year. For 1997 as a whole, the average price of Brent crude was US$ 19 per barrel, and this fell further during the first quarter of 1998 to a little over US$ 13 per barrel.

Overproduction 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.

Figure 28 • Current (nominal) and real price of light crude oil 1970-1997



Rising production . . .

Production methods for crude oil have become more efficient. Advanced computer methods have made it simpler to prospect for ol and bring oil wells on line. New technology has also made it possible to extract more oil from each well.

Between 1990 and 1996, world oil production increased by 6 %, amounting to almost 70 million barrels per day in 1996, with the OPEC member countries supplying about 40 % of total production. Production continued to increase in 1997, so that by the middle of the year, output was running at over 2 million barrels per day above the agreed production rate of 25 million barrels per day. During the latter half of 1997, the OPEC members states agreed to raise the production ceiling during the first half of 1998 by 10 %, to 27.5 million barrels per day.

Iraq and the UN reached agreement in 1997 that Iraq should again be allowed to export its oil, to a value of US$ 2 million per day at the end of the year. This amounted to about 800 000 barrels per day, or 1 % of the world market. At the beginning of 1998, the UN allowed Iraq to increase the value of its oil exports to over US$ 5 million per day.

At the end of March 1998, the OPEC member states (with the exception of Iraq) agreed to cut back production with effect from 1st April. Norway and Mexico have also undertaken to reduce their respective production rates by 10 000 barrels per day. Oman, Egypt and the Yemen also reduced production. Together, this represents a reduction in output of 1.5 million barrels per day, or 2 % of world production. The reason for this agreement is to prevent a further fall in prices.

. . . and falling demand

The demand for oil in Asia has fallen as a result of the economic crisis in the region. Much of this is due to rising prices in response to falling exchange rates, although the mild winter in the northern hemisphere also contributed to a reduced demand for oil.

Future demand 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 growing markets

A contributory reason to why there have 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 was halved after the break-up of the Union, falling in 1996 to just 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 Iraq crisis 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. By 1996, output had risen to 0.6 million barrels per day, or 0.8 % of world output. Further increases in output have been allowed by the UN during 1997 and 1998. It is in Iraq's interest to produce more oil, as it can use the resulting revenues to repair its damaged economy.

Oil prices are likely to fall when Russia and Iraq return to the world oil market. ■

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.

Half of all the coal that is mined is used as fuel, which means that coal accounts for about 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).

Estimates put the amount of coal and brown coal in the earth's crust at about 11 000 x 10^9 tonnes, although only a smaller fraction of this – about 1 000 x 10^9 tonnes – can be recovered. If production continues at the present rate of 4 630 million tonnes/year, proven and economically recoverable reserves would last for 224 years. The largest accessible reserves of 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.

In 1996, world coal output remained at the same level as during 1995, with the largest producers being China and the USA: China produced about 37 % of total world output and the USA produced 24 %. Production in the former Soviet Union has been falling for several years, so that today it produces about 8 % of total world production.

Total world trade in coal increased by 2.2 %, to 479 million tonnes, in 1996. The largest exporting countries were Australia, the USA and South Africa. Coal production in Europe is still falling and imports are rising. Poland is increasingly targeting the western countries as markets for its coal, while exports from other eastern European countries have fallen as a result of strikes, substantial price increases and freight problems. Russia is a partial exception, in that it has begun to get its coal market under control and increased its exports in 1996.

The entire coal industry has suffered from overcapacity since the middle of the 1980s, resulting in falling prices. However, in 1995, the price rose relatively sharply in comparison with the previous year, to US$ 51.5 per tonne, but remained unaltered in 1996. The price of coal has remained relatively stable for several years, and no larger changes are likely.

Figure 29 • World production of coal 1996 (million tonnes)

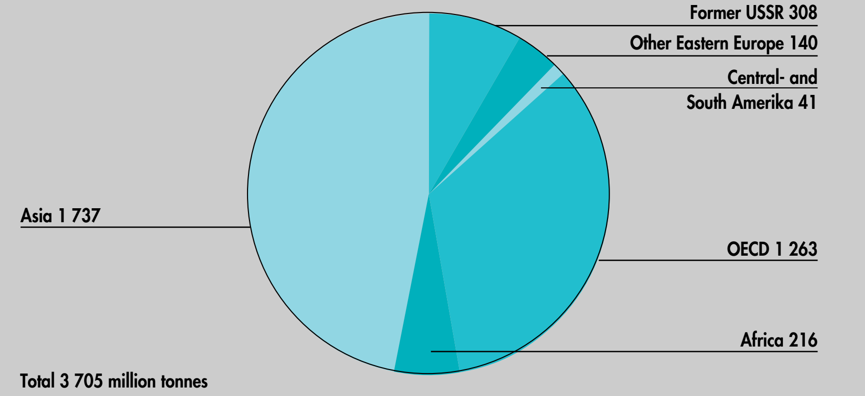
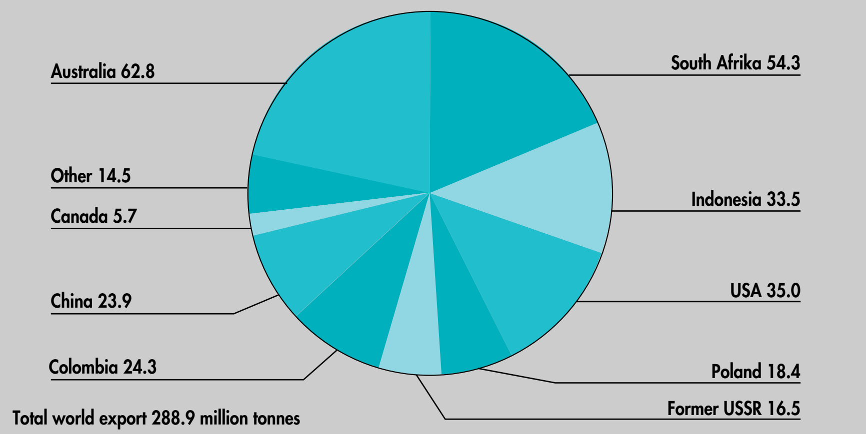


Figure 30 • The major exporters of steam coal 1996 (million tonnes)



The natural gas market

In Sweden, natural gas is still a marginal energy source, meeting about 2 % of the country's energy requirements. It supplies about 7 % of total energy demand in the Nordic countries as a whole, about a fifth of energy demand in the European Union, and about a quarter of in the world as a whole.

