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Box 310, SE-631 04 Eskilstuna
Fax: +46 16-544 22 59
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Preface

Conditions in the energy markets change rapidly, reflecting not only energy and environmental policy in Sweden, but also the effects of changes in the rest of the world. In recent years, Swedish energy and environmental policy has been increasingly concentrated on establishing or improving the long-term conditions for efficient energy markets and efficient use of energy. Restructuring of the Swedish electricity market, greater internationalisation and the effects of the energy system on the wider environment and on climate are important factors that influence the direction of energy policy and so also development of the energy markets.

The line that was started by the 2002 Energy Policy Agreement, under the name of Working Together for a Reliable, Efficient and Environmentally Aware Energy Supply (Bill no. 2001/02:143), continues. The shift in taxation policy to encourage the move towards a sustainable energy system and reduced environmental impact continues, as exemplified by the introduction of the electricity certificate system on 1st May 2003. The negotiations that were started in 2003 with a view to progressive shut-down of nuclear power generation were broken off in October 2004 without having reached agreement with the nuclear power companies. As soon as the breakdown of the negotiations was announced, the Government, together with the Left Party and the Centre Party, stated that Barsebäck 2 will be closed in 2005.

Sweden's climate policy is based on the Climate Strategy Act (Bill no. 2001/02:55), which was adopted by Parliament in March 2002. It is expected that trading in emission rights, in accordance with the EU Emissions Trading Directive, will start in January 2005, with publication of national emission rights allocations on 30th September 2004.

One of the more important tasks of the Swedish Energy Agency is to monitor developments in the energy and environmental fields, and to provide information on the current energy situation in respect of aspects such as changes in the pattern of energy use and energy supply, energy prices, energy taxes and the environmental effects of the energy system.

Energy in Sweden 2004, together with its statistics supplement, Energy in Sweden: Facts and Figures 2004, is intended to provide decision-makers, journalists and the public with a single source of easily available information on conditions and developments in the energy sector.

Eskilstuna, November 2004

Thomas Korsfeldt
Director-General

Zofia Lublin
Head of Department, System Analysis

Eva Centeno López
Project Manager

EDITORS:
Göran Andersson (Coal)
Johanna Andréasson (Residential and service sector)
Eva Centeno López (Energy balance, electricity market)
Erik Filipsson (Guide measures)
Per Grunéus (Industry)
Tobias Jakobsson (Energy gases)
Joachim Jämttjärn (Environment)
Anders Jönsson (Transport)
Therése Karlsson (International perspective)
Marcus Larsson (Oil, biofuels)
Mathias Normand (Guide measures)
Christian Sommer (Climate policy)
Paul Westin (Energy policy, district heating, district cooling)

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Current energy and climate policy areas

The framework conditions of energy markets are determined largely by political and legal considerations. In Sweden, the aim of the political decisions is to influence development of energy use and energy production and to create a sustainable energy system. The markets reflect primarily national and EU decisions, although global agreements are becoming increasingly important. This chapter discusses a number of areas of current interest in the fields of energy and climate policy.

Sweden's energy policy

Sweden's energy policy, in both the short and the long term, is to safeguard the supply of electricity and other forms of energy on terms that are competitive with the rest of the world. It is intended to create the right conditions for efficient use of energy and a cost-efficient Swedish supply of energy, coupled at the same time with minimum effect on health, the environment and climate and assisting the move towards an ecologically sustainable society.

The 1997 energy policy agreement[1] set out a strategy for continued restructuring of the country's energy system. The energy policy programme consisted of two parts: the short-term programme, which was concerned primarily with replacing the loss in electricity production capacity resulting from the closure of Barsebäck, and the long-term programme with its focus on research, development, demonstration and politically justified measures intended to counter climate change. The short-term programme was concluded in 2002, while the long-term programme was concluded in 2004.

Measures in the short and medium-long terms

The electricity certificate system, which was announced in the 2002 energy policy declaration, was introduced in 2003 with the aim of increasing the use of electricity from renewable sources by 10 TWh between 2002 and 2010. Local authorities must have agreed plans for 10 TWh/year of wind power by 2015. In addition, the 2002 energy policy decision also includes measures to improve the efficiency of energy use, such as those concerned with energy advisory services, technology procurement projects and the market introduction of energy-efficient technology.

A new measure introduced for 2004–2006 offers a tax reduction as an incentive to house-owners to fit high-performance windows in existing houses, or to install a biofuel-fired heating system in new houses. In the spring of 2004[2], the Government presented a proposal for a limited-time investment subsidy for certain environmental and energy investments in public buildings. This will take the form of a grant of 30% of the total cost of approved projects, rising to 70% to support the cost of installation of solar cells. It is expected that the subsidies will run from 1st January 2005 until 30th June 2006.

Long-term measures

In September 2003, the Commission on Energy Technology and Development submitted its report[3] on evaluation of the long-term elements of the 1997 energy policy agreement. The report states that although the various research, development and demonstration projects that have been carried out are both relevant and of good quality, they are not alone sufficient as a driving force for restructuring the country's energy system. The report includes proposals for a broader long-term energy policy programme, starting in 2005. The Commission also proposes stronger measures to assist commercialisation of new energy technology. In the 2004 Budget Bill[4], the Government proposes two separate but interacting objectives for the new long-term programme that will run from 2005: Building up the scientific and technical knowledge and competence within the country's universities, research institutes, public authorities and industry as are needed in order to enable new technology and new services to move the country towards a long-term sustainable energy system, and developing technologies and services that can be commercialised by Swedish industry, and thus contribute to modifying and

1 The agreement brings together the Social Democrats, the Left Party and the Centre Party.
2 Prop. 2003/2004:100.
3 ERDD – *one* element in restructuring the energy system (SOU 2003:80).
4 Bill no. 2004/05:1.
5 EU Directive 2003/54/EC of 26th June 2003.

developing energy systems not only in Sweden but also in other markets.

These proposed changes are intended to give greater priority to, and concentration on, resources, as well as to set higher targets for commercialisation of results, which will therefore assist not only Swedish restructuring of its energy system, but also the country's economic growth. Greater concentration on commercialisation of the results, with higher performance targets, closer links with industry and harmonisation with other guide measures and incentives require corresponding increases in analysis and strategic planning, together with more detailed knowledge of the operation of the energy system.

The Government proposes that a future programme of such work should run for seven years, from 2005 to 2011, for which it estimates an annual cost of SEK 440 million, or a total of SEK 3080 million over the period, starting from 1st January 2005. This represents a reduction in resources of about 40% compared with the previous programme. The Government proposes that, in future, such funding should be administered by the Swedish Energy Agency. In the previous programme, concluded in 2004, funding was administered also by the Swedish Research Council, the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas) and the Swedish Agency for Innovation Systems (Vinnova).

The Government is expected to submit a parliamentary bill for continued long-term work of research, development and demonstration activities, together with various climate measures that are compatible with energy policy.

The nuclear power negotiations

In 2003, the Government appointed a special negotiator to reach agreement with the nuclear power industry on long-term phasing out of nuclear power production. The negotiations were broken off in October 2004, without having reached an agreement with the power companies. However, the Social Democrats, the Left Party and the Centre Party have presented an agreement on a strategy for continued phase-out of nuclear power production. Under this strategy, Barsebäck 2 will be closed in 2005, and this will be followed by a review of the oldest remaining reactors. The actual rate of phase-out will depend on the rate of introduction of alternative energy production, improvements in the efficiency of energy use, energy research and technical development, and the effects of any EU guide measures of incentives.

Current investigations

The Electricity and Gas Market Commission was set up in 2003, with a task of putting forward proposals for harmonising Swedish legislation with the EU Electricity and Gas Market Directive[5]. An interim report[6] was published in December 2003, proposing that all non-domestic customers should be able to purchase natural gas on a deregulated market from 1st July 2004[7], with this freedom extending to all customers from 1st July 2007. Parliament is expected to debate a bill to realise this in the autumn of 2004, which will mean that the next stage of market relaxation could occur on 1st January 2005 at the earliest. The Commission's final report is expected in December 2004.

The Deregulation Commission was appointed in 2003, with the task of evaluating the long-term effects on consumers, industry, the labour market and the public economy of legislative and regulatory changes that have been made in the electricity, domestic aviation, railway, postal, taxi and telephone markets. Areas to be considered by the Commission include developments in competition, price and quality, as well as service to the public. The Commission's report will be based on the results of previous analyses within the various fields, and will include suggestions for further improvement of market performances. It is expected that the report will be published in January 2005.

In 2003, the Government appointed the District Heating Commission, to investigate the competitiveness of district heating in the heating markets, and to put forward proposals for improving consumer protection. The Commission will suggest possible changes in the legislation that prevents cross-subsidies between monopoly services and services that are exposed to competition within the fields of electricity and heat supply. In an interim report[8], the Commission proposes that the Electricity Act (1997:857) should include regulation of the separation between the supplies of district heating and of electricity. In addition, the Commission proposes that district heating activities should be accounted for independently, and that they should not be provided by the same legal entity as provides electricity. This would not apply to electricity from combined heat and power production (CHP), which would be regarded as being included in the district heating supply business. The Commission's final report is due on 31st December 2004. An additional sub-report, concerning Swedish implementation of the District Heating Directive (2004/8/EC), is due on 31st March 2005.

2003 also saw the establishment of the Re-

6 The electricity and natural gas markets – European harmonisation. (SOU 2003:113.)

7 Today, only customers buying more than 15 million m^3/year are allowed access to the deregulated market.

8 Protection for district heating customers – Greater transparency and separation of electricity and district heating activities. Interim report from the District Heating Commission, SOU 2003:115.

newable Motor Fuels Commission, to put forward objectives and strategies for continued introduction in Sweden of renewable motor fuels, in accordance with the EU Renewable Motor Fuels Directive[9]. The Commission will look at the requirement for petrol stations to supply at least one renewable-based motor fuel by 2005. At present, according to the Commission, there does not seem to be any prospect of a voluntary agreement with the sector[10]. The Commission is of the opinion that the national objective for use of renewable motor fuels should be 3% in 2005, which is one percentage point higher than the EU reference level. The Commission's final report is due for submission at the end of December 2004. This objective has been included in the Budget Bill put forward by the Government on 20th September 2004.

November 2003 marked the establishment of the Energy Performance of Building Commission, charged with putting forward proposals for implementation of the Energy Performance of Buildings Directive[11] in Sweden. The directive includes requirements in respect of energy certification of buildings in connection with sale, renting or construction. The Commission is due to submit its report on 1st November 2004. It will work in conjunction with a number of other commissions, including the Building Declaration Commission, whose remit is to produce a proposal for building declarations giving details of radon, ventilation and energy use. An interim report[12] has suggested a special law for building declarations for the indoor environment and energy use, together with proposals for how a national building register could be established. The Commission is expected to submit its final report in early January 2005.

Swedish climate strategy

The Government's Climate Policy Bill[13] was approved by Parliament in March 2002, setting out the objective of reducing the country's greenhouse gas emissions by 4% as a mean value over the period 2008–2012, in relation to the 1990 levels. This is a more ambitious objective than that required in accordance with the Kyoto Protocol, which in fact permits Sweden to increase its emissions by up to 4%. However, the international commitment (as opposed to the national objective) will become legally binding only when a sufficient number of countries has ratified the Protocol to bring it into force.

It is assumed that this emission reduction will be achieved by measures at national level, without having to credit measures carried out in other countries under the terms of the Kyoto Protocol flexible mechanisms or through the use of carbon sinks in the form of forests. Nevertheless, Sweden intends to obtain experience of, and contribute to, application of the flexible mechanisms in the Protocol. As Sweden has signed up to the EU emissions trading system, it is no longer possible to decide in advance where the emission reductions will be made.

Climate work and the national objective will be continuously monitored, with the Environmental Objective Council presenting an annual report of progress towards achieving the environmental quality objectives[14]. If emissions are not reduced in accordance with the objective, the Government may propose additional measures or, if necessary, reconsider the objective, subject to consideration of the competitiveness of Swedish industry. Progress checks will be carried out, with the first in 2004 and the next in 2008. The Government intends to complement the 2004 progress check with consideration of an objective for the flexible mechanisms.

The Environmental Protection Agency and the Swedish Energy Agency have prepared material for evaluating the efficacy of the country's climate policy in the 2004 progress check. This material includes developing a forecast of greenhouse gas emissions, and evaluation of the effectiveness of present guide measures and other actions.

In addition, the work includes investigation of the effects of further measures, and of the effects of integrating the flexible mechanisms into the national stage objective. The results were presented on 30th June 2004. In their '2004 Progress Check' report, the two authorities suggest that the present climate objective should be replaced by a new approach, in the form of what they call a 'countdown objective', which would allow the EU emission rights trading system to be integrated with the national stage objective. This approach would mean

FLEXIBLE MECHANISMS UNDER THE KYOTO PROTOCOL

The Kyoto Protocol, which was signed in 1997, contains three international cooperation mechanisms for greenhouse gas emission reduction:

- Joint Implementation (JI) enables industrialised countries to carry out emission reduction projects in other countries for which emission reduction targets have been set under the terms of the Protocol, but to credit the resulting reductions against their own commitments.
- Clean Development Mechanisms (CDM) are essentially the same as the Joint Implementation mechanism, except that they are carried out in countries that do not have emission reduction commitments under the Protocol, i.e. generally in developing countries. There is therefore a need for a strict regulatory framework in order to protect against a possible corresponding lack of framework in the country of implementation. CDM projects must also assist sustainable development in the reception country.
- Emission rights trading enables countries with emission reduction rights to trade these rights with other countries having reduction commitments.

9 EU Directive 2003/30/EC, dated 8th May 2003.
10 Renewable motor fuels – A national objective for 2005 and proposals for how the availability of these fuels can be improved (SOU 2004:4).
11 Directive of the European Parliament and of the Council concerning the Energy Performance of Buildings, 2002/91/EC, 16th December 2002.
12 Building Performance Declarations – The indoor environment and energy use (SOU 2004:78).
13 Bill no. 2001/02:55.
14 Environmental objectives – Are we achieving them? The Environmental Objective Council, 2004.

that emission changes in the trading sector[15], representing sale or purchase of emission rights, would not be included when deciding whether or not the national stage objective had been achieved. However, it is the intention that the sum of emission rights grants for the period from 2008 to 2012 and emissions from the non-trading sector should be less than 96% of 1990 emissions. The amount by which it will be necessary to reduce emissions in Sweden, and the need for additional guide measures or incentives to improve performance from the non-trading sector, will depend on the magnitude of the rights assigned to the trading sector. The report also recommends continuation of public support for the JI and CDM mechanisms over the period from 2005 to 2012.

Sweden's national allocation plan for emission trading within the EU over the period 2005-2007 was presented in April 2004, and has since been approved by the European Commission. The plan sets out the principles for allocation of emission rights to plants included in the trading system, together with a ceiling for the total number of emission rights. The plan foresees rights equivalent to 22.9 million tonnes of CO_2 equivalents per year over the period. The final, definitive quantity was determined in connection with conclusion of the allocation process on 30th September 2004, and amounted to 22.3 million tonnes/year.

The flexible mechanisms make it possible to, and encourage, achieve emissions-reducing measures where they are most cost-efficient. The Swedish Energy Agency is responsible to the Government for planning and managing JI and CDM projects. A special Joint Implementation Commission was appointed by the Government at the end of 2001 to investigate opportunities for Swedish JI projects in other countries. It presented its results in December 2002 in a report[16] that described excellent opportunities for cost-efficient JI projects in eastern European countries. As a result, negotiations for bilateral JI agreements have been started with Russia, Estonia and Lithuania, and have been successfully concluded with Romania. The Swedish Energy Agency is now drawing up a test portfolio containing three or four small and medium-sized JI projects for renewable energy and energy efficiency improvements in eastern Europe. In the summer of 2003, open invitations to tender were sent out to potential project-owners, inviting them to submit proposals for JI projects in eastern Europe. About 15 proposals were received, from which those that are now being processed include one project in Romania and two in Estonia, for which a total of about SEK 40 million has been approved. In Russia, other projects may be started now that the country has ratified the Kyoto Protocol.

For Clean Development Mechanisms, too, it is the intention of the Agency to put together a geographically balanced portfolio, concentrating on small-scale renewable energy projects that can, at the same time, contribute to sustainable development. During 2003–2004, the Agency has signed agreements for four such projects, which are expected to produce emission reductions of 4.3 million tonnes/year of CO_2 equivalents, at a price of about 5 öre/kg of carbon dioxide. This can be compared with the marginal cost of CO_2 reductions in Sweden, in a range of 50–100 öre/kg of CO_2. These projects are therefore cost-efficient, even in comparison with the EU trading system and its assessment of the prices of emission rights.

On behalf of the Government, the Swedish Energy Agency is also a participant in the Testing Ground Facility (TGF), a regional fund for climate cooperation under the Kyoto Protocol, and established within the framework of the Baltic Sea Region Energy Cooperation (BASREC) agreement, supported by the Nordic Council of Ministers. The fund's capital for the first stage of its work is estimated at about EUR 10 million. Of this, Sweden's proportion, which is financed from the international climate investment grant, amounts to almost EUR 4 million. It is the intention that private companies, too, can participate in the fund. Its activities are based on the decision to make the Baltic region an experimental area for climate investments, as agreed by the region's energy ministers at their meeting in Gothenburg in September 2003.

In addition, Sweden is a member of the World Bank Prototype Carbon Fund (PCF), which has now been running for a few years, and has assisted the development of climate projects and their regulatory structures. To date, the fund has entered into contracts for about 40 projects, in both developing countries and transitional economy countries.

Energy in the EU

In November 2000, the European Commission published a Green Paper[17] for the energy sector. It noted that the EU is still increasing its use of energy, and importing still-increasing quantities of energy products. If nothing is done over the next 20–30 years, 70% of EU energy requirements will depend on energy from imported products, as opposed to 50% today. The

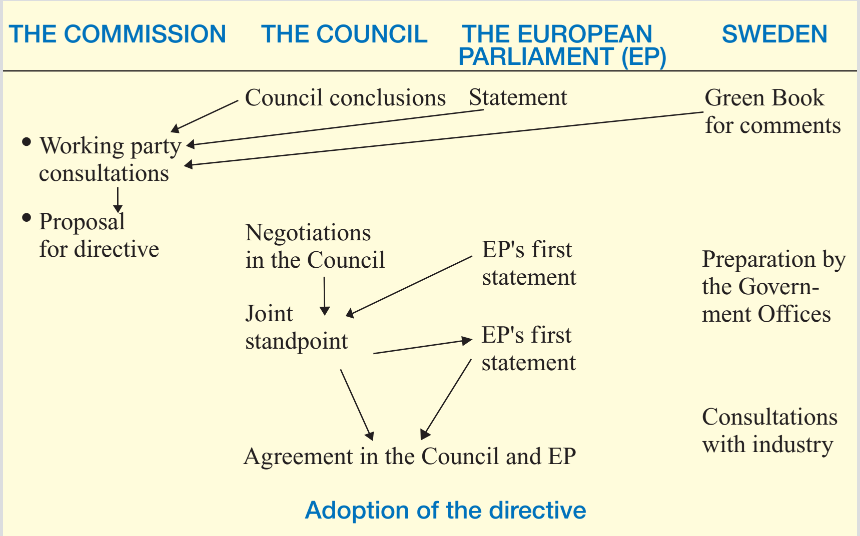
15 The trading sector consists of power stations, heating plants, oil refineries, iron and steel works, glass works, glass fibre manufacture, cement works and ceramic industries, as well as pulp and paper mills.