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 the CIS 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 141 300 x 10^9 m3, which would last for over 60 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, exports of gas from Russia may increase substantially.

There has been growing interest in natural gas on the European market for some years, based on such considerations as reduced pollution emissions compared to those from other fossil fuels, a more diversified and secure supply and better use of resources. An example of this interest is represented by the Russian/Swedish agreement aimed at encouraging development of an infrastructure for natural gas.

In February 1998, EU energy ministers agreed a policy direction for the proposed directive for a common natural gas market.

The natural gas market is in a state of change. Two investigations concerning a Nordic gas line to connect the Russian gas network with the western European network are at present in progress. One, the Nordic Gas Grid, aims to construct an integrated natural gas network between Denmark, Sweden and Finland, and to ensure the gas supply between Russia and the Baltic countries in the east and the European countries in the west. The second project, the North Trans Gas project, is concerned with planning and building a northern European gas trunk line from Russia, across Finland and to north-western Europe via an undersea pipeline across the Baltic Sea. Nine countries are involved: Russia, Finland, Sweden, Denmark, the Baltic countries, Poland and Germany.

Sweden has a central role to play in the question of an expanded natural gas system in the Nordic countries and in Europe. Although present use of gas in Sweden is small, there is considerable potential for greater use, which means that there is considerable interest on the part of foreign companies in establishing themselves in Sweden. In 1997, Vattenfall AB sold 49 % of the shares in Vattenfall Naturgas AB to the German Ruhrgas (14.5 %), the Danish DONG (10 %), the Finnish Neste Oy (10 %) and the Norwegian Statoil (14.5 %). In the longer term, changes in the ownership structure of the natural gas market in the Nordic countries can encourage the creation of a Nordic natural gas network. ■

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 significant steps have been taken to counter these mechanisms, such 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. These problems have been considerably more difficult to identify, as the damage that they cause becomes apparent only after a longer time, akin to the fatigue of metals. This has resulted in counter-measures intended to deal with such problems being applied only at later stages, in many cases when the damage has already occurred.

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 in Sweden. As the ability of the ground and water to neutralise acidification 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 con-

Figure 31a • Emissions of sulphur dioxide (SO_2) in Sweden 1980-1996

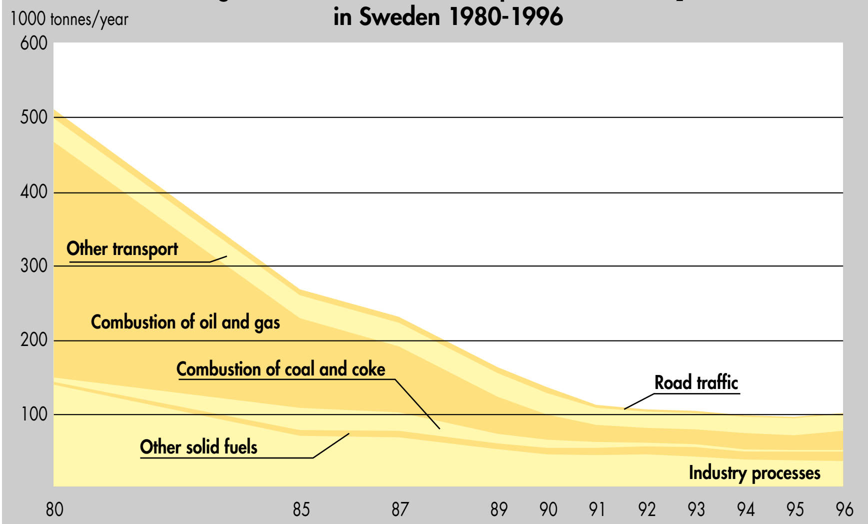
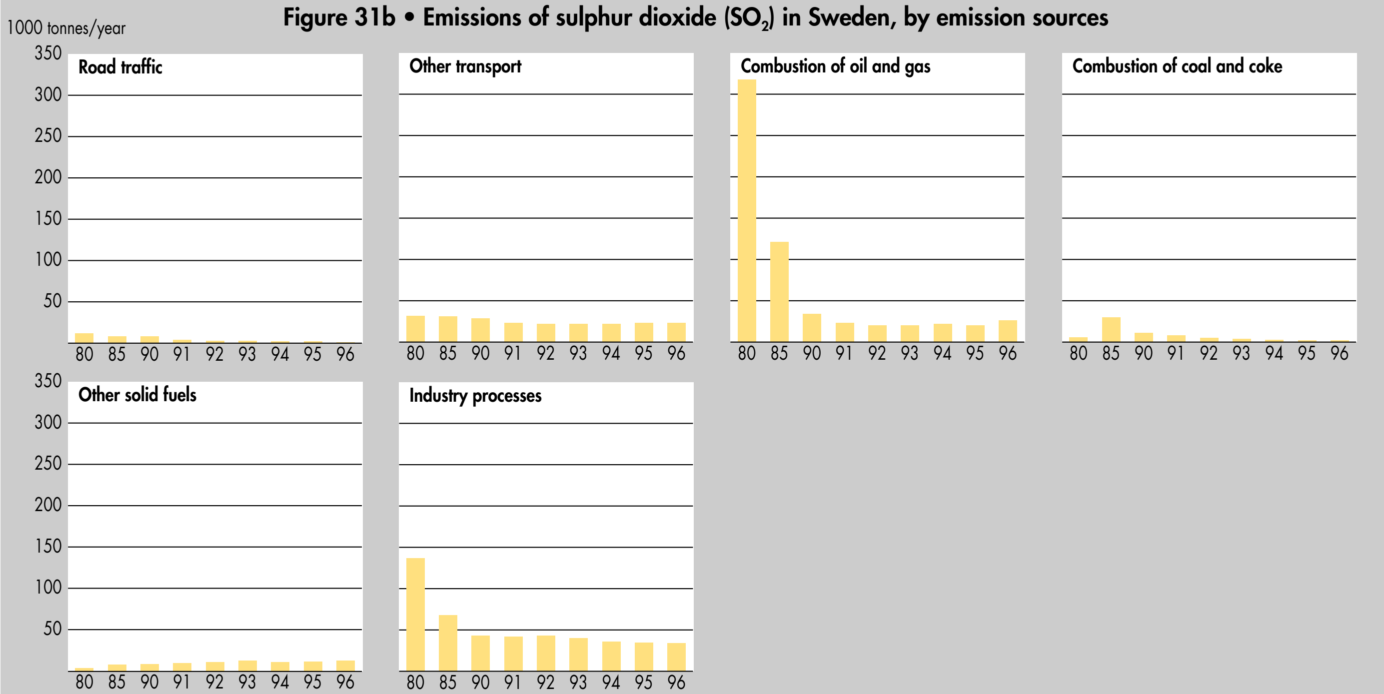


Figure 31b • Emissions of sulphur dioxide (SO_2) in Sweden, by emission sources



tributes 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.