15 Joint Implementation – Agreements for a better climate (SOU 2002:114).

17 Green Paper – an official Commission document presenting the first drafts or suggestions for possible actions at EU level. White Paper – an official document from the Commission, containing structured proposals for EU regulations. A Swedish Parliamentary bill is similar to a White Paper.

DECISION-MAKING IN THE EU

A schematic diagram of how EU directives are prepared, agreed, issued and incorporated in national legislation in member states. In Sweden, this means that the normal response is to set up a committee (SOU), which produces a draft legislation proposal. This then forms the basis of a Governmental parliamentary bill, which is sent to the Council on Legislation before being presented to a Parliamentary standing committee and then voted on by the Parliament. The directive can then be finally incorporated into Swedish legislation.



Source: Ministry of Industry, Employment and Communication.

Green Paper suggests some bases for a long-term energy strategy.

The single market, together with free competition in the energy sector, is one of the bases of EU energy policy. The Electricity and Gas Market Directive[18] was published in June 2003, replacing the Electricity Market Directive from 1996 and the Gas Market Directive from 1998. According to the present directive, the electricity and gas markets must be fully open for the commercial sector in 2004, and for all customers by 2007.

The Trans-European Network for energy (TEN-e) constitutes another important element of the EU's energy policy. Improving power and gas pipeline connections between countries increases cross-border carrying capacity, thus improving competition and security of supply.

New directives that have come into force

The Energy Taxation Directive[19] was adopted on 27th October 2003, setting out minimum tax rates for oil, coal, natural gas and electricity used as a motor fuel or for heating. As far as Sweden is concerned, this means that industry now becomes liable for tax (see Chapter 2, Guide measures and incentives).

The Biobased Motor Fuels and Energy Performance of Buildings Directives have been published, and application of them in Sweden is now being investigated. (See above, under 'Current investigations').

Proposals for new directives

In September 2003, the Commission submitted a Notice[20] to the Council and European Parliament concerning development of an industry policy for the expanded European Union, its neighbouring countries and its partner countries. Four objectives were defined:

1. To improve the security of energy supply in Europe,
2. To strengthen the single market for electricity in the expanded EU,
3. Modernisation of energy systems in the EU's new members and neighbouring countries,
4. To facilitate realisation of significant new energy infrastructure projects.

In December 2003, the Commission put forward its infrastructure and security of supply package, containing proposals for three directives (TEN-e, electricity supply and energy services) and for one ordinance (gas).

The current guidelines for the Trans-European Network for energy, TEN-e, were decided as recently as June 2003, and so negotiations are therefore concentrated on the new features of the proposal[21]. As the EU's need to import energy (primarily in the form of natural gas) is increasing, and as most of the energy sources are outside the EU, the construction of pipelines through southern and eastern Europe to the previous Soviet Republics and to the Middle East and Gulf region is important. It is proposed that such construction should be eligible for EU support.

The Electricity Supply Directive[22] reflects the Commission's unease in respect of the lack of competition on the electricity markets within and between member states, and in respect of the unsatisfactory level of security of supply. One of the effects of the proposal is that the member states should introduce clear rules governing supply, use and effect problems. Member states should also take steps to reduce concentration of ownership of the means of production. Most member states share these objectives, but are sceptical of the means. Sweden's view is that the various parties on the market should be responsible for ensuring that the demand for electricity can be met.

The Energy Services Directive[23] is intended to bring about more rational and cost-efficient end use of energy, and to remove obstacles in the market for energy services. The proposal contains a binding objective for each member state, requiring a 1% annual improvement in the efficiency of final use of energy, although

18 Directive 2003/54/EC of the European Parliament and of the Council concerning the Internal Market in Electricity and Gas.

19 Directive 2003/96/EC of the European Parliament and of the Council concerning Restructuring of the Common Framework for Taxation of Energy Products and Electricity.

20 COM (2003) 262, final, 13th May 2003.

21 Trans-European Energy Network (TEN-e), COM (2003) 742, final.

22 The Electricity Supply Directive, COM (2003) 740, final.

23 The Energy Services Directive, COM (20003) 739, final.

the energy-intensive industries in the emissions rights trading system are exempted, as are aviation and maritime transport. The required improvement in the efficiency of energy use can be achieved in a number of ways, including the use of energy services and energy efficiency improvement programmes. Sweden believes that it is important that the regulatory structure should be so designed as to avoid distorting the markets for energy, energy services or capital.

The objective of the Gas Ordinance[24] is to provide a stable framework that guarantees efficient utilisation of capacity, creates transparency in respect of available capacity and harmonises the conditions for gas distribution and demand/supply balancing services. The proposal represents part of the progress of realisation of the single market for energy (electricity and gas), and is seen by the member states as essentially uncontroversial.

The Commission Recommendation on the Recognition of Environmental Issues for Energy-using Products[25] was adopted by the Commission on 1st August 2003. The requirement for environmental design must be introduced, in order to guarantee free movement of energy-using products within the EU, while at the same time improving the overall environmental performance of such products. The Recommendation covers all products, apart from transport equipment, that use energy and which are responsible for a significant proportion of the sales and trading volume within the EU, and which have significant environmental effects at EU level. There must also be a worthwhile potential for reducing the environmental impact of the products. Sweden is in favour of the Recommendation, but emphasises that the requirements imposed must be appropriate to the reduction in environmental impact that can be achieved.

EU climate strategy and emission rights trading

The Emission Rights Trading Directive, governing trading within the EU, came into force in October 2003. Under the terms of the Directive, about 46% of expected EU carbon dioxide emissions would be covered by the trading system. Electricity and heating plants with an input power rating of more than 20 MW would be among those covered. The Directive also proposes that, between 2005 and 2007, all member states should issue emission rights to participating power plants at no cost. By not later than June 2006, the Commission shall have reviewed initial experience of operation in order to decide the most suitable harmonised method of allocating rights for continued use.

In April 2004, the Council and the European Parliament reached an agreement on what is known as the Link Directive Proposal, which modifies the Trading Directive by linking the JI and CDM project-based mechanisms to the trading system. According to the Directive, there must not be any restrictions on CDM projects during the 2005-2007 trial period. In their next national allocation plans for emission rights, member countries are required to specify how they intend to use international emission rights credits from JI and CDM projects. International measures must be supplementary to emission reduction measures in the home country. A Climate Change Committee, under the EU Commission, will monitor and assess how the member states fulfil this supplementarity principle.

Application of the Link Directive is still being discussed by the member states and by the Commission. A benefit of including the project-based mechanisms in the European trading system is that they could be expected to reduce the market value of emission reductions due to the fact that the reductions would be achieved in countries having lower marginal costs for the reductions. On the other hand, a drawback is that the lower market prices would reduce the incentive to develop expensive new environmental technology for application in Europe. ■

24 The Gas Ordinance, COM (2003) 741, final.
25 COM (2003) 453, final.

Guide measures and incentives

Several taxes and incentives have been introduced with the aims of achieving the objectives set out in the country's energy and climate policy: to reduce emissions of carbon dioxide, to increase the proportion of renewable energy, to increase the efficiency of energy use, and also to reduce the overall use of energy. The most wide-reaching means of achieving objectives in the energy policy, and which is also intended to meet several of the objectives, is energy taxation, in the form of energy tax as such, carbon dioxide tax and sulphur tax. Other important guide measures and incentives described in this chapter are the electricity certificate trading system, the energy efficiency improvement programme, technology procurement, information campaigns, trading in emission rights and the climate investment programme. Research, development and demonstration projects constitute an important element of long-term development strategy.

Energy taxation

The original objective of energy taxes was to finance the State's public spending requirements, but in later years the emphasis has increasingly been on the need to control the production and use of energy in order to achieve various energy and environmental policy objectives. Present energy taxation policy is aimed at improving the efficiency of energy use, encouraging the use of biofuels, creating incentives for companies to reduce their environmental impact and creating favourable conditions for indigenous production of electricity.

During the oil crises of the 1970s, the aim was to reduce the use of oil and increase the use of electricity. The environmental element of energy taxation was given greater importance at the beginning of the 1990s while, since Sweden's accession to the EU, there has subsequently been a need to bring taxation into line with EU requirements. The earlier Mineral Oils Directive and the associated Tax Rate Directive have been complemented by new minimum taxation levels as part of the process of harmonisation of fuels and electricity throughout the EU. A new Swedish taxation model is being developed at present, with the aim of designing a coordinated and consistent taxation structure for business, while complying with EU competition and public subsidy rules.

The present energy taxation system is relatively complicated. There are different taxes on electricity and fuels, on CO_2 and sulphur emissions, and a levy system on NO_x emissions. The taxes can then vary, depending on whether the fuel is being used for heating or as a motor fuel, whether it is being used by industry, domestic consumers or the energy conversion sector and, in the case of electricity, what it is being used for and whether it is being used in northern Sweden or in the rest of the country. In 2003, revenues from energy taxes raised over SEK 62 200 million, making up 10.2% of State revenue or 2.5% of GNP. (See Table 1.)

TABLE 1

Revenues raised by energy taxes in accordance with the 2003 taxation structure, SEK million.

Energy carrier	Energy tax	CO_2 tax	Sulphur tax	Total
Petrol	15 979	9 438		25 417
Oil products	4 900	12 960		17 860
Unrefined tall oil	24			24
Other fuels	145	1 355		1 500
All fuels			136	136
Electricity	15 450			15 450
Electricity from nuclear power plants	**1 824**			**1 824**
Total	**38 322**	**23 753**	**136**	**62 211**
Proportion of national tax revenue				10.2%
Proportion of GNP				2.5%

Source: National Tax Board, National Financial Management Authority, Statistics Sweden.

Types of tax and tax rates

'Energy tax' is an umbrella name for spot taxes on fuels and electricity. They can be roughly divided up into fiscal taxes and those intended to achieve environmental objectives. This latter group of taxes includes the carbon dioxide and sulphur taxes, while the general

TABLE 2

General energy and environmental taxes from 1st January 2004, excluding VAT

	Energy tax	CO_2 tax	Sulphur tax	Total tax		Tax, öre/kWh
FUELS						
Gas oil, SEK/m³, (< 0.05% sulphur)	732	2 598	0	3 330	(3 344)	33.4
Bunker oil, SEK/m³, (0.4% sulphur)	732	2 598	108	3 438		32.5
Coal, SEK/tonne, (0.5% sulphur)	312	2 260	150	2 722		36.0
LPG, SEK/tonne	143	2 732	0	2 875		22.5
Natural gas/methane, SEK/1000 m³	237	1 946	0	2 183		21.9
Unrefined tall oil, SEK/m³	3 330	0	0	3 330		33.9
Peat, SEK/tonne, 45% moisture (0.3% sulphur)	0	0	50	50		1.84
MOTOR FUELS						
Petrol, unleaded, env. class 1, SEK/l	2.68	2.11	-	4.79	(4.96)	53.0
Diesel fuel, env. class 1, SEK/l	0.73	2.60	-	3.33	(3.65)	33.4
Natural gas/methane, SEK/m³	0	1.11	-	1.11		11.1
LPG, SEK/kg	0	1.34	-	1.34		10.5
ELECTRICITY USE						
Electricity, northern Sweden, öre/kWh	18.1	-	-	18.1	(19,4)	18.1
Electricity, rest of Sweden, öre/kWh	24.1	-	-	24.1	(25.4)	24.1
ELECTRICITY, GAS, HEAT OR WATER SUPPLY						
Northern Sweden, öre/kWh	18.1	-	-	18.1		18.1
Rest of Sweden, öre/kWh	21.5	-	-	21.5		21.5
ELECTRIC BOILERS, > 2 MW, 1/11-31/3						
Northern Sweden, öre/kWh	20.5	-	-	20.5		20.5
Rest of Sweden, öre/kWh	24.1	-	-	24.1		24.1

Note: Figures in brackets are as proposed in the 2004/05:1 Budget Bill.
Source: National Tax board, Swedish Energy Agency processing.

TABLE 3

General energy and environmental taxes for industry, agriculture, heat production in CHP plants, forestry and fisheries from 1st January 2004

Energy carrier	Energy tax	CO_2 tax	Sulphur tax	Total tax	Tax, öre/kWh
Gas oil, < 0.05% sulphur, SEK/m³	-	546		546	5.5
Heavy fuel oil, 0.4% sulphur, SEK/m³	-	546	108	654	6.2
Coal, 0.5% sulphur, SEK/tonne	-	475	150	625	8.3
LPG, SEK/tonne	-	574	-	574	4.5
Natural gas, SEK/1000 m³	-	409	-	409	4.1
Unrefined tall oil, SEK/m³	546	-	-	546	5.6
Peat, 45% moisture, 0.3% sulphur, SEK/tonne	-	-	50	50	1.8
Electricity use, öre/kWh	0.5	-	-	0.5	0.5

Source: Source: National Tax board, Swedish Energy Agency processing.

energy tax is essentially a fiscal tax. However, there is no strict boundary between the types, as both groups have an environmental effect as well as a fiscal function. The general energy tax, which has existed for several decades, and with varying purposes, is levied on most fuels, and is not only dependent of their energy content (see Table 2). The carbon dioxide tax, which was introduced in 1991, is levied on the emitted quantities of carbon dioxide from all fuels except biofuels and peat. In 2004, the general level of carbon dioxide tax is 91 öre/kg of CO_2. A sulphur tax was introduced in 1991, and is levied at the rate of SEK 30 per kg of sulphur emission from coal and peat, and at SEK 27/m³ for each tenth of a percent of sulphur by weight in oil. Oils containing less than 0.05% of sulphur by weight are exempted from the tax. The environmental levy on the emission of NO_x was introduced in 1992, at a rate of SEK 40/kg of NO_x emissions from boilers, gas turbines and stationary combustion plant supplying at least 25 GWh per annum. However, it is intended to be fiscally neutral, and is repaid to plant operators in proportion to their energy production so that only those with the highest emissions are net payers.

Taxation to encourage sustainability

It was decided in the spring of 2000 that a total of SEK 30 000 million of taxation revenue should be transferred over a ten-year period. This means that taxes on energy use and emissions will be increased, offsetting a corresponding reduction in taxes on employment.

Sweden's carbon dioxide emissions are to be cut, not least in order to comply with the country's commitments under the Kyoto Protocol. The carbon dioxide tax on fuels was raised by 20% from the beginning of 2004, with the intention of increasing the impact of the CO_2 tax in relation to the energy tax and of reducing CO_2 emissions. There was no rise in the tax on LPG, natural gas or methane when used as motor fuels. A simultaneous change in the tax reduction rules has had the effect of ensuring that carbon dioxide tax remains unchanged for manufacturing industry, agriculture, forestry and fisheries etc.

Higher carbon dioxide taxes would mean that electricity would become cheaper in relation to other forms of energy carriers, and so the tax on electricity was raised by 1.4 öre/kWh from 1st January 2004, thus ensuring that relative competitiveness has not been affected by the increase in environmental taxes, while at the same time contributing to more efficient use of electricity.

The 2005 Budget Bill proposes that the energy tax on electricity use in the domestic and service sectors should be raised by 1.2 öre/kWh, in order to improve the efficiency of utilisation of electricity. It is also proposed that the tax rate on fossil fuels should be increased at the same time. The change in the rate of CO_2 tax, on the other hand, is equivalent only to an indexed uprating. All the changes will come into effect on 1st January 2005.

Electricity and heat production

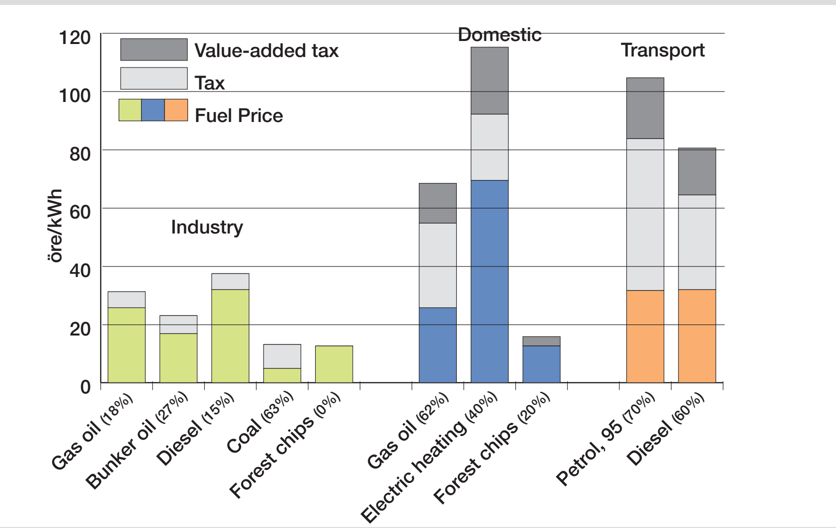
Fuels that are used for electricity production are exempt from energy and carbon dioxide tax, although they are subject to the NO_x levy and sulphur tax in certain cases. However, the use of electricity is taxed, at rates that vary depending on in which part of the country the electricity is used, and on what it is used for. Nuclear power plants were previously taxed on the basis of their electricity production, but since 1st July 2000 the tax has been based on the maximum thermal power rating of their reactors[26]. In addition, there is a levy of 0.15 öre/kWh for decontamination and decommissioning of the country's previous nuclear facilities at the Studsvik research centre[27], and a further levy that amounts to about 1 öre/kWh for financing future storage facilities for spent nuclear fuel[28].