Since the 1970s, acidified lakes have been treated with lime in order to counter acidification, which has resulted in the number of seriously acidified lakes being reduced from about 17 000 at the end of the 1970s to about 13 000 at the beginning of the 1990s. However, critics of this policy say that certain lakes are naturally acidic, and that liming them therefore alters the natural conditions for plant and animal life in them.

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 objectives for the reduction of sulphur emissions by 80 % by the end of the century, relative to 1980 emission levels. This has already been achieved, with emissions having been reduced by more than 80 %.

As far as emissions of NO_x are concerned, over 80 % comes from the transport sector. Sweden's objective has been to reduce emissions to 70 % of their 1980 level by 1995. However, between 1980 and 1996, emissions were reduced by only 16 %.

Examples of administrative guide measures 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 sources within the country. By 1996, this figure had been reduced to about 6.5 % (see Figure 32a). Among the countries from which much of today's precipitation in Sweden comes are Germany and Poland: together, they account for almost a quarter of the precipitation. As far as precipitation of NO_x is concerned, about 16 % at present originates from domestic sources: again, it is Germany, with 12 %, and the UK, with 8 %, 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 sources account for between 30 and 40 % of sulphur emissions and about 50 % of NO_x emissions, while the local sources in Gothenburg and Bohuslän account for about 15 % of both sulphur and NO_x precipitation. 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 de- →

Figure 32a • Emissions of oxides of nitrogen (expressed as NO_2) in Sweden 1980-1996

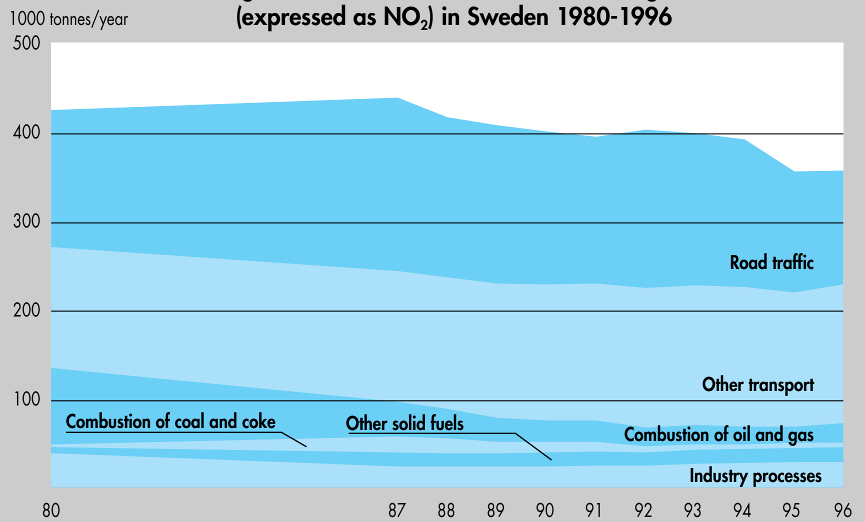
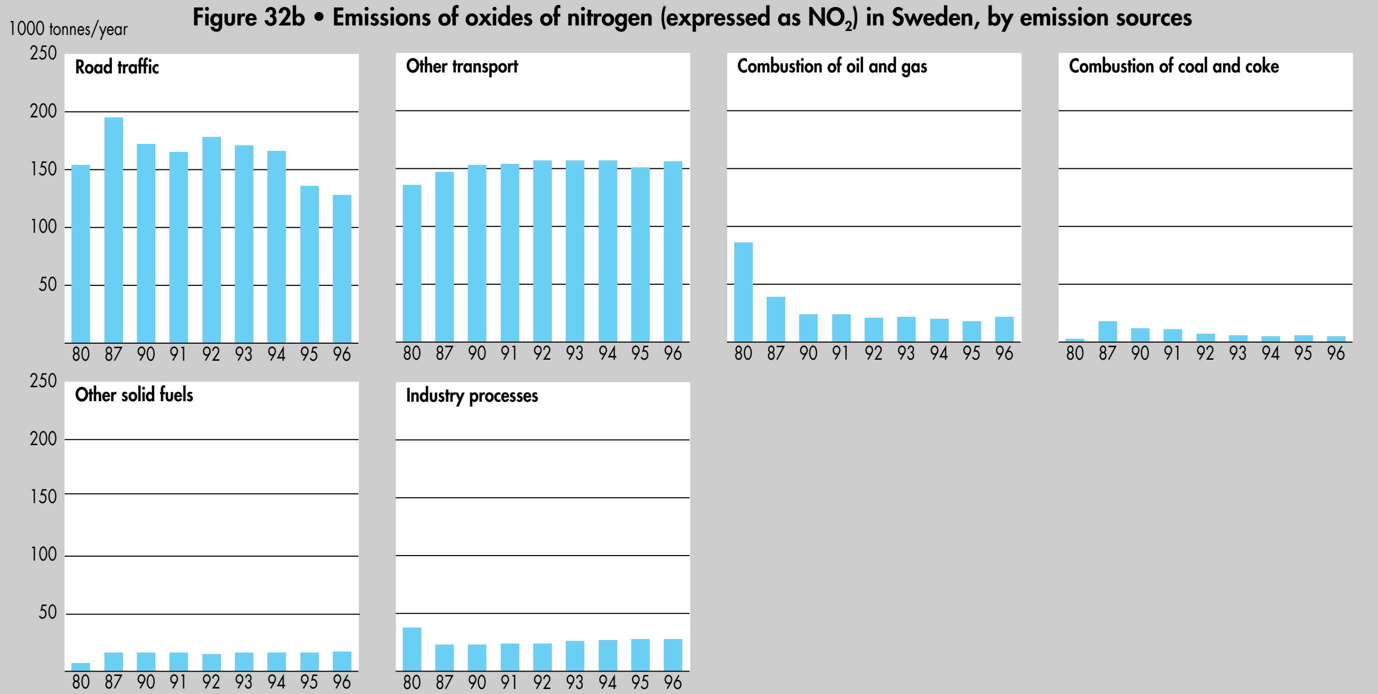


Figure 32b • Emissions of oxides of nitrogen (expressed as NO_2) in Sweden, by emission sources



creased 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 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 do not exceed their 1987 emissions.

As most of the acidified deposition in Sweden comes from other countries, Sweden can do very 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) at its 1994 meeting in Oslo. 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, still have most of their reductions to meet. The protocol comes into force on 5th August 1998, and is legally binding as it has now been ratified by a sufficiently large number of countries.

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

Figure 33a • Deposition of oxides of sulphur in Sweden 1996 from various sources (%)

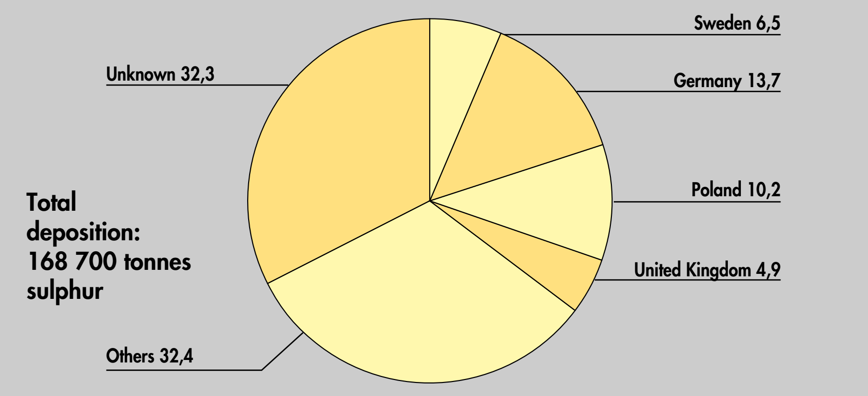


Figure 33b • Deposition of oxides of nitrogen in Sweden 1996 from various sources (%)

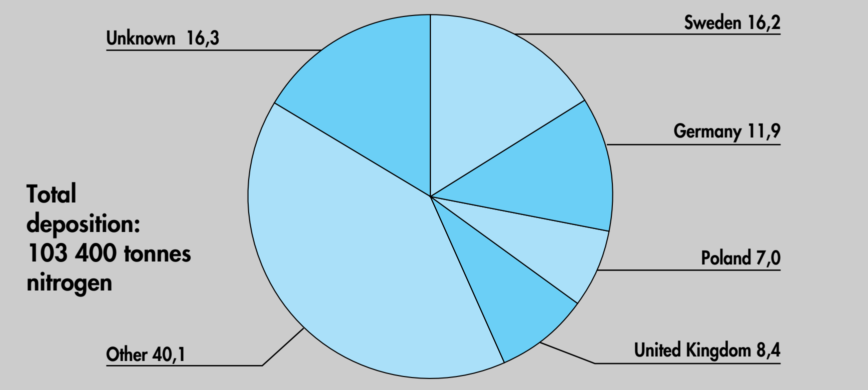


Figure 34a • Emissions of carbon dioxide (CO_2) in Sweden 1980, 1987-1996

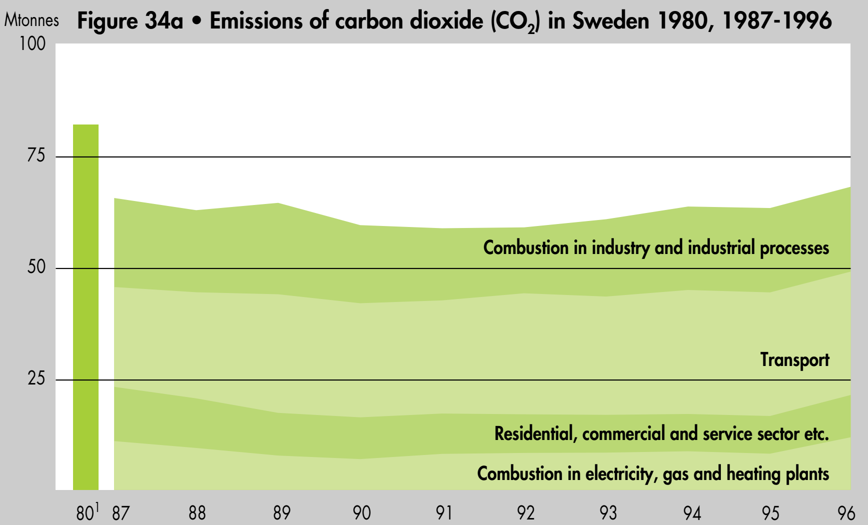
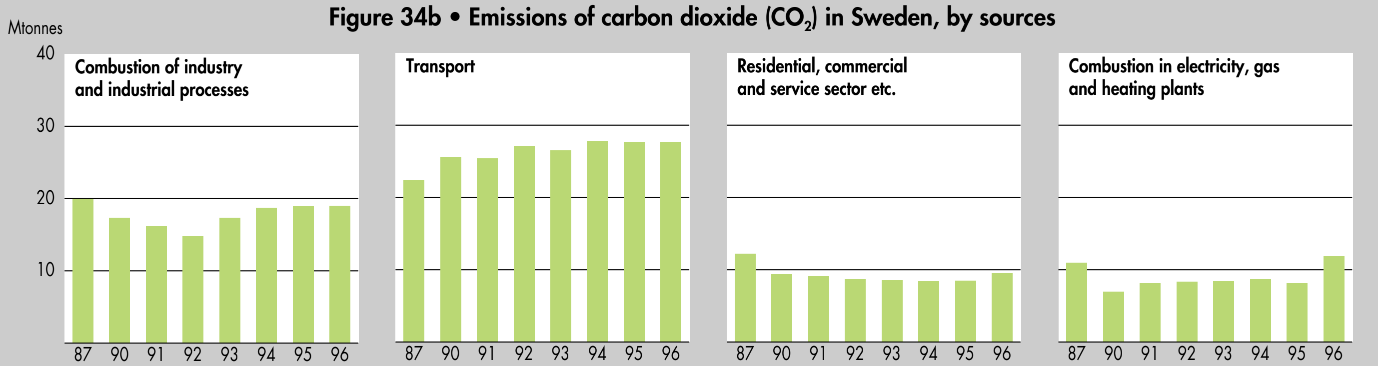


Figure 34b • Emissions of carbon dioxide (CO_2) in Sweden, by sources



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

stand, will be reduced by 50 % for each country.