Fuels used for heat production pay energy tax, carbon dioxide tax and, in certain cases, sulphur tax, as well as the NO_x levy. The use of heat, however, is not taxed. In principle, biofuels and peat are tax-free for all users, although the use of peat attracts the sulphur tax. The taxation regime for simultaneous production of heat and electricity (CHP) has been changed with effect from 1st January 2004, so that the tax on the fuels used for heat production in such plants is taxed at the same rate as on these fuels when used in industry. However, that portion of the fuel which is used for the electricity production receives a full rebate of energy and carbon dioxide tax, although that part of the fuel which is regarded as producing electricity for internal use is subject to full taxation. Fuels that are used for the net beneficial heat from a CHP power station pay the reduced level of carbon dioxide tax as applied to industry, and no energy tax. With the introduction of these changes, CHP utilities were no longer allowed themselves to allocate the proportions of fuels used for heat and electricity respectively: Instead, all the fuel usage must be assigned in proportion to the actual quantities of electricity and heat produced.

26 The tax rate is SEK 5514 per MW and calendar month.
27 The Act (1988:1597) Concerning Financing of Handling of Certain Radioactive Waste etc.
28 The Act (1992:1537).

FIGURE 1

Final fuel prices for various customers, 2003



Source: Swedish Petroleum Institute, Statistics Sweden, National Tax Board.

Consumption

Manufacturing industry, horticulture, farming, forestry and fisheries[29] pay no energy tax on fossil fuels, and only 21% of the carbon dioxide tax[30]. For 2004, simultaneous reduction of the carbon dioxide tax rate and an increase in the general level meant that the overall carbon dioxide tax rate for these activities would be essentially the same as it was in the previous year. In the 2005 Budget Bill, the Government proposes that the carbon dioxide tax on diesel fuel used in commercial farming, forestry and fisheries activities should be reduced by 77%, with effect from 1st January 2005. There are special rules for energy-intensive industrial activities, reducing that part of the carbon dioxide tax that exceeds 0.8% of the sales value of the products concerned.

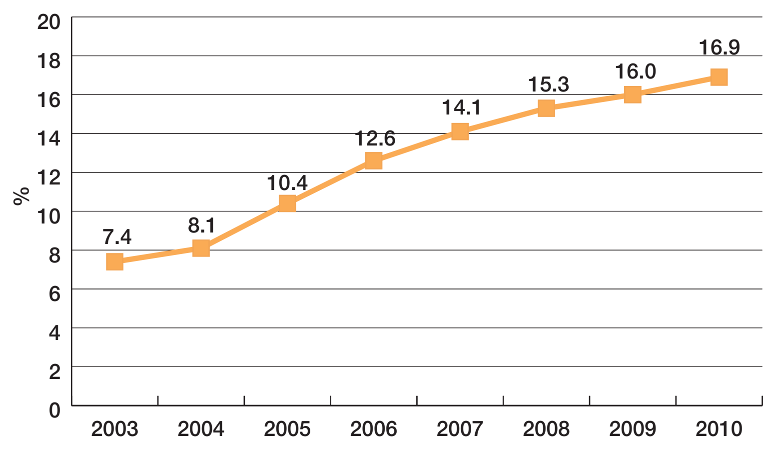
There are various tax levels for transport, depending on the environmental class of the fuel, which have resulted in reduced emissions of some pollutants. Apart from increases due to indexing, petrol and diesel fuel taxes are largely unchanged from the previous year. No energy tax is payable on the use of diesel fuel or fuel oils used in commercial maritime traffic or railbound traffic, or on aviation petrol/kerosene.

Domestic users pay different rates of electricity tax, depending on whether they live in the north of the country or in the rest of the country (see Table 2).

The final price paid by consumers depends largely on taxation. In addition to the various spot taxes on energy, there is value-added tax of 25%, which is not paid by industry. In 2003, the tax paid by a consumer heating his house with gas oil accounted for 62% of the total cost, which can be compared with 60% in 2002. For petrol, the total proportion of tax (including value-added tax) accounted for 70% of the total price in 2003, while the corresponding proportion for forest wood chips was 20% (see Figure 1).

FIGURE 2

Quota obligation requirement in the electricity certificate system, 2003–2010



Source: Bill no. 2003/03:40: Electricity certificates to support renewable energy sources.

TABLE 4

Number of plants, installed capacity and renewable electricity production in the electricity certificates system, as of 16th May 2004

	No. of approved plants	Installed capacity, MW	Electricity production, MWh
Hydro	1 029	743	1 725 827
Wind	562	416	719 081
Biofuel	100	3 192	6 986 721
Solar	1	0,008	0
Total	**1 692**	**4 351**	**9 431 629**

Source: Svenska Kraftnät, Swedish Energy Agency.

TABLE 5

Market statistics for the electricity certificate system, 2003 (1st May – 31st December)

No. of certificates issued (2003, eight months only):	6 425 600
Quota obligations (2003, eight months only:	4 518 868
No. of certificates cancelled (2003, eight months only):	3 486 086
Quota obligation fulfilment:	77%
Quota obligation revenue:	181 Mkr

Source: Svenska Kraftnät, Swedish Energy Agency

Electricity certificate system

Since the beginning of the 1990s, several different systems intended to support the production of electricity from renewable energy sources have existed. They have included investment subsidies for the production of electricity from biomass, wind power and hydro power, as well as what is known as the environmental subsidy for production of electricity from wind power. On 1st May 2003, a new support system for renewable energy was introduced, based on trading in electricity certificates for renewable electricity. During a transition period, the certificate trading system will be complemented by targeted support for wind power production in the form of the environmental subsidy which, at present, is 12 öre/kWh, but which will be progressively phased out by 2009.

The aim of the certificate trading system is to bring a greater proportion of electricity production from renewable sources into the country's energy system, increasing it by 10 TWh between 2002 and 2010. All electricity users, with the exception of manufacturing processes in energy-intensive industries, must buy a certain percentage of their electricity from renew-

29 Fisheries cover the raising or cultivation of all types of animals and plants in water.

30 Energy tax is payable, however, on unrefined tall oil and electricity.

able sources. The system is intended to reduce the production costs of such electricity, and thus increase its proportion in the long term, by creating competition between different types of renewable electricity production.

In 2003, the proportion of renewable electricity that affected users were required to buy was 7.4% of their use. This proportion will be progressively increased year by year, so that it will have reached 16.9% in 2010, by which time the trading system should have resulted in about an extra 10 TWh/year of electricity production from renewable sources (see Figure 2).

Qualifying renewables are electricity from wind power, solar energy, geothermal energy, biofuels, wave energy and small-scale hydro power. With effect from 1st April 2004, electricity from peat also qualified for certificates. Table 4 shows data for approved production sources, installed capacity and energy production for each type of source.

The system covers only electricity produced in Sweden. Norway is at present planning to introduce an electricity trading certificate system, and is holding discussions with Sweden concerning a joint certificate market. The effects of this market are being investigated, and the result is due to be reported in January 2005.

In 2003, the average consumer price of the certificates was 2.4 öre/kWh, including VAT. 63% of the total payments for certificates by domestic users reached the producers of renewable electricity in 2003. The other 37% consisted of VAT (20%) and the balance retained by the electricity suppliers (17%).

Performance of the trading system is being monitored, and the results were reported to the Ministry of Industry and Commerce on 1st November 2004.

The energy efficiency improvement programme

An energy tax on the electricity used in manufacturing industry, agriculture, forestry and fisheries was introduced on 1st July 2004, at a rate equivalent to the minimum required tax rate as set out in the Energy Taxation Directive[31]. This means that, where manufacturing industry previously paid a zero tax rate on electricity, it must now pay an electricity tax of 0.5 öre/kWh.

In June 2004, the Government put forward a bill setting out an energy efficiency improvement programme, with the intention that the programme should come into force on 1st January 2005[32]. From that date, companies participating in the programme can receive a full rebate of the energy tax on electricity: In return, they undertake to introduce an energy management system and continuously to perform energy audits in order to determine their potentials for improving the efficiency of their energy use. A condition for continued participation in the programme is that, over a five-year cycle, companies must apply all the energy efficiency improvement measures that have been identified, and which have a payback time of less than three years.

Another requirement for participation in the programme is that the company must be an energy-intensive company, as defined in the Energy Taxation Directive. This means that it must fulfil one of the following criteria:

a) Its energy products expenditure amounts to at least 3% of its production value.
b) The total energy and carbon dioxide tax for the company amounts to at least 0.5% of its added value.

Through the energy management systems and energy audits that make up the programme, companies will improve their awareness of their potentials for cost-efficient energy efficiency improvements. The underlying intention is that companies should improve their efficiency of electricity use without being subjected to the pressure of taxation that could have an adverse effect on their international competitiveness. The electricity efficiency improvement measures taken as a result of the programme are expected to give more or less the same effect as an energy tax of 0.5 öre/kWh would have done.

Technology procurement

Technology procurement is a guide measure intended to encourage the development of a new technology. It should be seen as a process, rather than as a project, consisting of a number of phases (actions) and several different groups and types of parties involved. The various phases involve execution or establishment of a feasibility study, a purchaser group, performance specification, tendering procedure, evaluation, dissemination and further development. It forms a complete tendering process, with the aim of encouraging and accelerating the development of new technology, and is often carried out in the form of a competition between manufacturers. When entries have been received, they are tested and evaluated, with one or perhaps more winners being announced. The winners are given assistance with the market introduction process, and are

31 Directive of the Council, 2003/96/EC.
32 Energy efficiency improvement programme etc., Bill no. 2003/04:170.

guaranteed a defined initial order volume for the new product. The overall intention of the process is to arrive at new products, systems or processes that better meet purchasers' requirements than do existing products on the market. Another way of describing the process is to say that technology procurement is a guide measure intended to bring about market changes and to encourage the spread of new, efficient technology in the form of new products, systems or processes. The main application areas of technology procurement are in the fields of heating and control systems, domestic hot water and sanitary systems, ventilation, white goods, lighting and industry. The Agency has prepared a list[33] of all technology procurement projects within the energy field that have been carried out by the Agency, and by its forerunners, NUTEK and the National Energy Administration.

Information campaigns

Information, training and testing are some of the means by which more efficient use of energy can be achieved. The objective of the Agency's information campaigns for more efficient use of energy is to increase awareness of, and encourage, interest in economically and environmentally justified energy efficiency improvements on the part of specific user groups and of the public. The same objectives apply for the National Consumer Agency's activities in connection with the testing and labelling of domestic white goods.

The Agency employs a number of approaches in its information activities aimed at improving awareness of energy efficiency improvements in industry, through such ways as the development of energy auditing systems and environmental management systems. At local authority level, energy advisers play an important part in bringing information to the general public. Some larger, special-themed campaigns are also run, e.g. the 'Domestic heating' travelling information campaign. The Agency has also been given the duty of improving statistics of energy use in the built environment, in order to improve knowledge of this area. During 2004, the Agency has been working on a government project to investigate the most suitable methods and measures that can be used to quantify the results of information and training campaigns aimed at selected target groups.

Energy research, development and demonstration

The overall objective of the Agency's research, development and demonstration activities is to develop cost-efficient energy systems based on renewable energy sources, and to develop system solutions for more efficient use of energy. The overall approach is important, and special elements of the work cover the relationships between man, technology, economics and the environment. This working area has been structured in six theme areas: Energy/climate and society, Fuel-based energy systems, Transport, Electricity production systems, Industry and the Built environment.

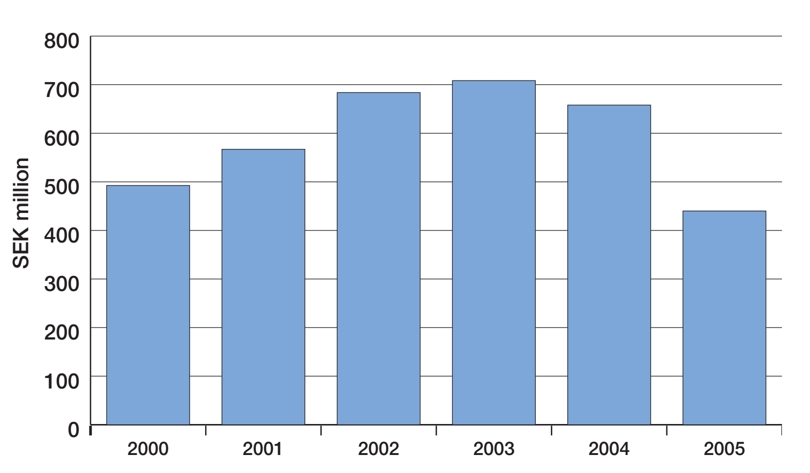
The social aspects of energy research consider areas such as energy policy guide measures, operation of the energy markets, behavioural science and acceptance considerations, innovation and implementation aspects, energy-related climate effects, modelling of energy systems, local and regional energy matters etc. The programmes are intended to enhance knowledge and competence of the energy system and of international climate policy. The scientists and their research results provide important resources for material on which to base energy and climate policy decisions.

The fuel-based energy systems working area concentrates on research and development of sustainable energy production, with the main emphasis on biofuels. Investigations of

33 This list can be downloaded from the Agency's website, www.stem.se

FIGURE 3

Approved grants for research, development and demonstration activities, 2000–2003, and appropriations for 2004–2005



Note: For 2004 and 2005, the diagram shows appropriations rather than approved grants, which means that the information for these years is not exactly comparable to that for the previous years.

Source: Swedish Energy Agency Annual Report, 2003; Official document placing appropriations at the disposal of the Agency etc. in expenditure area 21, Energy, 2004; Budget Bill, 2004/05:1 the extraction of forest fuels, in the light of effects on the ground and biological diversity, together with practical trials of the return of ash, are important for a continued high level or increase in the use of bioenergy for sustainable supply. Sweden is one of the world's leading countries in terms of the production and use of solid processed forest-based fuels, such as pellets. Developments in the field of heating and combined heat and power production are intended to improve the efficiency of established technologies and to introduce new, more efficient technologies with less environmental impact. Hydrogen can come to play an important part in future energy systems, particularly in the transport sector. Work is concentrated on research and development of means of production (such as artificial photosynthesis), storage, handling and use of hydrogen. One major project is looking at the use of hydrogen production via gasification of biomass, as described below.

The transport working area includes research and development of biobased motor fuels, combustion engines and electrical drive systems. In the longer term, biobased motor fuels should make a valuable contribution to the Swedish supply of such fuels: See below for further details of three pilot plant projects.

Research into electrical drive systems is concentrated on electrical and hybrid vehicles, as well as on fuel cells.

The electricity production and power transmission area includes hydro power, wind power, solar cells, wave power and power transmission. Swedish work on new electricity production is concentrated on the renewables of wind power, solar electricity and the development and modernisation of hydro power. Training and the establishment of expertise are important working areas for future modernisation of existing hydro power production facilities. Research into wind power is aimed at creating the right conditions for increasing the proportion of the country's power supply by wind, and for reducing its cost. The Agency is also running pilot projects for offshore and upland-based wind power production. Sweden now has a commercial market for self-contained solar cell power supplies (lighthouses, traffic lights, recreational craft, isolated summer cottages etc.). Research and development are concentrated on thin film solar cells and nano-structured cells, as well as on integration, installation and use in buildings. Research into power systems is concentrated on creating a safe, efficient system suitable for supporting new technologies and means of production as they are introduced.

The industry working area gives priority to improvements in the efficiency of energy use, and particularly for energy-intensive process stages in the pulp and paper industry and in the steel industry. Gasification of black liquor (see below) can provide the forest products industry with a fuel for additional electricity production capacity, and may also provide a means of motor fuels production.

The built environment includes the supply and distribution of heating, electricity for domestic and building services systems and the underlying design and operation of building services systems. The objective of research into the performance of buildings as climate screens is that specific energy use for heating, domestic hot water and building services systems should be reduced by 50% over a 40–50 year period. The work is concentrated on several different technology areas, such as small-scale combustion of biofuels, district heating and district cooling, heat pumps, solar heating and buildings as energy systems.

Bearing in mind Swedish conditions such as large land areas, the existing industrial structure and existing knowledge, the Agency attaches particular importance to the development of three larger projects, covering the entire chain from research to demonstration. Together with expansion of the existing gasification plant in Värnamo, the pilot production plant in Örnsköldsvik for the production of ethanol from forest raw materials is a concrete manifestation of the intention and work to develop motor fuels from renewable sources as a replacement for fossil fuels. This work also accords well with the country's climate policy and the EU Motor Fuels Directive. Meanwhile, in Piteå, a pilot plant is being constructed for the gasification of black liquor. The objective of this project is to develop new technology for increasing the production of electricity in the pulp industry: a potential of 10 TWh/year in Sweden is indicated. Alternatively, the technology could be used to produce large quantities of motor fuels, meeting up to 30% of Sweden's present needs.

Emissions trading system

In the autumn of 2003, the European Parliament and Council adopted the Emission Rights Trading Directive (2003/87/EC), which will come into force on 1st January 2005. The first trading period will run from 2005 to 2007, and is intended to serve as an introductory phase prior to the start of international emission rights trading in 2008, as part of the work of the first commitment period of the Kyoto protocol.

The main objective of the trading system is to enable the EU and its member states to fulfil their commitments in a cost-efficient manner that is also efficient in terms of the individual countries' budgets. The EU as a whole has a quantitative commitment to reduce its emissions of six greenhouse gases by an average of 8% over the period from 2008 to 2012, relative to the emission levels in 1990. However, the first phase applies only to carbon dioxide, during the first trading period, from 2005 to 2007.

One of the benefits of the emission rights trading system is that it enables the various parties concerned to decide in advance on a definite quantity of emission reductions. Actual emissions will correspond to the quantity of emission rights initially allocated to the market during the period concerned.

Initially, European emission rights trading will cover emissions from power stations, heating plants, oil refineries, iron, steel, glass and glass fibre works, cement works and ceramic industries, as well as pulp and paper mills, all as shown in Table 6. This will mean that the proposed system will cover about 46% of carbon dioxide emissions within the EU. According to figures from the Agency's and the Environment Protection Agency's 2004 Progress Check report, this trading sector accounted for about 38% of Swedish emissions in 2000. The European Parliament has stated that, in the longer term, the system should be expanded to include other sectors as well, such as the chemical industry, the aluminium industry and the transport sector.

According to the Directive, member states are required, prior to each new trading period, to prepare a national allocation plan, setting out details such as the total quantity of emission rights that are intended to be allocated during the period, and the principles on which allocation will be based. In its allocation plan that was notified to the Commission in April 2004, the Government proposed to allocate emission rights equivalent to about 22.9 million tonnes of CO_2 per year during 2005–2007 to the Swedish plants in the system. The plan also includes a list of the companies and plants involved, together with indicative allocations for each of them. The 25 allocation plans are examined by the Commission, which decides whether the proposed allocation quantities and principles meet the criteria set out in the Directive. The Swedish allocation plan was approved by the EU Commission on 7th July 2004. The final decision on allocation to all the existing plants for each of the three introductory years has been determined on the basis of an application procedure that was concluded on 30th September 2004.