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 spotted and discussed in recent years.

OECD countries emit about 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 (see Figure 37).

Sweden contributes a few parts per thousand to the world's emission of carbon dioxide, although its specific emissions per inhabitant are below the average for both the OECD countries and for the European Union. Most of the emissions come from the transport sector, from which emissions have risen by 21 % since 1980. However, overall emissions from the energy sector have fallen by 20 % between 1980 and 1996, mainly as a result of greater efficiency of energy use and the switch from oil to nuclear power for electricity production. In recent years, from 1990–1996, total emissions have increased by about 13 %, although the increase up to 1995 was only 5 %. 1996 was a dry year and also colder than normal, which explains the substantial difference between 1995 and 1996. However, if we consider climatic variations, i.e. apply corrections for statistically average climatic years, and base the figures on those for 1995, the increase is considerably less at only 1.5 %. It is the transport sector, with the electricity, gas and heat production sectors, that are responsible for this increase. 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	1995 emission relative to 1980, %
Austria	-81
Sweden[1]	-80
Finland	-84
Norway	-75
France	-70
Denmark	-67
Federal Republic of Germany	-60
United Kingdom	-52
Poland	-43
Europe total	**-48**

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

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Figure 35a • Emissions of sulphur dioxides (SO_2) in Europe 1980-1995

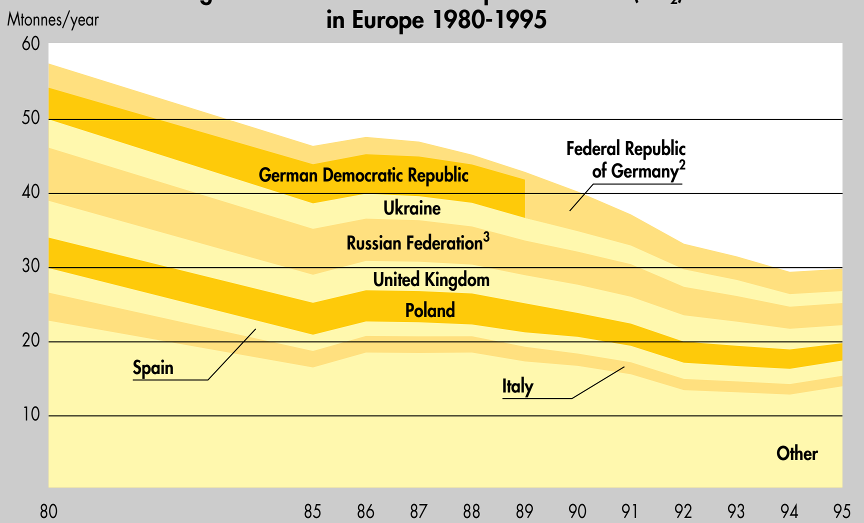
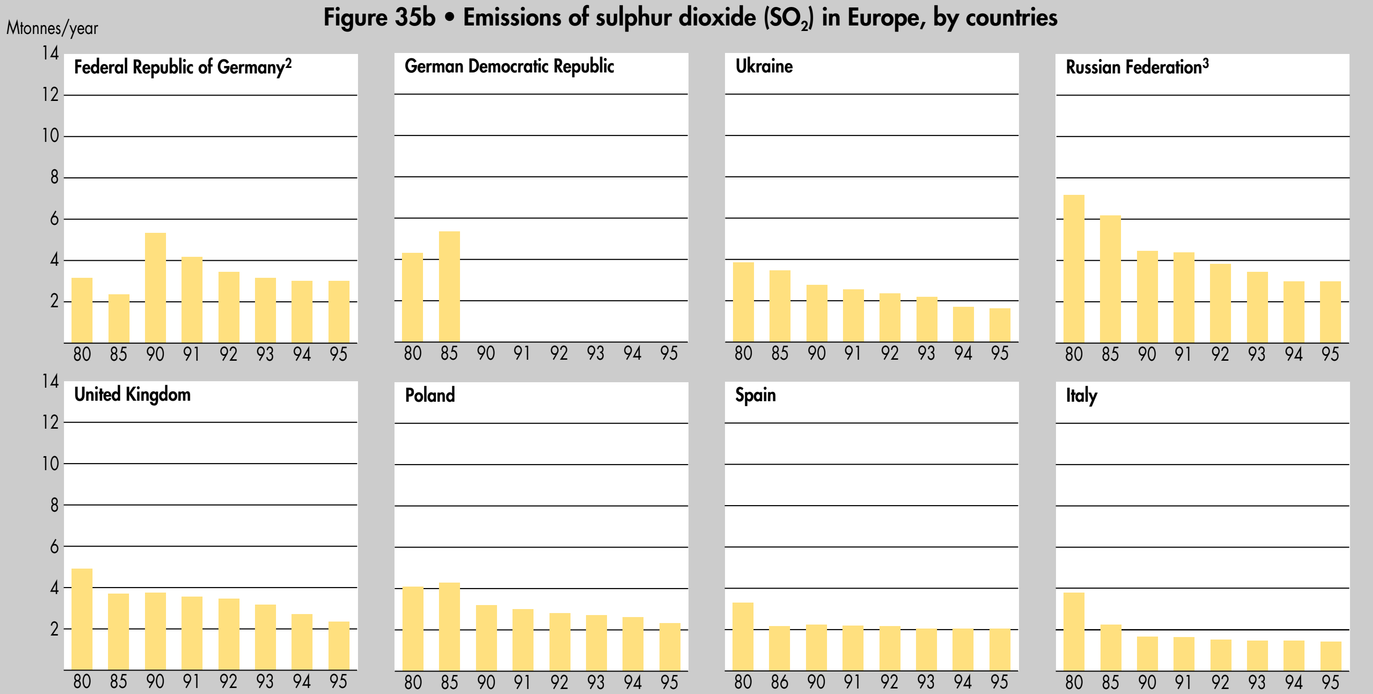


Figure 35b • Emissions of sulphur dioxide (SO_2) in Europe, by countries



[1] Bill no. 1992/93:179.
[2] West Germany until 1989.
[3] The part included in EMEP's calculations.