TABLE 6

Sectors included in the European emission rights trading scheme, during the period 2005–2007

SECTOR	
Energy	Combustion plants with a rated thermal input exeeding 20 MW, or boiler plants connected to district heating systems with a total power capacity of at least 20 MW.
	Mineral oil refineries.
	Coking plants.
Production and processing of ferrous metals	Sintering and ore preparation.
	Iron or steel manufacture, including continuous casting, with a production capacity of at least 2.5 tonnes/hour.
Minerals industry	Cement clinker (capacity, at least 500 tonnes/day).
	Lime (capacity, at least 20 tonnes/day).
	Ceramic products (capacity, at least 75 tonnes/day).
	Glass and glass fibre (capacity, at least 20 tonnes/day).
Other activities	Pulp.
	Paper and board (capacity, at least 20 tonnes/day).

The climate investment programme

The Swedish climate investment programme has run since 2003, and is a continuation of the local investment programmes. These were programmes under which grants amounting to about SEK 2500 million were awarded between 1998 and 2002 for long-term climate research and investments. The continuation programme is part of the work of achieving Sweden's climate objectives in accordance with the Kyoto Protocol. It provides grants for local authorities and other parties to make long-term investments in measures intended to reduce the emission of greenhouse gases, assist restructuring of the energy system or to represent interesting new technology that can contribute to these objectives. These grants are also available to companies, although they must relate to measures undertaken in more than one Swedish county.

The first tranche of grants was awarded in December 2003, when 14 programmes were awarded a total of SEK 300 million for measures associated primarily with transport and energy. These programmes include environmental investments amounting to a total of almost SEK 1 100 million. They provide intended reductions of 114 000 tonnes of carbon dioxide equivalents per year, together with a reduction of 263 GWh/year in energy use.

Decisions on awards of the next tranche, amounting to about SEK 500 million, will be made at the end of 2004. At present, about SEK 50 million are available for 2005, and SEK 150 million for 2006, intended for grants under this programme. ■

FIGURE 4

Energy supply and use in Sweden, 2003, TWh.[1]

Note:
1 Preliminary statistics. Due to arithmetical rounding of the individual items, there may be a small difference in the totals.
2 Large heat pumps in the energy sector (e.g. supplying district heating systems). Energy supplied to the energy system is the output heat, 6.6 TWh. Heat absorbed from the surroundings was over 4 TWh, while input drive energy from electricity was somewhat over 2 TWh.
3 Nuclear power is gross energy, i.e. as the gross input energy in the fuel, in accordance with the UN/ECE guidelines.
4 Net import of electricity, treated as electricity supply.
5 Use of oil products for transport includes ethanol, about 0.9 TWh.

Source: Statistics Sweden, Swedish Energy Agency processing

Sweden's energy balance

Energy can never be destroyed or consumed, but only converted (which, in everyday terms, means 'used'). The total quantity of energy used must therefore always be balanced by a corresponding quantity of energy supplied. An energy system can be represented by two sides – supply and use. This chapter gives details of the balance between Sweden's total energy supply and its total energy use. The energy balance is based on statistics from Statistics Sweden (SCB). The statistics are definitive for the period 1970–2001. For the years 2002–2003, they are preliminary, and may therefore be changed when SCB has processed additional material.[34]

Figure 4 shows (aggregated and simplified) Sweden's energy system in terms of the energy flows from supply to end use. Energy is supplied in order to meet users' demand for energy, which in turn depends on their needs in terms of functions such as lighting, heating, cooling, computer processes etc. It is this use that decides the amount of energy in the form of electricity, heat etc. that needs to be produced. The figure does not show the losses that occur in the final conversion processes in residential buildings and the service sector, in industry or in the transport sector.

Total energy use, as shown in the figure, consists of the total final energy use, i.e. the use of energy in the residential and service sectors, industry and transport, together with losses, international maritime transport and energy materials used for non-energy purposes. The losses consist largely of thermal energy that, of necessity, is removed by cooling when producing electricity in nuclear power stations. Other losses include conversion losses in energy plants[35], distribution losses in connection with the supply of electricity, district heating, natural gas and town gas, coke oven and blast furnace gas, together with processing and transport losses for solid fuels. However, they do not include the losses in hydro power production. Conversion losses also include internal consumption in the energy sector. The use of energy products for non-energy purposes is made up of raw materials for the plastics industry, lubricating oils and oils used for surface treatments in the building and civil engineering sectors (asphalt and binders).

Sweden's total energy supply consists of its net import (the difference between imports and exports) of energy carriers such as oil, natural gas, coal and electricity. To this must be added changes that occur in storage, together with the indigenous supply of biofuels, hydro power and fuel rods for nuclear power production. The total energy supply is therefore made up of the quantity of energy used in the Swedish energy system to meet end-users' demands. This differs from the utilised energy, as the total quantity includes losses.

Total energy use

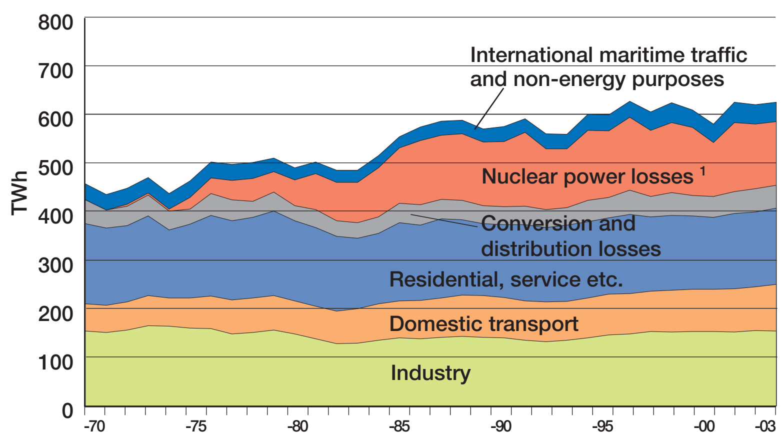
Total energy use in 2003 amounted to 624 TWh. Of this, total final energy use made up 406 TWh, and conversion and distribution losses made up 177 TWh, of which 131 TWh were in nuclear power production. Bunker oils for foreign maritime transport, together with the use of energy products for non-energy purposes, accounted for a further 40 TWh.

[34] This means that there may be differences between the statistics in this year's edition of Energy in Sweden in comparison with those given for 2001 and 2002 in last year's edition. In the same way, statistics given here for 2002 and 2003 may be changed in next year's edition of Energy in Sweden.

[35] In this context, energy plants are those that produce electricity and/or heat, refineries, gas works, coking plants and blast furnaces.

FIGURE 5

Sweden's total energy use, excluding net exports of electricity, 1970–2003.



Note: 1 In accordance with the UN/ECE method for accounting for nuclear energy.

Source: Statistics Sweden, Swedish Energy Agency processing

Industry, and the residential and service sector, use essentially the same amount of energy now as in 1970. However, much has changed: the total heated floor area of premises, for example, is greater, population numbers have risen by about 10%, and industrial production is considerably higher than it was in 1970. On the other hand, total energy use by the transport sector (excluding international maritime traffic) has increased by 71% since 1970. For the industrial sector, variations in energy use from one year to another are due mainly to economic conditions, while for the residential and service sector they are partly due to differences in the climate from one year to another.

Energy use in the various sectors shows that electricity and district heating are the most important energy carriers for the residential and service sector, that electricity and biofuels are the most important for industry, and that oil products totally dominate energy use in the transport sector. This latter sector uses about twice as much oil as the two other sectors together, despite the fact that they each account for about two-fifths of energy use, while the transport sector accounts for only about one-fifth of energy use. Ethanol and other biobased motor fuels supply about 1 TWh.

Total energy supply

Sweden's total energy supply in 2003 amounted to 624 TWh, including a net importation of about 13 TWh of electricity. (See Figure 6.) The greatest proportions of energy supply were met by oil and nuclear fuel, followed by biofuels and hydro power. Total energy supply varies from one year to the next due to a number of factors, including variations in temperature. Years that are warmer than statistically average result in a reduced need for energy, while colder years increase the need. 2003 was warmer than an average year. Energy supply has increased by 36% since 1970, from 457 TWh to 624 TWh[36]. Over the same period, demand[37] for energy has increased by 8%, from 375 TWh to 406 TWh. The reason for this difference between the increase in supply and the increase in demand is that much oil has been replaced by electricity in the two user sectors of industry and the residential and service sector. Electricity is a highly efficient energy carrier as far as users are concerned, although there are considerable losses in the production stage. By changing from oil to electricity, much of the conversion losses have therefore been transferred from the end-users to the supply side of the energy system, and this can be seen best in the substantial losses associated with nuclear power generation. In addition, the shift to electricity production from nuclear power also resulted in an inherent increase in conversion losses. Taken together, all this means that the make-up of energy supply has changed since 1970. The supply of crude oil and oil products has fallen by over 40%, while the net production of electricity has increased by over 240% as a result of the construction of nuclear power stations and expansion of hydro power production. The supply of biofuels has more than doubled. During the 1980s, local authority energy utilities installed large heat pumps for supplying district heating. In the middle of the 1980s, natural gas was brought to towns along the west coast, while wind power construction started in the middle of the 1990s. Supplies of coal and coke as fuels increased at the beginning of the 1980s, but are now declining.

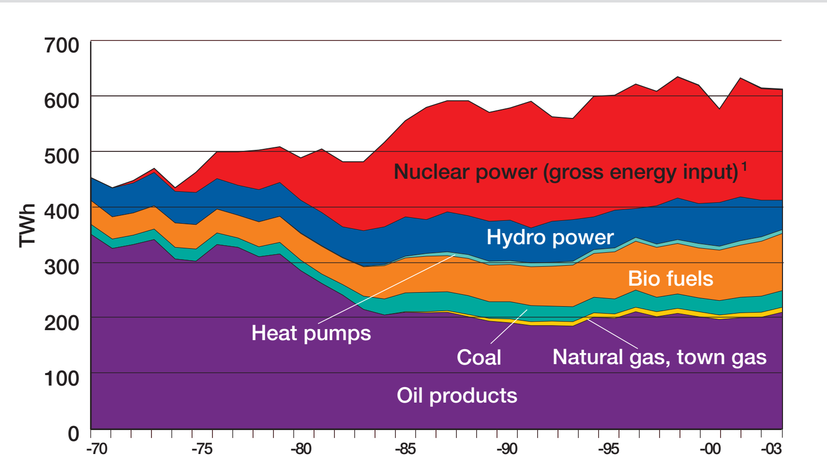
Nuclear power used 199 TWh of fuel energy input in 2003, to produce 65.5 TWh of electricity. Hydro power, meanwhile, produced 53 TWh of electricity, which was considerably less than the previous year's production of 66 TWh. Hydro power production varies widely, depending on the amount of precipitation during the year. Fuel-based thermal power production produced 13.5 TWh of electricity, while wind power supplied 0.6 TWh. About 56 TWh of fuels were used for district heating production in 2003. Renewable sources, which include biofuels, hydro power and wind power, provided about 25% of the country's energy in 2003, which is a relatively high figure in international terms. ■

36 Figures in accordance with the UN/ECE method, which means that the energy conversion losses in nuclear power stations are included.

37 'Demand' is used here as meaning the total final energy use.

FIGURE 6

Energy supply in Sweden, excluding net electricity imports, 1970–2003



Note: 1 In accordance with the UN/ECE method for accounting for nuclear power production.

Source: Statistics Sweden, Swedish Energy Agency processing

Energy use

Modern society is very dependent on energy: Energy for heating, for lighting and domestic equipment, for travel and for the production and distribution of goods and services. The amount of energy used is affected by many factors, including economic conditions, technical development, prices and guide measures and incentives employed in energy and environmental policy. The use of energy can be divided up into three sectors: the residential and service sector, industry and transport. This chapter describes energy use in 2002/2003, together with developments in energy use since 1970.

The residential and service sector

In 2003, energy use in this sector amounted to 156.5 TWh, which was about 2 TWh more than during the previous year, and represented about 39% of Sweden's total final energy use.

The residential and service sector consists of residential premises, commercial premises, holiday homes and other service activities, which include the construction sector, street lighting, sewage treatment plants and waterworks. The sector also includes residual items from the statistics, in the form of changes in stock levels of fuels etc. and the statistical difference between supply and use. However, these items constitute only a very small part of the sector's energy use.

About 86% of energy use in the residential and service sector is used for space heating, domestic hot water production and the powering of appliances. Energy used in land use applications accounts for about 5% of total energy use in the sector; holiday homes account for another 2%, and other service applications for 7%.

Over 60% of the energy use in the sector is used for space heating and domestic hot water production. As this is affected by temperature conditions, there can be considerable variations in energy demand from one year to another. To enable proper comparisons to be made, it is necessary to correct for climatic conditions, to arrive at a statistically average year[38]. 2003 was 4% warmer than a statistically average year, which means that the amount of energy used for space heating was lower than normal. After applying such correction, energy use in the sector in 2003 amounted to 159 TWh, which is the same as for the previous year, which was 8% warmer than an average year.

Between 1970 and 2003, the number of dwelling units (single-family houses and apartments in apartment buildings) in the country increased by almost 40%, to about 4.4 million. The rate of new building during the 1990s was very low, amounting on average to 14 300 dwelling units per year. However, since 2000 an upturn has started and in 2003 work began on 23 100 dwelling units. Floor areas of commercial premises increased substantially from 1970 until the beginning of the 1990s. The rate of construction has been very low in recent years.

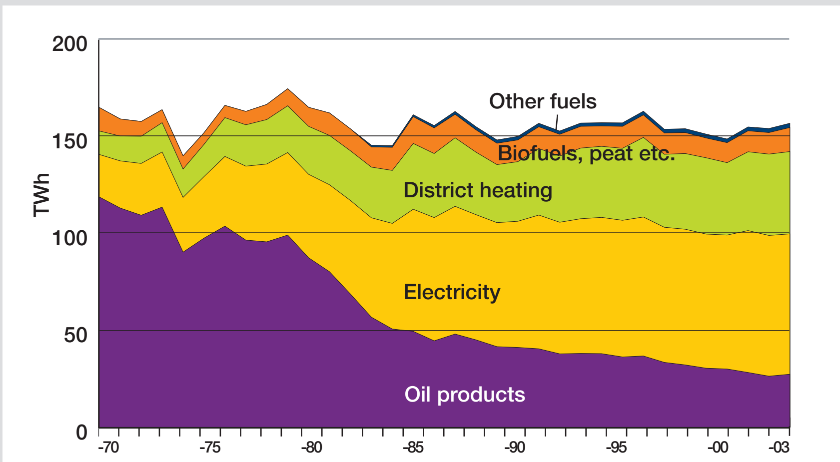
Total energy use in the sector has remained stable

The total energy use in the sector has remained relatively stable between 1970 and 2003, although the relative proportions of the different energy carriers have changed. (See Figure 7.) Oil crises, rising energy prices, changes in energy taxation and investment policies have all affected the shift from oil to other energy carri-

38 With effect from 2003, the reference period for determining average use is from 1970 to 2000. Until 2002, this reference period was 1961/62 to 1978/79.

FIGURE 7

Final energy use in the residential and service sector, by energy carriers, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

ers. In 2003, total use of fossil fuels in the sector amounted to 29.5 TWh, as against 118.6 TWh in 1970. Much of this reduction is due to a move away from the use of oil for heating to electricity and district heating.

Several factors have helped to hold down the increase in energy use. The average annual efficiencies[39] for electric heating and district heating are, on the whole, higher than those for oil, due to the fact that the conversion losses for electricity and district heating reduction are debited to the supply sector. This means that if oil is replaced by electric heating or district heating, it will have the effect of reducing final energy use in the residential and service sector.

The number of heat pumps in use has grown substantially in recent years, due partly to high oil prices and rising taxes on fossil fuels, and also for the need to replace large numbers of oil-fired boilers at the end of their lives.

Use of heat pumps reduces the actual use of energy for space heating and domestic hot water production in buildings. Heat pumps deliver 2–3 times as much thermal energy as they use in the form of energy for driving them. This 'free' heat is not included in the statistics of the amount of energy used in the sector. 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 include various energy conservation measures, such as retrofitting additional thermal insulation or upgrading windows in older buildings. Technical development is steadily improving the efficiency of equipment – particularly white goods in the domestic environment – that replaces older products having higher energy consumptions. Commercial users constantly replace equipment, the energy efficiency of which is steadily improving, although this is countered by the general parallel increase in the number of items used. The low rate of new residential building during the 1990s can also be assumed to have helped retard the rise in energy use.

The use of electricity grew continuously from 1970 until the middle of the 1990s, stabilising at about 70 TWh in recent years. The corrected[40] values for 2000 and 2001 showed an increase, but declined somewhat in 2002 and 2003. A contributory reason for this was the price of electricity, which was low in 2000 and 2001, but which rose in 2002 and 2003.

Electricity is used for heating, domestic electricity and building services systems. Domestic electricity is that which is used for powering domestic appliances and other equipment in residential premises. Electricity for building services systems is used for powering equipment in non-residental premises and in other service applications. After correction, use of electricity for heating increased from 4.7 TWh in 1970 to 29 TWh in 1990, but has subsequently fallen, to 23.2 TWh in 2002.

Heating and domestic hot water

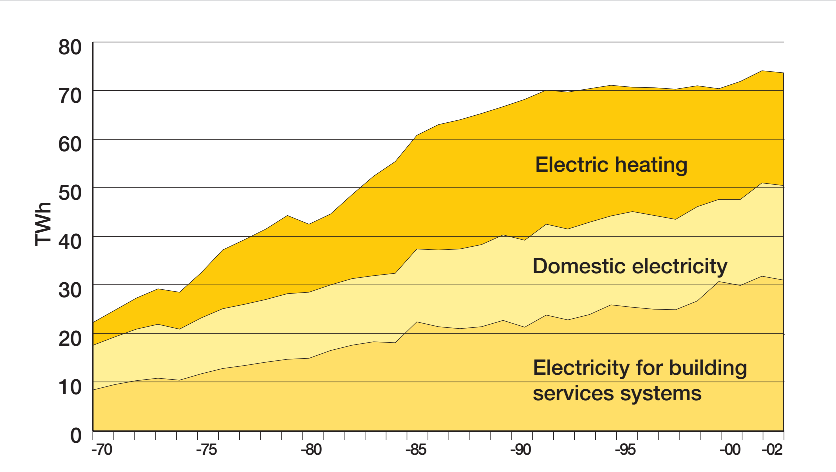
Of the 89 TWh that were used for space heating and domestic hot water production in 2002, it is estimated that about 44% were used in detached houses, 31% in apartment buildings and 25% in commercial premises and public buildings. Electricity used for such applications as floor heating and fan heaters – 'hidden' electric heating – also contributes to the heating of a building, but is partly accounted for in the statistics as domestic electricity.

Over a third of all detached houses in the country were heated by electricity alone in 2002. Approximately 17% of detached houses have only direct-acting electric heating, with 16% having waterborne electric heating. About 10% of detached houses are heated by oil alone, 8.4% by district heating and 5.9% by wood alone. The main reason for the high proportion of electric heating is that it is cheap to install and simple to run. The use of electric heating increased substantially in the sector from 1970 to the middle of the 1980s, after which a slight decline began in its use in detached houses.

Another common heating system in detached houses is electricity in combination with a wood and/or oil fired boiler, which allows users to change between electricity, oil or wood. The proportion of detached houses with

FIGURE 8

Electricity use in the residential and service sector 1970–2002, temperature-corrected.



Source: Statistics Sweden, Swedish Energy Agency processing

39 Average annual efficiency: The various forms of energy carriers subject to different distribution and conversion losses at the point of consumption used for heating, which can be expressed as average annual efficiencies. This efficiency is calculated so that it allows for the combustion efficiency of the building's heating system, waste heat and distribution losses arising in the building, together with the effects of regulation and balancing of heating systems.

40 i.e. corrected for a statistically average climate year.

such systems is a little under 30%. They are therefore relatively flexible in their choice of fuel, with the selection being largely determined by the relative price levels of the different energy carriers. Other households, not having this ability quickly to change their energy carriers, are more vulnerable to changes in the relative prices. The total use of electricity for space heating in detached houses and agricultural properties amounted to 16.5 TWh in 2002.

District heating is the commonest form of heating in apartment buildings, with about 77% of apartments being heated by it, equivalent to a use of about 23 TWh. Oil is used as the sole or main heat source for 5% of apartments, equivalent to 2.4 TWh of oil. The use of electric heating in apartment buildings is relatively low, amounting to 1.5 TWh in 2002.

The main source of heat in offices, commercial premises and public buildings is also district heating, with about 58% of such buildings being supplied, equivalent to 14.8 TWh. The use of electricity for space heating and domestic hot water production in non residental premises amounted to 3.8 TWh, while 3.3 TWh of oil were also used for this purpose.

Domestic electricity and electricity for building services systems

The use of electricity for domestic purposes doubled between 1970 and 2002, from 9.2 TWh to 19.5 TWh. Although most of this increase occurred during the 1970s and 1980s, it has still continued over the last few years. This rising use can be explained by an increase in the number of households, greater ownership of domestic appliances and greater ownership of electronic equipment. To some extent, it can also be explained by an increase in the 'hidden' use of electric heating. In 2002, the average domestic electricity use amounted to about 5900 kWh in detached houses, and in apartment buildings to about 40 kWh/m^3.

The use of electricity for building services systems has increased substantially, from 8.4 TWh in 1970 to 31.0 TWh in 2002. The reasons for this development include rapid growth in the service sector and greater use of office machines. The high growth rate of private and public services has also resulted in a relatively substantial increase in the total floor area of non-residental premises, which has increased the need for lighting and other services. Lighting and ventilation which, at the beginning of the 1990s, accounted for about 70% of the use of electricity in building services systems, have become more efficient as a result of improved light sources, more sophisticated operational control and correct sizing of systems at the time of installation. Never-the-less, the potential for further improvements in the efficiency of electricity use in offices, commercial premises and public buildings is still regarded as considerable.

Improving the efficiency of energy use and reducing carbon dioxide emissions

Parliament has approved a number of measures intended to encourage improving the efficiency of energy use in the residential and service sector, with an accompanying reduction in carbon dioxide emissions. These measures include substantial investment in technology procurement projects to improve the efficiency of energy use and reduce the use of electricity. There has also been a substantial emphasis on the provision of energy advisory services at local authority level since 1998: by 2003, such services were available in all local authority areas. The climate investment programme (KLIMP) is another major investment area for the state: it was introduced in 2002, and provides subsidies, primarily to local authorities, for measures intended to reduce carbon dioxide emissions from the residential and service sector, as well as from other sectors. (See Chapter 2, Guide measures and incentives, for further details.)

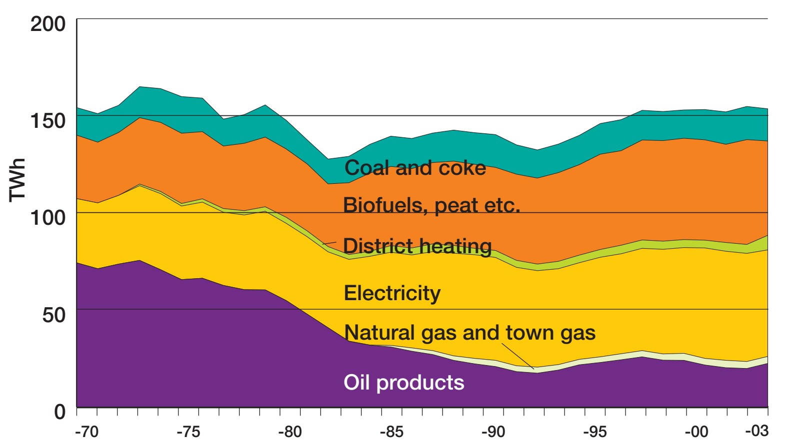
The EU Commission has prepared several draft directives, aimed at reducing energy use within the EU. The Energy Performance of Buildings Directive came into force on 4th January 2003. One of its requirements is that energy declarations must be produced for buildings. A proposal for introduction of the directive in Sweden was submitted to the Government by the Energy Performance of Buildings Commission in November 2004. A draft proposal for an energy services directive has been prepared, and will require the efficiency of energy use in the residential and service sector to be improved by 1 percentage point per year. The corresponding improvement for buildings in the public sector is 1.5 percentage points per year. One of the effects of a draft directive for ecologically-aware design of energy-using products will be that mandatory efficiency levels will be set for the products.(Further details of EU work can be found in Chapter 1, Current energy and climate policy areas.)

Industry

In 2003, industry used 1.2 TWh less energy than during 2002, amounting to 153.6 TWh, or 38% of the country's final energy use.

FIGURE 9

Final energy use in industry, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

Classified by energy source/carrier, industry's use of energy was met by 22.4 TWh of petroleum products, 16.6 TWh of coal and coke and 54.9 TWh of electricity. Use of natural gas amounted to 3.6 TWh, and that of district heating to 7.5 TWh. Supplies of biofuels, peat etc. amounted to 48.6 TWh: (see Figure 9). Final energy use in industry therefore consisted of 28% of fossil energy and 32% of biofuels, peat etc., with the remainder consisting of electricity and district heating.

Energy and fuel use in various sectors

In Sweden, a small number of sectors accounts for the bulk of energy use in industry. The pulp and paper industry uses about 47%, primarily as electricity or from black liquors. The electricity is used mainly for grinders producing mechanical pulp, while the black liquors provide fuel for soda recovery boilers in sulphate mills. The iron and steel industry uses about 15% of industry's energy, primarily in the form of coal, coke and electricity. Coal and coke are used as the reducing agents in blast furnaces, while the electricity is used chiefly for arc furnaces for melting steel scrap. The chemical industry uses about 6.8% of industrial energy use: here, electricity is used mainly for electrolysis processes.

Together, these three energy-intensive sectors account for over two-thirds of total energy use in industry. The engineering industry, although not regarded as energy-intensive, never-the-less accounts for about 8% of total energy use in industry, as a result of its high proportion of total industrial output in Sweden.

The relationship between industrial output and energy use

In the short term, energy use in industry essentially follows variations in industrial output. In the longer term, it is affected also by such factors as taxation, changes in energy prices, improvements in the efficiency of energy use, investment, technical development, structural changes in the sector and changes in the types of goods produced.

Between 1990 and 1992, industrial output fell by 6% per annum, which was reflected by a fall of almost 6% in energy use over the period. Industrial output recovered in 1993, and continued to rise substantially until 2000, during which period output increased at nearly 8% per annum.This was reflected in energy use, which increased by 13% over the period. Electricity use increased by 15%. This was followed by an economic downturn in 2001, and a recovery over the period 2002–2003. Over the period 2000–2003, industrial output increased by about 1% per annum. Energy use increased by 0,3% over the whole period, although the use of electricity fell by 3,6%. In total, industrial output has increased by 78% between 1992 and 2003, for an increase of about 16% in total energy use and about 10% in electricity use.

Changes in use of the most important energy carriers

Despite rising industrial output, the use of oil has fallen substantially since 1970, due to greater use of electricity and improvements in the efficiency of energy use. This trend started in connection with the oil crises of the 1970s, which resulted in both state and business starting intensive work aimed at reducing the use of oil. In 1970, the use of electricity constituted only 21% of industry's total energy use, which can be compared with the present proportion of 36%. At the same time, the use of oil has fallen from 48% to 15% in terms of industry's energy use. Other forms of energy carrier, such as electricity, have therefore replaced the use of oil. One reason for this is that the cost of fossil fuels has risen. Nevertheless, despite this, the use of oil products increased by almost 5 TWh, or 29%, between 1992 and 2003. Contributory factors for this have included increased industrial output, lower energy and carbon dioxide taxes and a greater use of oil as a replacement for disconnectable electric boilers[41]. Between 1970 and 2003, the proportion of biofuels, peat etc. has increased from 21% to 32% of total energy use in industry.

[41] These are boilers in which the heat source can be switched between electricity or some alternative fuel. This occurs, for example, in response to high electricity prices.

Changes in specific energy use

Specific energy use, i.e. the amount of energy used per monetary unit of output value, provides a measure of how efficiently the energy is being used. Since 1970, specific energy use in industry has fallen continuously: between 1970 and 2003, it fell by 54%, reflecting a clear trend towards less energy-intensive products and production processes, together with structural changes in the sector. During this period, industrial output value has more than doubled.

The change from oil to other energy carriers, particularly electricity, is reflected in the specific use of oil and electricity per unit of output value. Specific use of oil fell by 81% between 1970 and 1992, while specific use of electricity increased by 23%.

The upturn in the economy between 1992 and 2003, coupled with changes in the energy taxation of industry, is reflected in changes in specific energy use, which has continued to fall. Over this period, it fell by 36%, with specific use of oil falling by 29% and that of electricity by almost 38%. More generally, the reduction in specific energy use is due to the fact that production value has increased considerably more than has energy use.

For several reasons, we can expect a continued fall in specific energy use. Over a longer period of time, specific energy use has been reduced by technical development and structural changes.

Transport

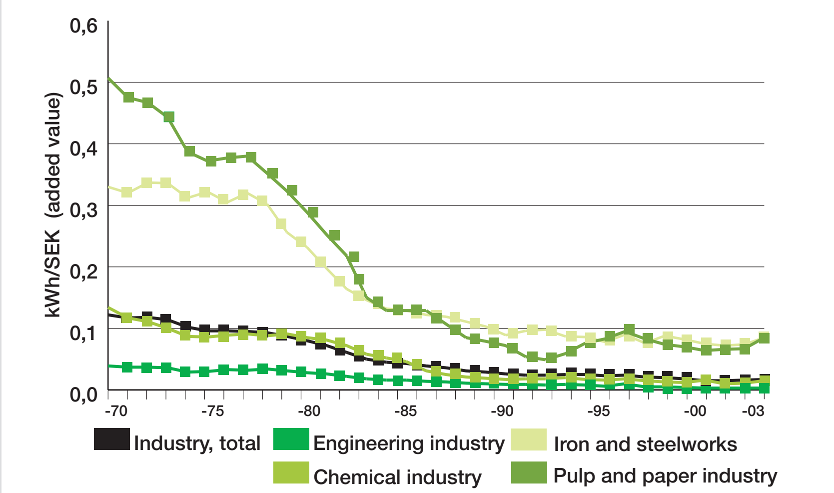
Total energy use for transport in 2003 amounted to 114 TWh: of this, 95 TWh were used by domestic transport, equivalent to 23% of the country's total final domestic energy use. Foreign maritime traffic used 19 TWh of bunker oils. (See Figure 13.)

Energy use in the transport sector

Energy use in the transport sector consists mainly of oil products, primarily petrol and diesel fuel. In 2003, the use of these two fuels provided 83% of the country's energy requirement for domestic transport, i.e. excluding bunkering for international maritime traffic. After having shown a declining trend since 1995, the use of petrol increased in 2001 and 2002, and then more or less levelled off in 2002/2003. The use of diesel fuel increased steadily over the period 2000–2003, but that of aviation fuel decreased. This reduced use is due partly to economic conditions and partly to general world unease. Bunkering for international maritime traffic increased in 2003, partly

FIGURE 10

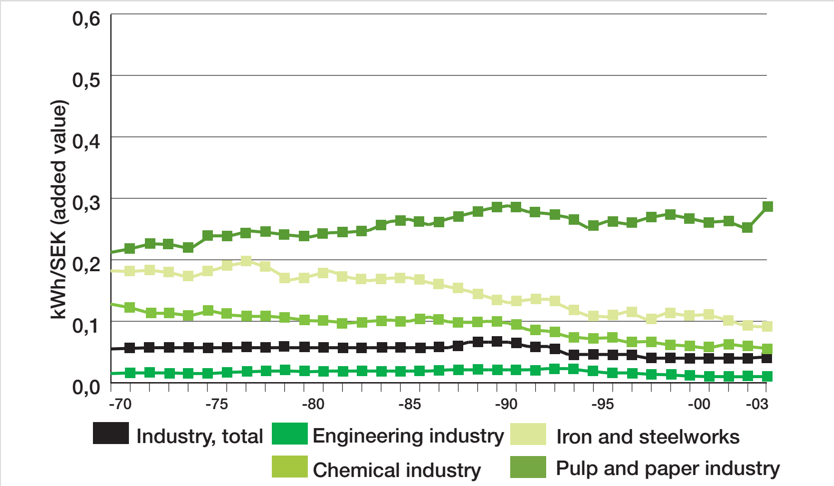
Specific use of oil in industry, 1970–2003, 1991 prices



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 11

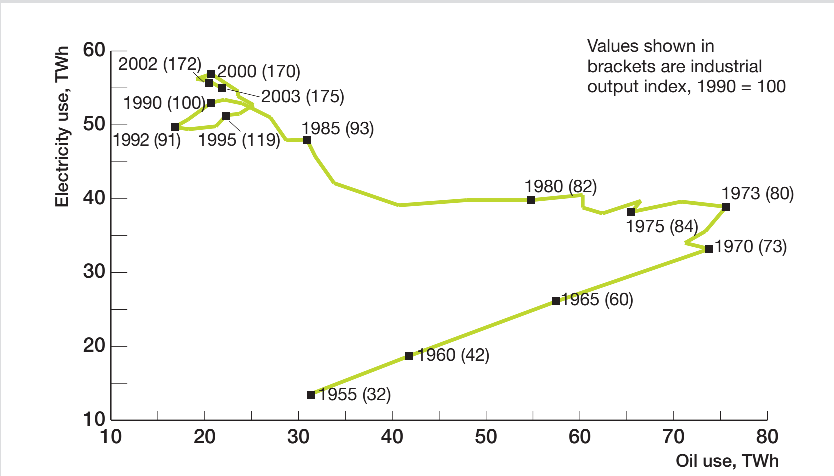
Specific use of electricity in industry, 1970–2003, 1991 prices



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 12

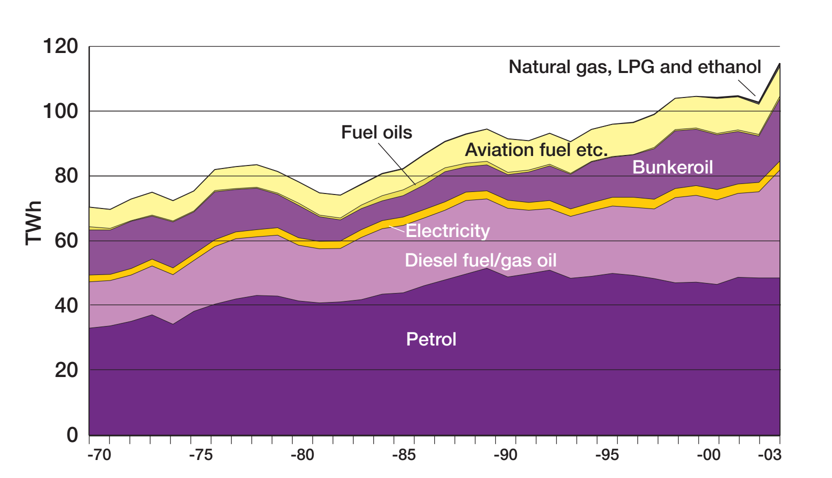
Use of oil and electricity in industry, 1955–2003



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 13

Final energy use in the transport sector, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

due to the production by the Swedish oil refineries of low-sulphur fuel oils that meet stringent environmental requirements.

Energy use in the transport sector is largely dependent on economic conditions and technical development. The two main guide measures, intended to reduce the use of energy by the transport sector, are energy tax and carbon dioxide tax, but other measures are being investigated.

Transport work

Since 1990, domestic passenger transport work has increased by 22%, so that it amounted to about 130×10^9 person-km in 2003. Road traffic dominates this, with about 90% of passenger transport work. About 70% of long-distance passenger travel (i.e. over 100 km) was provided by car traffic. For short-distance travel, car and motor cycle use accounted for about 79% of journeys, which is the same as in 2001 and 2002. Railways carried about 8% of passenger traffic, and aviation somewhat over 2%.

Domestic goods transport has increased by 17% since 1990, amounting to over 91×10^9 tonne-km in 2003. Of this, 41% were carried by road, 22% by rail and 37% by ship. Over the last ten years, goods transport by road has increased by 26%, maritime traffic by 12% and rail traffic by 2%.

Development and use of alternative motor fuels

A strategy for the introduction of biobased motor fuels has been developed by the Agency in conjunction with VINNOVA (the Swedish Agency for Innovation Systems), the National Road Administration and the Environment Protection Agency. It recommends that biobased motor fuels should be introduced by means of a low admixture of between 5 and 25% in existing motor fuels. This approach has several important advantages, in that it does not require the development of new types of engines, modification of older engines or any expansion of the present distribution infrastructure. Nor does it face vehicle-owners with having to make a choice, as they will be able to utilise the mixed fuel wherever it is available. On the other hand, a risk of the low admixture approach is that it could reduce the incentive for development of, and investments in, new motor fuels and new vehicle technologies. In order to counter this possible effect, it is important that there should be active research and development of both fuels and vehicles.