International environmental cooperation

1972 marked the start of international environmental cooperation on global and regional problems, when the UN Conference on the Human Environment was held in Stockholm. The conference adopted an action plan to safeguard the human environment, which was complemented by the establishment of the United Nations Environment Program (UNEP). Following on from the conference, many countries set up environmental ministries. Many special interest organisations were also established, further assisting the potential for international cooperation. Today, this cooperation covers a wide range: we have chosen here to concentrate on describing the work associated with climate problems,

The work on climate problems was started in the UN when the World Meteorological Organisation (WMO) arranged the First World Climate Conference in Geneva. This was followed in 1985 by meetings of scientists concerned at the hole in the ozone layer, which agreed on the seriousness of the greenhouse problem.

In 1987, the Brundtland Commission published its report, 'Our Common Future'. The climate problems was described in a report to the UN General Assembly in 1988, which resulted in a resolution concerning protection of the global environment for present and future generations. The Intergovernmental Panel on Climate Change (IPCC) was also set up at the same time, consisting of a large number of scientists whose duty is scientifically to assess the greenhouse effect and to suggest ways of limiting it.

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.[3]

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, the Convention 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.[4]

At a 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 the process of producing a legally binding document was started. Part of this process was the third meeting of the Convention nations in Kyoto in December 1997. After intensive negotiations, with the parties at first relatively far from each other, a protocol was agreed under which the emissions not only of carbon dioxide are to be regulated, but also those of five other greenhouse gases.

The agreement includes confirmed reductions for all Annex I countries, i.e. the OECD countries and the previous Eastern Bloc countries. The EU, for example, is required reduce

Figure 36a • Emissions of oxides of nitrogen (expressed as NO_2) in Europe 1980-1995

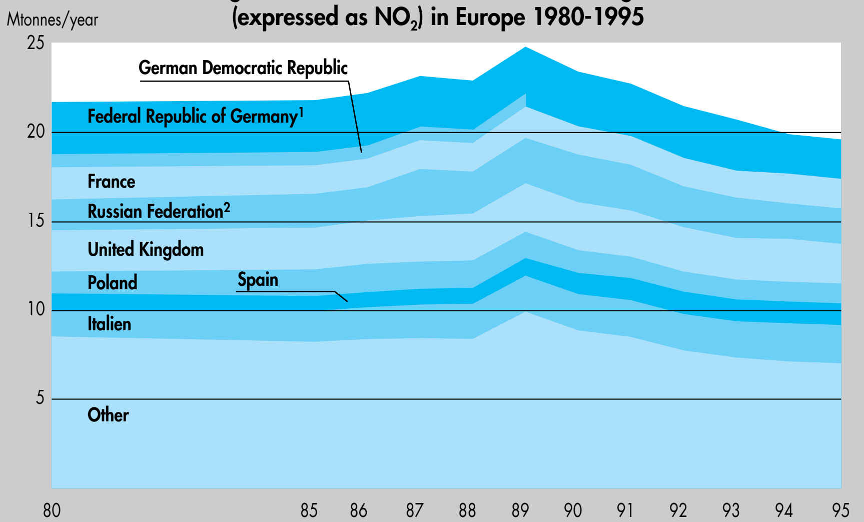
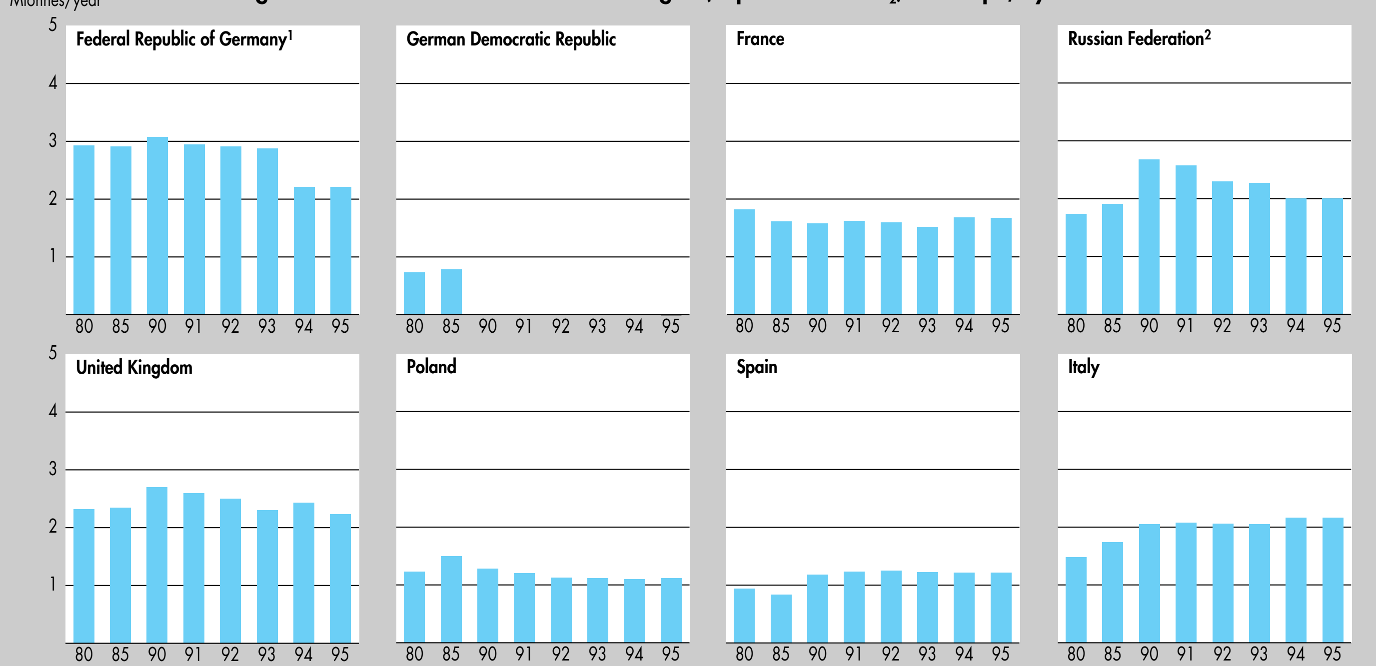


Figure 36b • Emissions of oxides of nitrogen (expressed as NO_2) in Europe, by countries



[1] *West Germany until 1989.* [2] *The part included in EMEP's calculations.*

its emissions by 8 %, the USA by 7 % and Japan by 6 %, with these percentages being related to 1990 emissions and those of an average year over the period from 2008 to 2012. The EU negotiated as a group, which means that there will be further internal negotiations between individual states on emission levels.