The energy tax on ethanol in E85 fuel (which consists of 85% ethanol and 15% petrol) was removed on 1st January 2003, thus reducing the price by 94 öre/litre, to about SEK 7:50/litre. However, as ethanol has a lower energy content than petrol, a vehicle running on E85 consumes about 25–35% more fuel by volume than if it had been running on petrol alone. This means that the cost of using E85 today is about 50 öre/litre lower than the cost of petrol (which cost about SEK 10/litre in July 2004). For some years now, all petrol sold in Stockholm and the Mälar Valley has contained 5% ethanol (E5). During 2003, the Government reduced taxation on considerably greater volumes of ethanol than was previously the case. One of the effects of this is that fuel companies, together holding over 80% of the Swedish petrol market, now mix in up to 5% ethanol in 95-octane petrol throughout the country.

RME (rapeseed oil methylester) is used partly as a 2% admixture in diesel fuel, and partly as 100% RME fuel. Almost 4800 m^3 of RME was used as a low-admixture additive in 2003, together with 600 m^3 of 100% RME. RME is not regarded as having a development potential for use as a biobased motor fuel, due primarily to the fact that the potential volumes are too small. It does, on the other hand, have unique lubricating properties, which can be utilised in the form of additives in various 'dry' fuels. For example, one of Sweden's largest construction companies has started to add 2% RME to the diesel fuel that it uses to power its approximately 1000 vehicles, having an annual diesel fuel consumption of about 15000 m^3/year.

The use of alternative motor fuels, such as ethanol, natural gas and biogas, is still marginal, accounting for about 1.3% of energy use within the transport sector (excluding foreign maritime transport). Renewable motor fuels (in principle, alternative motor fuels with the exception of natural gas) meet about 1.1% of energy use in the transport sector (again excluding foreign maritime traffic). The costs of producing most of the alternative motor fuels are at present higher than the corresponding costs of supplying petrol and diesel fuel. However, the cost differential is falling in step with technical developments and the introduction of environmental taxes.

A total of 149 600 m^3 of ethanol was used in the transport sector in 2003. Sweden has at present two factories that produce motor fuel ethanol. The factory in Norrköping produces about 50 000 m^3 of ethanol per year from grain, while that in Örnsköldsvik produces about 180 00 m^3 from by-products from various processes in an adjacent pulp mill. The balance of the ethanol is imported from a number of countries, including Brazil, which has an annual production of about 15 million m^3 of ethanol from sugar cane. A pilot plant for the production of bioethanol from forest raw materials was opened in Örnsköldsvik on 26th May 2004. In addition to this plant, the Agency is also financing a plant in Värnamo for gasification of biofuels and a black liquor gasification plant in Piteå.

Infrastructural and technical development

Technical development occurs both in the form of improvements to existing technology and in the form of completely new technical solutions. The new solutions that are thought to be likely to achieve commercial breakthroughs during the next ten years are hybrid vehicles, 'bi-fuel' vehicles and flexible fuel vehicles (FFV). A hybrid vehicle has two alternative drive systems, generally an electric motor and a combustion engine. During the autumn of 2004, two larger car manufacturers will start to sell hybrid-drive SUVs. Bi-fuel vehicles have two separate fuel systems supplying the same engine, which means that they can run on gas (natural gas or biogas) and petrol. The gas tank is generally incorporated in the floor of the vehicle, complemented by a smaller petrol tank. Today, one of the Swedish vehicle manufacturers has five different car models available with bi-fuel engines. FFVs enable different fuels, such as ethanol and petrol to be used at the same time. At the beginning of 2004 there were almost 8000 FFV vehicles in Sweden. At present, only one vehicle manufacturer sells FFVs in Sweden, although one of the Swedish manufacturers is planning to launch such a vehicle in 2005. Looking further ahead than ten years, the automotive industry is pinning its hopes on fuel cell technology.

Environmental impact

All forms of transport produce emissions that are harmful to the environment and to health. Although the introduction of catalysers has substantially reduced the emission of several hazardous substances, with about 85% of all cars on the road being fitted with catalysers at the beginning of 2004, carbon dioxide emissions cannot be reduced in this way, which means that they have continued to increase in step with the greater use of fossil fuels. It has been found difficult to reach agreement on harmonised fuel taxes within the EU. However, the European automotive industry has entered into a voluntary agreement with the EU Commission to reduce carbon dioxide emissions from new passenger cars by 25% by 2008, relative to the 1995 levels. In terms of fuel consumption, this means that average fuel consumption should be reduced to 5.9 litres per 100 km for petrol cars, and to 5.2 litres per 100 km for diesel cars. Corresponding agreements have also been reached with Japanese and Korean vehicle manufacturers.

In May 2003, the EU Parliament and Council adopted Directive 2003/30/EC on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport (see also Chapter 1, 'Current energy and climate policy areas'.)

Current investigations

In 2003, the Government appointed the Renewable Vehicle Fuels Commission, to suggest national strategies and objectives for the introduction of renewable motor fuels. (See also Chapter 1.) In an interim report (SOU 2004:4) that was presented in February, the Committee suggest that all filling stations selling more than 1000 m^3/year of petrol and diesel fuel must have at least one pump for alternative motor fuels. This would mean that about 200–400 filling stations would have such pumps by 2008. The interim report also puts a figure of 3% as the proportion of biobased motor fuels for transport purposes by 2005. The Commission has also been asked to investigate the feasibility of introducing some form of fuel certificates, known as 'green certificates', to encourage the introduction of renewable motor fuels.

The Road Traffic Taxation Commission presented its final report (SOU 2004:63, Road tax) in May 2004. Among its proposals it includes a 50 öre/litre rise in the level of tax on diesel fuel. In the longer term, it is suggested that petrol and diesel fuels should pay the same amount of tax. The Commission also suggests that vehicle tax should be charged on the basis of CO_2 emissions per kilometre, instead of on vehicle weight. The Commission has also investigated the feasibility of introducing a kilometre tax in Sweden.

Examples of vehicle projects using renewable motor fuels

Trials of various public transport systems powered by renewable or alternative fuels are being held in a number of Swedish towns. The need to provide fuel for public transport vehicles also helps to increase the availability of such fuels for private cars and other users.

Landskrona has been running what is at present Sweden's only trolley bus line since September 2003. Trolley buses were previously used in both Stockholm and Gothenburg, but the last line was shut down in 1964. The route in Landskrona is served by three trolley buses, powered by renewable electricity from wind and hydro power.

Two buses running on EcoPar (also known as Fischer-Tropsch fuel, after its inventor) started service in Sundsvall in April 2004. EcoPar is a synthetic motor fuel, consisting of 99% n-paraffins. It is at present manufactured from natural gas, but could also be made from woodchips and other biomass. Its benefits include an absence of sulphur and reduced emissions of particulates and hydrocarbons in comparison with diesel fuel. On the other hand, a disadvantage at present is that it costs twice as much as diesel fuel.

Since the summer of 2001, buses in Malmö have been powered exclusively by natural gas. The city now wants to take a further step, testing the admixture of hydrogen in the natural gas. Trials have been in progress since 2003, involving the use of two buses. One is operating with an 8% admixture of hydrogen, and the other with a 20% admixture. The advantages of this method include reduced fuel consumption and the fact that no new technical developments are required for the vehicle. Disadvantages include higher fuel prices.

Stockholm is one of the cities in the CUTE (Clean Urban Transport for Europe) EU project, the objective of which is to obtain experience of how fuel cell-powered buses operate in practice. As part of the project, hydrogen-powered buses are being trialled in nine European cities. Three such buses have been in traffic in Stockholm since the beginning of January 2004. By June 2004, they had run 16 000 km, and their performance has hitherto exceeded expectations.

In addition to the above-named projects, several Swedish towns have invested in biogas as a renewable vehicle fuel. Biogas buses are at present in traffic in nine Swedish towns, with the numbers increasing constantly. Europe's largest biogas filling station was opened in Linköping in June 2004. In addition to all the city's 65 local buses, all its refuse trucks and about half of its taxis are at present running on biogas. ■

Energy markets

The energy markets are changing in step with developments in technology and with awareness of the effects of energy systems on the environment, society and the economy. Electricity markets in several countries have been opened to competition in recent years, and the same process is now occurring in the natural gas markets. Work on reducing emissions of greenhouse gases is in progress in most countries of the world, and is affecting the markets for fossil fuels and biofuels. This chapter describes the present markets for electricity, district heating and district cooling, energy gases, oil, coal and biofuels, with a review of the changes that have occurred over the last 30 years.

The electricity market

Major changes have occurred in the electricity markets in the Nordic countries and the EU over the last few years. These changes have resulted in a move away from national or regional monopolies to international markets, subject to competition, where electricity users can choose their electricity suppliers. In 1991, Norway was the first Nordic country to set up a competitive market, and was followed by Sweden in 1996, Finland in 1998 and Denmark in 2003. Today, all the Nordic countries except Iceland are trading on the Nordic electricity exchange, Nord Pool. The Nordic electricity market is becoming increasingly integrated with the electricity markets on the south of the Baltic (particularly Germany and Poland), and there is already trade in electricity between Finland, Russia and the Baltic states.

The price of electricity in the Nordic countries is determined largely by hydro power availability in Sweden and Norway, the availability of the nuclear power stations in Sweden and Finland, international price levels of various fuels and policy guide measures and incentives. In recent years, too, increases in taxation have also contributed to increased electricity prices to comsumers.

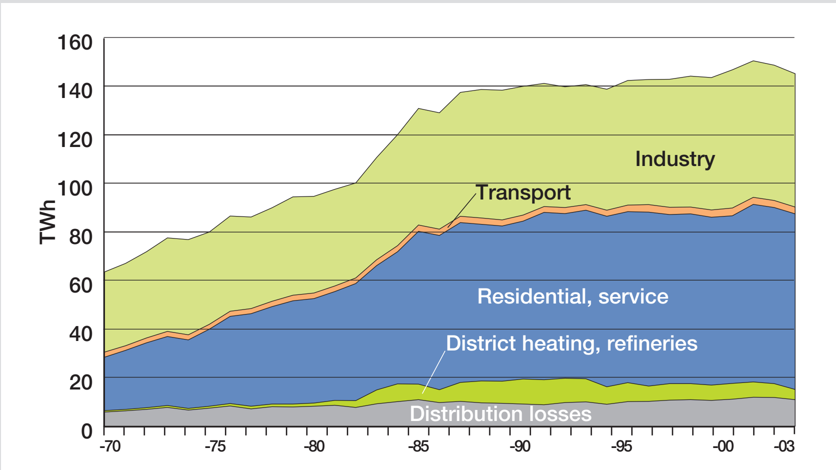
Electricity use

In 2003, electricity use in Sweden amounted to over 145 TWh. Between 1970 and 1987, electricity use increased very substantially, at an average rate of about 5% per annum. However, this rate of increase has since declined, so that electricity use increased by only 0.3% per annum on average between 1998 and 2003. Between 2002 and 2003, electricity use in Sweden fell by 2.3%, which can possibly be ascribed to high electricity prices during 2003. However, general economic conditions have a greater effect on electricity use, and less electricity is used during a warmer year than during a colder year.

Electricity use in Sweden is linked primarily to two sectors, the residential and service sector and the industrial sector, which together accounted for 127 TWh in 2003, i.e. 88% of the country's total electricity use. Between 1970 and 1987, annual electricity use in these two sectors increased on average by 6.7% and 2.7% respectively. These increases stabilised over the following years, so that between 1988 and 2003 the annual increases in the two sectors were only 0.8% and 0.3% respectively. The substantial increase in the use of electricity in the residential sector up to 1987 was the result mainly of a change from oil to electricity for heating purposes. In recent years, it has been primarily the

FIGURE 14

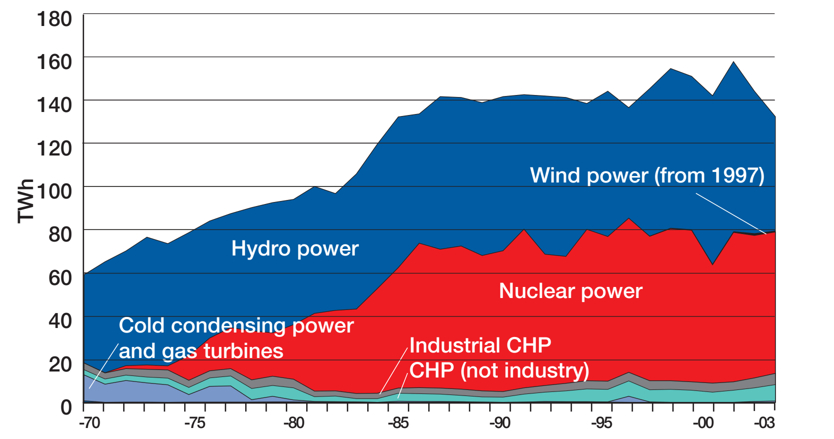
Electricity use in Sweden, by sectors, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 15

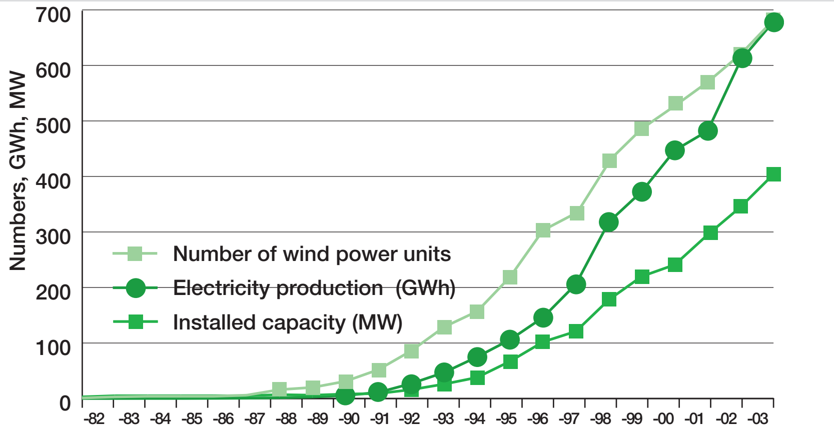
Swedish electricity production, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 16

Wind power production, 1982–2003

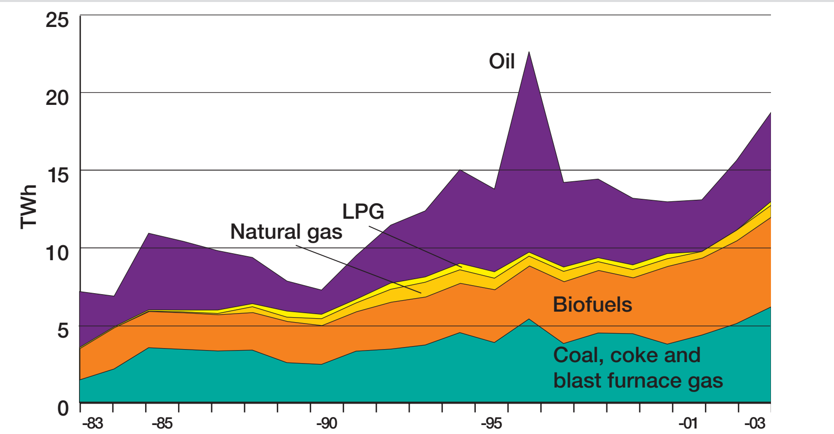


Note: The numbers of wind power plants as given in this figure and as given in the table of the number of plants in the green certificate scheme (Chapter 2, Guide measures and incentives) differ, because the green certificate scheme statistics are based on the number of metering points. Several wind power units can be connected via a single metering point, while Elforsk statistics count each plant separately. In addition, the electricity certificate scheme receives statistics only from units taking part in the system.

Source: Elforsk and the Swedish Energy Agency.

FIGURE 17

Fuel sources for electricity production (excluding nuclear fuel), 1983–2003



Source: Statistics Sweden, Swedish Energy Agency processing

use of domestic electricity and electricity for building services systems that has increased in this sector. The use of electricity for heating has remained at a stable level for some years now, which has been assisted by the availability of grants for conversion from electric heating. Electricity use in industry is closely linked to conditions in a small number of important sectors: the pulp and paper industry, for example, uses over 40% of all the electricity used in industry. Electricity use in the transport sector is relatively little, amounting to slightly over 2.8 TWh in 2003, and being used almost entirely for rail transport. Total electricity use also includes transmission losses and the use of electricity in district heating plants and refineries.

Electricity production

In 2003, electricity production amounted to somewhat over 132 TWh. Over the last 30 years, there have been considerable changes in the production mix of the country's electric power. At the beginning of the 1970s, hydro power and conventional oil-fired cold condensing power produced most of the electricity in Sweden. The oil crises of the 1970s coincided with Sweden's construction of nuclear power plants, which reduced the country's dependence on oil. Today, hydro power and nuclear power supply a very substantial proportion of the country's electricity, amounting to about 92% in 2002 and 90% in 2003, with oil-fired cold condensing production and gas turbines providing primarily reserve capacity. 2003 was a dry year[42] in terms of hydro power production, which amounted to 53 TWh, or less than 40% of total electricity production. Nuclear power supplied 65 TWh, i.e. about 46% of total electricity production.

The Swedish and EU targets for the reduction of greenhouse gases have also affected the production mix of electric power, in the form of a greater share of renewable energy. Wind power is a renewable energy source which has expanded substantially in Sweden over the last ten years. Despite this, however, its share of the country's electricity production is still very modest. Wind power production 2003 amounted to 0.62[43], or almost 0.5% of total electricity production 2003. At the end of 2003 there were 682 wind power mills in operation.

In addition to nuclear power, hydro power and wind power, Sweden also operates a certain amount of combustion-based power production. In 2003, it supplied 13 TWh, or about 10% of total electricity production. 31% of the fuel for this production was accounted for by biofuels, 33% by coal, 32% by oil and 4% by gas. As far as combustion-based electricity production is concerned, it is expected that the use of cogeneration (i.e. combined heat and power) production based on biofuels and energy gases will increase over the next few years, partly due to the effect of new taxation rules which will favour cogeneration.