The protocol includes flexible mechanisms to permit more cost-efficient reductions. They allow Annex I countries to trade emission rights or perform Joint Implementation projects, under which work will be carried out by one country in another country, resulting in emission reductions that the first country can claim. There is also a provision for cooperation between Annex I countries and other countries, known as the Clean Development Mechanism (CDM), which will work in much the same way as Joint Implementation mechanism, except that CDM is intended not only to reduce emissions but also to assist non-Annex I countries to move towards sustainable development. Much work remains in order to determine the exact forms of these flexible mechanisms, and their final shape is not yet clear. For the protocol to come into force, it must be ratified by at least 55 countries who were responsible for at least 55 % of the total emissions from the Annex 1 countries in 1990. The next meeting of the parties will be held in November 1998.

Climate problems and the EU

Work is at present in progress within the European Union on apportioning the emission reductions as agreed at Kyoto among the individual member states. In addition to unilateral measures, EU member states may also take multilateral measures to reduce carbon dioxide emissions, and this may be preferable for them in some areas. The actual detailed formulation and application of the flexible mechanisms will have a considerable effect on how the agreed emission reductions are achieved, both for the EU and for other Annex 1 countries.

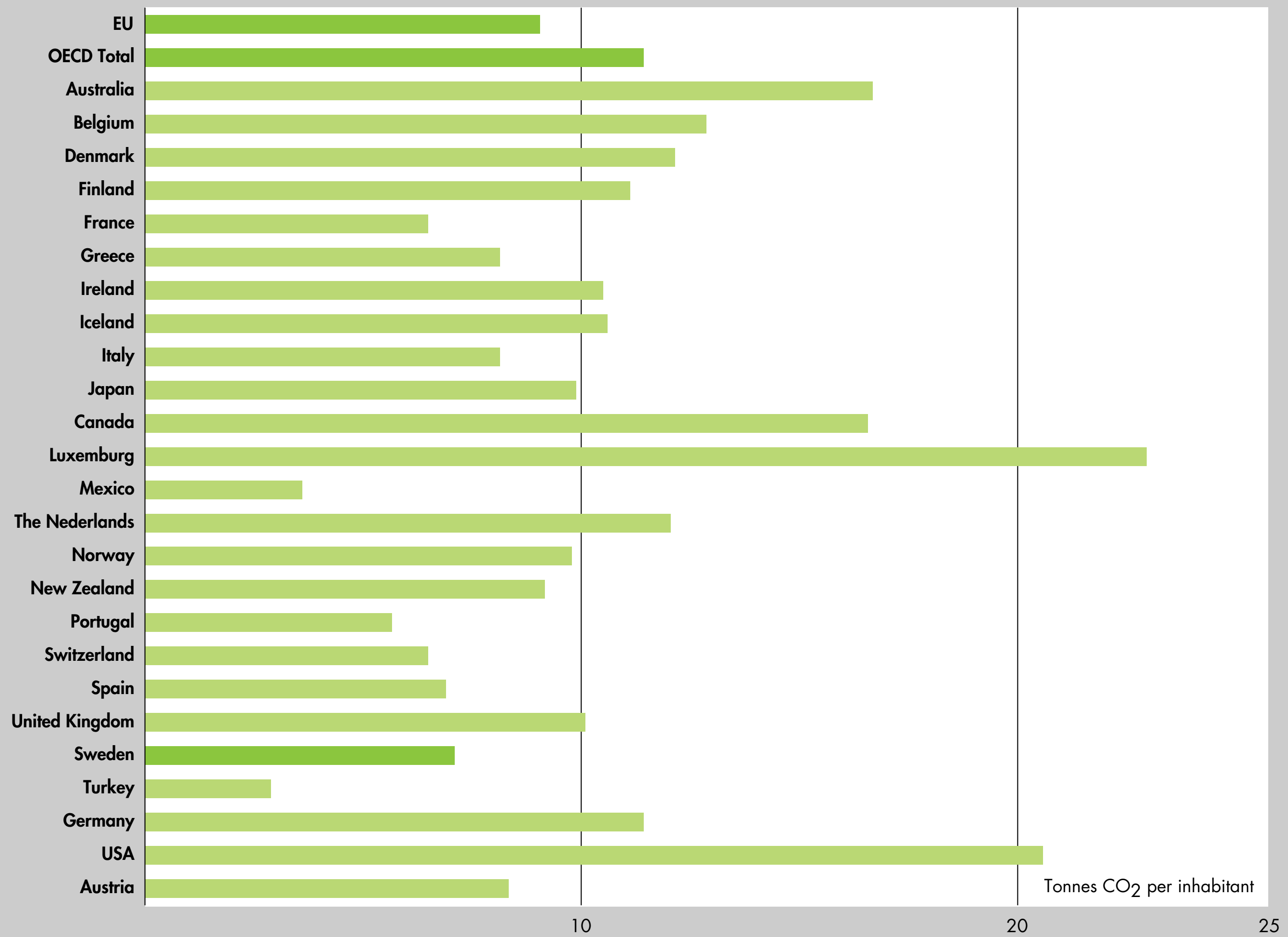
Other current matters within the EU

Much work is in progress within the EU that will directly or indirectly affect the energy and environmental sectors. Planned eastward expansion of the Union, for example, will have a very considerable effect. Most of the Eastern European countries have poorer environmental performance than is the case within the EU. When they join the EU, they will have to apply very much more stringent environmental performance criteria in order to be able to comply with EU regulations. This cannot, of course, be brought about overnight, but should, in the longer term, result in an improvement in the European environmental situation.