Transmission of electricity

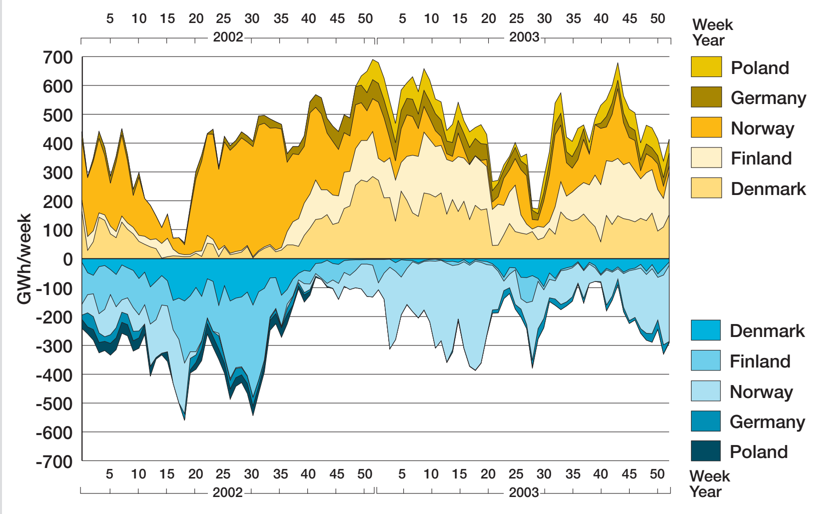
A condition for proper operation of the competitive electricity market is that all parties should have unrestricted access to the power grid. The Swedish Energy Agency is the authority having jurisdiction over the grid in accordance with the Electricity Act (1997:857) and the Electricity Ordinance. This means that the Agency exercises surveillance of the tariffs of the grid owners, ensures that they comply with regulations concerning metering and ensures that they provide a good delivery quality. Grid tariffs must be reasonable in relation to the service provided by the company, and must also be based on actual circumstances. In order to improve its surveillance of tariffs, the Agency has developed the Performance assessment Model, as a means of providing an initial assessment of the fairness of a tariff. At the same time, there needs to be a system operator who, independently of other parties on the market, ensures that there is at all times a balance of power flows between power demand and power production. The Swedish system operator is Svenska Kraftnät, with responsibility for the country's grid[44] and for most of the interconnections with the neighbouring countries.

There are at present links between Sweden and Norway, Finland, Denmark, Germany and Poland. Interconnection capacities between these countries have been increased in recent years: a DC link between Sweden and Poland was commissioned in 2000, and transmission capacity between Sweden and Norway was increased in 2001. Reinforcing the grid by means of a new 400 kV line in western Sweden is planned for operation in 2006. Finland's plans for a new, 1600 MW, nuclear power station by 2009 will require reinforcement of the transmission capacity between Sweden and Finland.

Sweden's total installed capacity was a little over 33 300 MW in 2003. Maximum demand in 2003, of 26 400 MW, occurred on 31st January. However, total installed capacity can never be 100% available[45], and there are also limits to the transmission capacity between northern and southern Sweden. Normal capacity allows up to 7 000 MW to be transmitted from northern to central Sweden. From central to southern Sweden, the transmission capacity is about 4 500 MW.

FIGURE 18

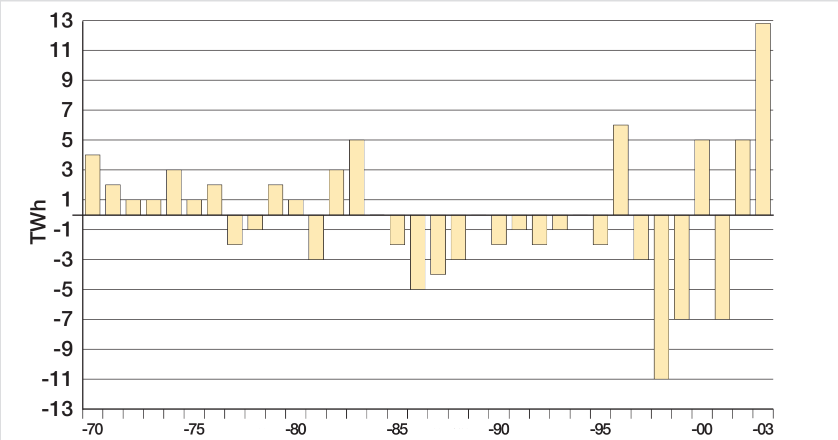
Swedish electricity imports (+) and exports (-), Jan. 2002–Dec. 2003



Source: Swedenergy, Swedish Energy Agency processing.

FIGUR 19

Swedish net electricity imports (+) and net exports (-), 1970–2003



Source: Swedenergy, Swedish Energy Agency processing.

Trade in electricity

Prior to reform of the markets in the Nordic countries, electricity was traded between countries under the terms of bilateral agreements. Today, there is also a joint Nordic power exchange, Nord Pool, which trades in both electricity and financial instruments. In 2003, about 31% of the electrical energy used in the Nordic countries (apart from Iceland) was traded on Nord Pool's electricity spot market. The benefits of a Nordic trading exchange are Nordic power plants can be run in more economic effective way, and that with pricing becoming more effective as a result of reduced transaction costs and greater transparency. In addition, the exchange´s spot price can also be used as a reference for bilateral trade. Border tariffs have been removed between Norway,

42 A normal year's hydro power production is about 65 TWh.
43 This figure is based on Statistics Sweden's data, which here differs slightly from the Elforsk´s data.
44 The grid, which is owned by Svenska Kraftnät, operates at voltages of 220-400 kV and provides the backbone of the country's bulk power transmission system.
45 Plant can, for example, be undergoing planned maintenance.

Sweden, Finland and Denmark, which has also helped to encourage trade.

Trade in electricity between the Nordic countries varies during the year and from year to year, depending on weather and economic conditions. However, the prime factor in determining power trading is annual precipitation to the Swedish and Norwegian reservoirs, coupled with the marginal costs for electricity production. In 2003, Sweden was a net importer of electricity, mainly due to low precipitation during the year. Most of these imports came from Finland and Denmark. Sweden was also a net importer of electricity from Germany and Poland, but a net exporter to Norway.

Price developments

Electricity prices vary between customer categories, between urban and rural areas and between the Nordic countries. This is due to varying transmission costs across regional and local distribution systems, different taxation regimes, subsidies, national rules and the structure of the electricity market. The spot price of electricity on the power exchange is not the price that private customers see on their electricity bills. The final price of electricity to a customer consists of a grid tariff, a price for the electrical energy itself, electricity certificates, taxtes and VAT. The price of the underlying electrical energy may be fixed or variable, while the grid price generally consists of both a fixed and a variable portion. It is the price of the electrical energy that is subject to competition. For a domestic customer without electric heating, for example, the electricity itself accounted for 34% of the total cost, grid charges about 27%, electricity certificates about 2%[46] and taxes and value-added tax for the remaining 36% in 2003.

The spot price has varied widely since deregulation of the market in 1996, due primarily to variations in precipitation from one year to another. The hitherto highest price occurred at the end of 2002 and the beginning of 2003, reaching a record spot price of 104,1 öre/kWh on Nord Pool. Over 2003 as a whole, the average spot price was 33,3 öre/kWh. See Figure 20.

The joint Nordic electricity spot market is divided into a number of bidding areas, depending on various physical transmission limitations within and between the individual countries. These bidding areas on the Nord Pool exchange are determined and agreed by the national grid operators[47].

International development

The electricity market in many parts of the world is at present undergoing extensive changes in terms of changing market conditions, new technology and more stringent environmental requirements. One of the effects of the EU Electricity Market Directive is that the electricity markets in the member states must be progressively opened to competition. The degree of openness varies between states: the electricity markets in Sweden, Finland, the UK, Germany, Austria, Denmark and Spain are fully open to competition, which means that all companies and households are free to choose their electricity suppliers. Other countries, such as France and Greece, have decided to observe the minimum requirements of the Directive. A new time plan for opening the electricity and gas markets was approved by the EU Parliament in June 2003. Under the present Electricity and Gas Markets Directive, the market must be fully open to competition for sales to the commercial sector by 2004, and for sales to all other customers by 2007.

Reform of the electricity markets means that electricity becomes an energy carrier that

[46] The average price of the electricity certificate in 2003 was 2.4 öre/kWh. Source: Swedish Energy Agency.

[47] See also the Agency's report 'Price areas for tackling bottlenecks'

TABELL 7

Total electricity cost (excluding electricity certificates) for various customer categories, including tax and VAT, öre/kWh

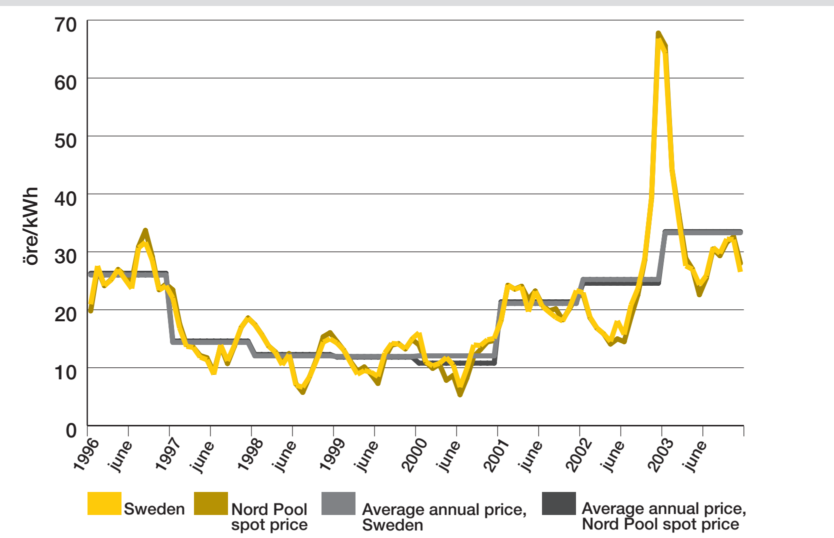
Date	Electricity-intensive industries[1]	Small industries[2]	Detached house with electric heating[3]	Detached house without electric heating[4]
1 januari 2002	34.0	43.8	87.9	111.3
1 januari 2003	53.7	59.9	111.4	135.4
1 januari 2004	51.3	62.4	117.9	143.6

Note: The prices in the table are average prices from the electricity utilities, available to the various customer categories as of the dates shown.
[1] Annual consumption 140 000 MWh, power demand 20 MW. [2] Annual consumption 350 MWh, power demand 100 kW or 160 A supply rating. [3] Annual consumption 20 000 kWh, 20 A supply rating. [4] Annual consumption 5000 kWh, 16 A supply rating.

Source: Svenska Kraftnät, Swedish Energy Agency.

FIGURE 20

Nord Pool spot prices and Sweden's price range, monthly and annually



Source: Nord Pool, ftp server.

can be traded and supplied across national borders. The power utilities are developing into larger and more integrated energy utilities, operating in several countries. The large dominating companies on the Nordic electricity market – Vattenfall in Sweden, Statkraft in Norway and Fortum in Finland – have all bought into competing companies on the northern European market. In the same way, other companies, such as the German E.on, are investing in the Nordic countries. In a trans-national market, electricity is produced where it is technically and economically most favourable to do so, subject to physical limitations set by the capacities of cross-border links and national transmission systems.

Electricity from renewable energy sources

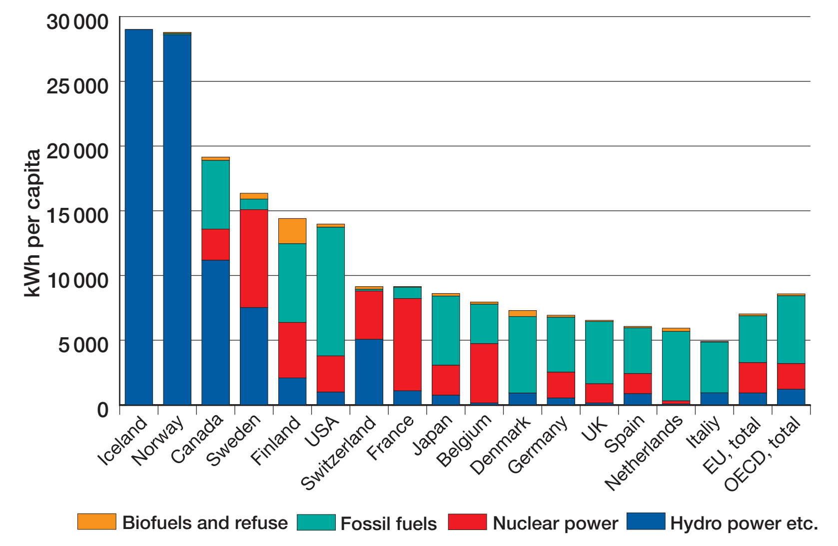
Reform of the electricity markets and natural gas markets in Europe are important steps towards an internal energy market, with greater competition and lower prices. However, as a result of higher production costs, electricity from renewable sources can find it more difficult to break into the competitive markets. A directive aimed at encouraging the production of electricity from renewable sources was approved by the Council of Ministers in August 2001. It requires the production of electricity from renewable sources in the EU to be increased from somewhat less than 14% at present to over 22% by 2010. Each state is free to choose whatever method it prefers to encourage the production of renewable electricity. Examples include traditional investment grants, fixed price systems48, certificate trading schemes etc. Sweden has chosen a certificate system. Trading in emission rights will also encourage electricity production from renewable sources.

International comparison of electricity use

Per-capita electricity use in Sweden is relatively high in comparison with that of other countries: only Norway, Iceland and Canada have higher per-capita uses. Conditions in all these countries are similar to those in Sweden: plentiful supplies of cheap hydro power, a relatively cold climate and a high proportion of electricity-intensive industries. 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 Swedish per-capita electricity use would be reduced by about 20%. Per-capita

FIGURE 21

Per-capita electricity production and relative breakdown of production sources, 2002



Note: Hydro power includes wind power, solar energy and geothermal energy. Fossil fuels are primarily coal or gas.

Source: IEA, Electricity Information 2004.

electricity use in the USA is about 21% lower than in Sweden, while that in the industrialised EU states is about 58% less than that in Sweden. Another factor of considerable importance for the high per-capita electricity use in Sweden is the early change from oil-based to electric heating as a result of the 1970s oil crises and other causes.

Sweden is one of the world's countries that have a high proportion of hydro power and nuclear power in their electricity production. Only Iceland, Norway, Switzerland and Canada had higher proportions of hydro power in 2002, and only a few countries, including France, Belgium and Lithuania, had higher proportions of nuclear power in 2002[49].

District heating and district cooling

District heating has been used in Sweden since the 1950s, but district cooling did not appear until the 1990s. District heating supplies residential buildings, commercial premises and industries with heat for space heating and domestic hot water production. District cooling, on the other hand, finds a market almost exclusively in the commercial sector for air conditioning of shops and offices, and in industry for process cooling and cooling large computer centres. District heating systems are geographically much larger than district cooling systems, which are confined to the centres of urban areas.

48 Under which the producer of electricity from renewable sources receives a guaranteed fixed price.

49 Bulgaria, Slovakia and the Ukraine had a lrger share of nuclear power for electricity production than Sweden in 2001. Source: IAEA and World Nuclear Association, 2003.

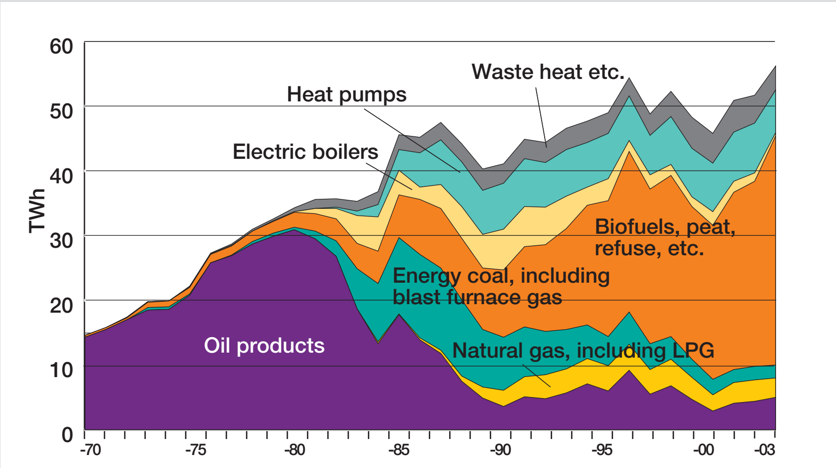
FIGURE 22

Use of district heating, 1970–2003

Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 23

Energy input sources for district heating, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

District heating

District heating can be defined in technical terms as the centralised production and supply of hot water, distributed through a piping system and used for the space heating of buildings. It is the commonest form of heating in apartment buildings and commercial premises, supplying about half of the country's end use of heating. It is the main form of heating in the centres of 227 of the country's 290 municipalities[50].

Local authorities began to look at district heating during the latter half of the 1940s, when it was seen as a good way of increasing electricity production in Sweden by providing a heat sink for CHP production. Its use spread during the 1950s and 1960s as a result of the extensive investments in new housing and other buildings that were being made during that period, in conjunction with a substantial need for modernisation or replacement of boilers in the country's existing building stock. Group heating systems[51] were gradually linked up to form larger systems, which were then in turn connected to district heating systems. There was a particularly substantial expansion of district heating over the period from 1975 to 1985, partly due to its ability to replace oil through its flexibility of fuel use. This was also the period of expansion of nuclear power generation, and the continued expansion of district heating resulted in it becoming a net user of electricity, in electric boilers and large heat pumps, rather than a net producer of electricity, which is more common in most other countries with substantial district heating systems. However, in recent years, interest in CHP (now mainly biofuel-fired) has again revived in Sweden due to such factors as changes in the taxation regime for CHP, the electricity trading certificate scheme and carbon dioxide taxation.

Energy policy has favoured district heating through various forms of state support, e.g. grants for the extension of existing district heating systems and the connection of group heating systems and even individual buildings to existing systems. Replacing a multitude of small individual boilers in residential buildings and commercial premises by district heating enables the heat to be supplied from a much smaller number of larger boilers with high efficiency, reducing both fuel requirements and emissions. The urban environment in most Swedish towns has been significantly improved as a result of the expansion of district heating and improved flue gas treatment, which have reduced emissions of SO_2, particulates, soot and NO_x.

District heating is not price-controlled, although the regular price comparisons by the Public Service Fee Group[52] and the Agency's annual surveys of the heating markets provide information on price differences between areas. A more in-depth review of district heating in the heating markets has been started, in the form of the District Heating Commission. An interim report from the Commission[53] recommends separate accounting of district heating activities and separating electricity and district heating supply activities into separate companies.