The question of renewable energy sources is being tackled in a number of ways. Several programmes aimed at increasing the proportion of energy provided by such sources, and at supporting their development, are being operated. The European Commission has also published a strategy document on renewable energy sources, in the form of a White Paper.

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 Market Directive in February 1998. Both are intended to improve operation of the markets, with common rules for the member states. They will be implemented gradually, and at different rates in different countries, which means that it may be some time before true common markets for electricity and natural gas are established. ■

Figure 37 • Emissions of carbon dioxide(CO_2) per inhabitant in EU and OECD-countries, 1995



[3] Bill no. 1992/93:179

[4] Sweden published its second national report on climate change in the spring of 1997 (Ds 1997:26).

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.

Back-pressure power
Electricity production utilising the heat drop in a steam process, with the simultaneous production of heat in a combined heat and power station. The heat may be used as process heat in a factory or in a district heating system.

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, CO2, 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 station
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

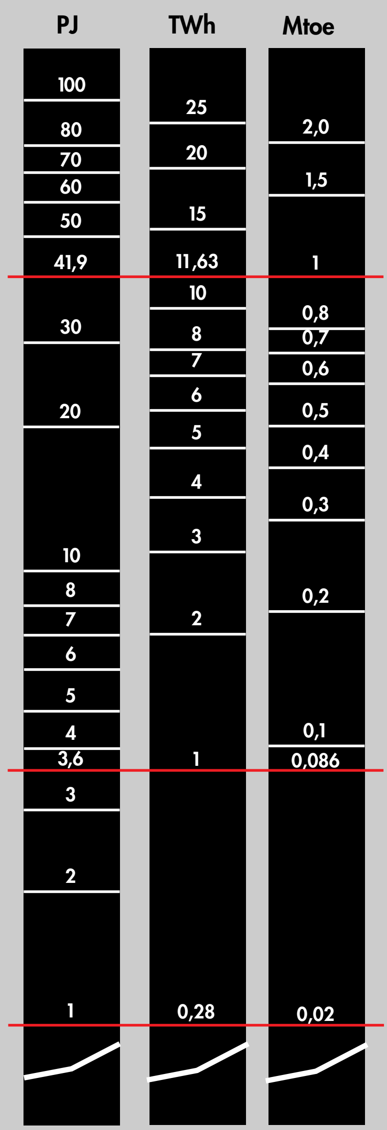
Units commonly used for comparison are the PJ, TWh and Mtoe. See the diagram on the right for conversions between them.

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

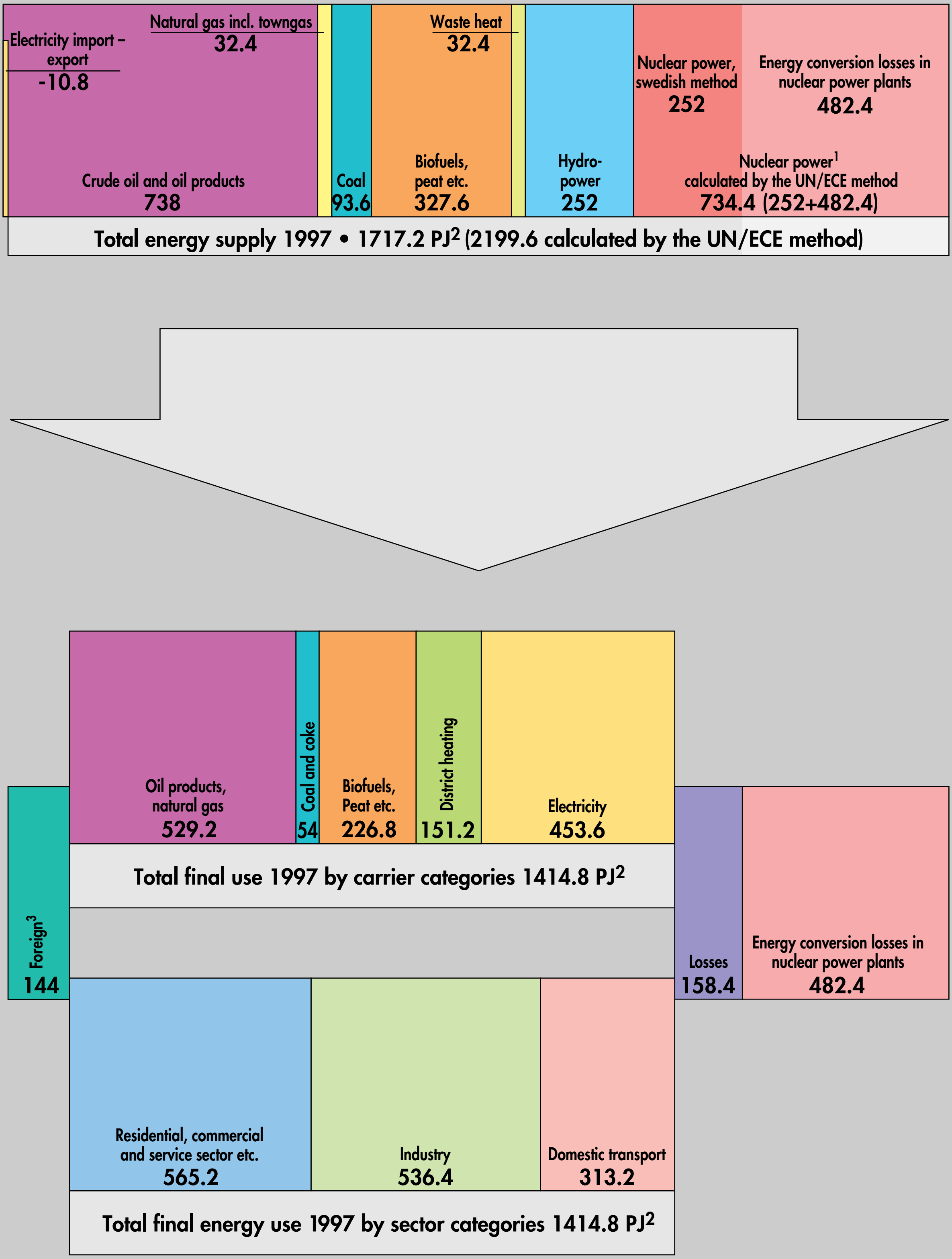
Domestic energy use

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.

Energy supply and use in Sweden 1997, 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.

The Administration will be located in Eskilstuna in September 1998.

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