Today, district heating supplies over 40%[54] of the total residential and commercial premises heating requirement. It is the commonest form of heating in apartment buildings, supplying heat to about 77% of the heated floor area, while about 58% of commercial and similar premises are heated by it. In detached houses, on the other hand, the proportion is only about

50 The Nils Holgersson Survey 2003, carried out by five major housing organisations.
51 Heating systems that supply one or just a few blocks of buildings. Commonly included in most development.
52 Formed by five large housing organisations, and monitors local authority charges for heating, domestic hot water, water, sewage treatment, electricity and public cleaning. Also known as the Nils Holgersson Survey.
53 'Security for district heating customers – Greater transparency and separation of electricity and district heating supply activities', SOU 2003:115.
54 Calculated as 'purchased energy'.

8%. (See also 'Residential and service sector' in the 'Energy Use' chapter.)

The country has about 13 000 km of distribution mains, which supplied 50 TWh of heating in 2003; an increase of about 7% over 2002. Of this, over half was used for residential space heating, about 30 % for heating commercial premises and 15 % by industry.

One of district heating's advantages is its flexibility in respect of choice of fuel. In 1980, over 90 % of the fuel input for district heating and CHP plants was in the form of oil. Nowadays, the fuel mix is more varied, with biofuels being the main energy source.

Total energy supply to the district heating sector in 2003 was 56 TWh, of which biofuels accounted for 35 TWh, or over 62%. The use of electricity in the sector, with most of it being accounted for by electric boilers, has fallen substantially since 1996. The electrical energy input to heat pumps, however, has remained relatively constant.

District heating losses have fallen since the 1980s as a result of improved technology and higher load factors. In 2003, distribution and conversion losses amounted to about 11% of the total energy input, as against about 20% during the 1980s. Some of the reduction, however, is due to the greater use of heat buyback, as described above, which requires no network distribution.

Until the beginning of the 1980s, most district heating systems were operated as local authority services. However, since then, most have been restructured as limited companies, owned by the local authorities. Today, there are about 220 companies supplying heat in Sweden, although many have common owners. After deregulation of the electricity market, there has been a considerable consolidation of ownership as a result of some of the larger electricity utilities buying up local authority energy companies, including their district heating operations. Nevertheless, about 60% of the country's district heating utilities are still owned by local authorities, although many of the really large systems, such as Stockholm, Malmö, Uppsala, Norrköping and Örebro, are partly owned by private or state[55] interests.

District cooling

District cooling is used mainly in offices and commercial premises, as well as for cooling various industrial processes. Its principle is similar to that of district heating: cold water is produced in a large central plant and distributed through pipes to customers. The statistics provide data only for commercial district cooling, i.e. with the supplier and consumers being different parties. It is primarily existing district heating suppliers that have established commercial district cooling systems in Sweden.

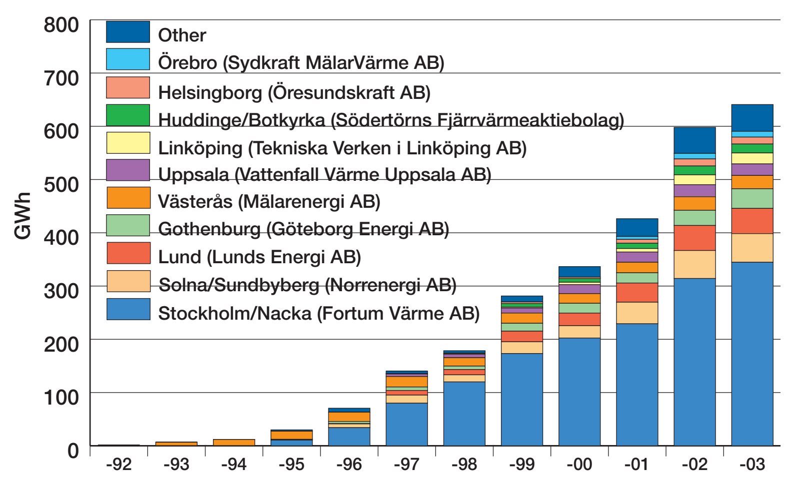
The commonest means of production in Sweden is to use waste heat or lake water as the heat source for heat pumps, with the cooled water from which this heat has been abstracted then providing the district cooling water, while the heated output water from the heat pumps is generally used for district heating. Another common method of production is simply to use cold bottom water from the sea or a lake, i.e. free cooling. A further alternative is to install absorption refrigerant plant in or near a customer's premises, and powered by district heating, which increases the load factor of the district heating system in the summer.

One of Europe's largest district cooling operations has been built up in central Stockholm since 1995. The market for district cooling has expanded strongly since the first system was started up in Västerås in 1992, powered by such factors as higher internal heat loads in offices and shops, greater awareness of the importance of good working conditions and the phase-out of ozone-destroying refrigerants. The progressive prohibitions on the use of such refrigerants have meant that property-owners have been forced to buy new equipment, convert existing equipment or invest in replacement systems. Connection to district cooling is an attractive alternative.

In 2003, there were 30 commercial district cooling suppliers, some operating more than one system. 640 GWh of district cooling were supplied.

FIGURE 24

District cooling, by city (and supplier), 1992–2003

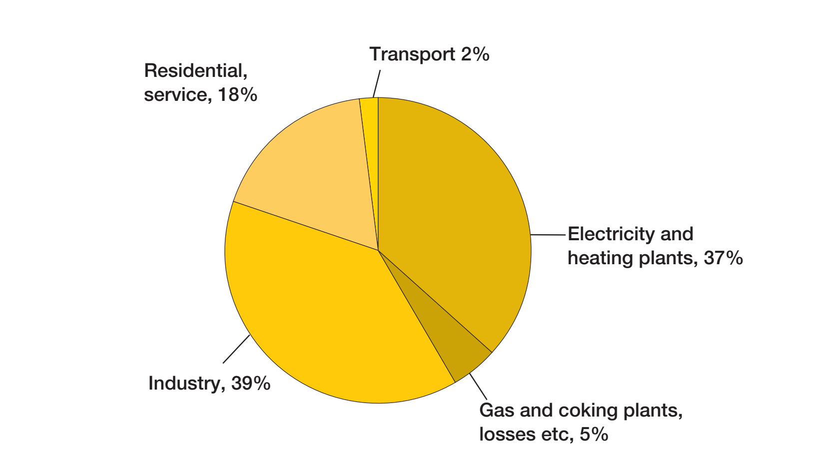


Source: Swedish District Heating Association

55 Particularly the Swedish state through Vattenfall and the Finnish state through Fortum.

FIGURE 25

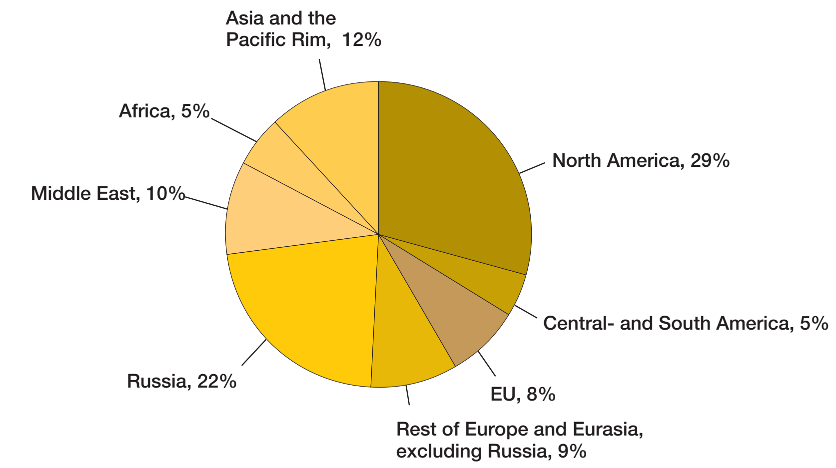
Supply of natural gas in Sweden, 2003, by sectors. Total 929 × 10^6 m^3



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 26

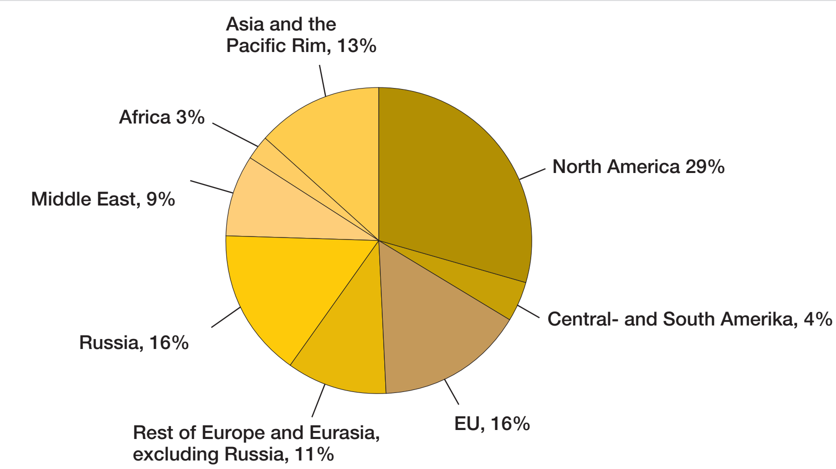
World natural gas production, 2003 Total 2 618 × 10^9 m^3



Source: The Statistical Review of World Energy 2004, www.bp.com.

FIGURE 27

World natural gas use, 2003 Total 2 591 × 10^9 m^3



Source: The Statistical Review of World Energy 2004, www.bp.com.

The energy gases market

Sweden uses a relatively small quantity of energy gases[56] in comparison with many other European countries. However, the distribution network for natural gas in Sweden is being extended. The rest of Europe is covered by an extensive natural gas distribution network. The use of natural gas in Europe has increased over the last couple of decades, primarily by replacing coal and oil.

Natural gas

Natural gas was introduced to Sweden in 1985. Its use increased rapidly until 1992, after which growth continued at a more modest rate. In 2003, imports amounted to 929 million m^3, equivalent to 9.3 TWh. Industry, on the one hand, and CHP and district heating plants on the other, each account for almost 40% of total use, with domestic consumers accounting for almost 20%. A small amount of natural gas is also used as motor fuel.

Natural gas is distributed at present to about 30 areas, where it provides about 20% of energy use. On the national level, it supplies a little over 1% of total energy use.

The gas is supplied exclusively from fields in the Danish sector of the North Sea. After transiting Denmark, a pipeline under Öresund brings the gas ashore at Klagshamn outside Malmö. A trunk main extends from Trelleborg in the south to Gothenburg, with a number of branches, including one to Gislaved in Småland. Nova Naturgas AB owns, and is responsible for operation of, the trunk main. Its trading activities were sold in 2004 to Dong Natural Gas. Sydkraft Gas AB is responsible for the branch mains in southern Sweden, and completed extension of a main from Hyltebruk to Gislaved and Gnosjö at the end of 2002. A concession application has been submitted for extension of the existing main from Gislaved /Gnosjö to Jönköping. In conjunction with Verbundnetz Gas, Sjællandske Kraftværker and Norsk Hydro, it is planning to build a transmission pipeline between Germany and Sweden, via Denmark, under the name of the Baltic Gas Interconnector. The application for the Swedish part of the project has been processed by the Swedish Energy Agency, which supported the application in its report to the Government in April 2003.

In May 2004, Nova Naturgas AB concluded construction of the west coast distribution main from Gothenburg to Stenungssund and Bohus.

Production and use of natural gas internationally

Although natural gas is a marginal energy source in Sweden, it provides somewhat over 20% of energy supplies in the EU states and in the world as a whole.

The world's natural gas reserves are substantial: at the end of 2003, commercially viable reserves amounted to 176×10^{12} m^3, which would last for almost 70 years at the present rate of use, with present technologies and present prices. Most of the reserves are to be found in the former Soviet Union (32%) and in the Middle East (41%). Less than 2.0% of the world's natural gas reserves lie within the EU states. At the present rate of use, this would last for only 14 years. Over the last decade, natural gas supplies to the EU states have been increasingly based on production from the North Sea and imports from Russia and Algeria. In order to increase the security of supply, there is European interest in increasing the number of links between the Russian and Norwegian natural gas fields and the continent.

Today, the world's major producing countries are Russia, the USA and Canada. Within the EU, the major producers are the UK and Holland.

The proportion of total global energy supply met by natural gas has increased rapidly during the last decade, by over 25% between 1992 and 2003. Consumption of natural gas is highest in the USA, Russia and the UK. Within the EU, natural gas has a part to play in reducing environmentally hazardous emissions, primarily by replacing coal and oil.

Transportation of natural gas

Pipeline transportation of natural gas is the main way of transporting natural gas between producers and consumers. The physical transport system can be approximately divided up into transmission and distribution. Transmission pipes carry the gas over long distances under high pressure: the quantities of energy represented by the gas can be very significant. At the reception points, the pressure is reduced in metering and pressure regulation stations, before the gas is supplied to local distribution networks for delivery to the end-users.

Several Asiatic countries, particularly Japan and South Korea, are far from their sources of supply. Gas is delivered to them by ship in liquid form, having been liquefied by extreme cooling. Liquefied natural gas (LNG) has historically been unable to compete to any greater extent with pipe-borne natural gas, due to the cost of liquefaction and maritime transport. However, recent reductions in the cost both of production and transport have partly changed this situation.

Opening the natural gas markets to competition

The underlying purpose of deregulation of the natural gas markets around the world has been to create the right conditions for effective utilisation of resources, thus keeping down the prices of gas. Several structural regulatory changes have been introduced in order to ensure smoother operation of the markets. Some of the most important of these are unbundling and third-party access. Unbundling involves separation of sales and transport of the gas, and can operate at various levels. In the most extreme case, it involves a complete separation of ownership between the transport activity and the sales activity. In Sweden, the requirement is simply that the reports and accounts of the two activities must be separated, in order correctly to assign the costs for each and to prevent cross-subsidisation. (Cross-subsidisation is the practice of applying the revenue from one activity to support another, thus distorting competition.) Third-party access requires the owners of transmission and distribution networks to allow other parties to use the networks. The UK provides an example of a country with third-party access to both its transmission network and its distribution networks. One of the reasons for its introduction has been to create competition in the sale of natural gas: in practice, if it is to work properly, it must also be accompanied by unbundling.

The USA and Canada were the first countries to begin restructuring their gas markets at the end of the 1970s. The process started by deregulating pricing of the gas itself at the production level, and this was followed by extending deregulation to create competition at the wholesale level. This required a legal distinction between trade in gas on the one hand, and its transport on the other, i.e. unbundling. Another feature of the North American gas market reform was the requirement for third-party access to the large interstate transmission pipelines.

Similar reforms were launched in the UK during the middle of the 1980s, so that, since 1998, the market there is completely open. All customers, regardless of size, have a free choice of supplier.

The EU Natural Gas Directive was issued in February 1998, with the aim of increasing competition on the European natural gas markets. It was incorporated in Swedish legislation on 1st August 2000, in the form of a new Natu-

56 Energy gases are here defined as natural gas, LPG, biogas, town gas and hydrogen.

ral Gas Act. A new Natural Gas Directive (2003/55/EC) was issued in June 2003, with the aim of accelerating deregulation of the natural gas markets, and setting a timetable for opening the markets. By not later than 1st July 2004, all non-domestic customers must be able freely to choose their suppliers. This group is known as eligible customers. This freedom must have been extended to all customers by 1st July 2007, thus achieving complete liberalisation of the EU gas markets. In addition, there are requirements for unbundling and third-party access of and to transmission and distribution networks. (See Chapter 1, 'Current energy and climate policy areas'.)

Other energy gases

LPG

LPG is a petroleum product, consisting of the hydrocarbons propane, propene and butane, or mixtures thereof. Its environmental characteristics are very similar to those of natural gas.

Imports of LPG to Sweden in 2003 amounted to 854 000 tonnes, while 400000 tonnes were exported. 451 000 tonnes were supplied to the Swedish energy system, equivalent to 5.8 TWh.

LPG is used mainly in industry, as well as in the restaurant trade and in horticulture. As LPG and oil and also, to some extent, biofuels are interchangeable fuels in these applications, the use of LPG is sensitive to changes in energy taxation or fuel prices. In 2003, 5.1 TWh of LPG were used in industry and 0.5 TWh in the residential sector.

Biogas

Biogas consists of methane, formed by the breakdown of organic materials such as sewage sludge, refuse or industrial waste under anaerobic (oxygen-free) conditions. The process, known as digestion, occurs spontaneously in nature, e.g. in marshes. Today, Sweden has about 100 biogas plants in operation, most of them in sewage treatment plants or at landfill sites, producing digester gas and landfill gas respectively. Most biogas is used for electricity and heat production. In 2002, 38 GWh were used for electricity production, 325 GWh for heat production and 85 GWh in the transport sector. Biogas can also be cleaned and distributed via the natural gas network as 'green natural gas'.

Town gas

Town gas (gasworks gas) is produced by cracking naphtha. Fortum Värme AB in Stockholm is the only producer of such gas in the country: the town gas used in Malmö and Gothenburg nowadays consists of natural gas mixed with a small proportion of air. It is used for heating detached houses, larger properties and industries, as well as for cooking in homes and restaurants. During the year, 0.5 TWh of town gas were used.

Hydrogen

Pure hydrogen does not occur naturally, but must be produced from sources such as methanol, LPG or natural gas, or by electrolysis of water. Production of hydrogen by electrolysis is energy-intensive: to produce hydrogen with an energy content of 100 kWh requires about 125 kWh of electricity. Research is in progress, with the aim of improving production technology and developing effective means of storage. Hydrogen is used today primarily by the chemical industry, but can also be used as a fuel in fuel cells, where it is converted to electricity and heat.

The oil market

Crude oil makes up about 40% of the trade in raw materials for the world's commercial energy markets. For over 140 years now, oil has been one of the most important energy raw materials, on the back of which industrialisation, motor traffic and economies have grown. Recent decades have seen a rapid expansion of the oil markets in the new industrialised countries in the Far East and Pacific rim, as well as in the major oil-producing countries of the Middle East. The use of oil is at present increasing rapidly in the developing countries.

Oil in Sweden

In 2003, oil provided over 33% of Sweden's energy supply. On the user side, it is the transport sector that is most dependent on oil, using over twice as much oil as do the industry and residential/service sectors together.

Oil dependence has been substantially reduced since 1970, falling by about 43% since 1970. It is particularly the use of fuel oils that has been reduced: instead, Sweden has become more dependent on electricity, although district heating has also replaced a considerable quantity of oil for heating supplies. (See Figure 28.)

Another important change since before the oil crises is the fact that Sweden nowadays exports, rather than imports, refined oil products. Prices of refined products rose steeply during the 1970s oil crises, and so an increase in refinery capacity was an important means of helping to protect the Swedish economy against excessive price rises. In 2003, Sweden imported over 20 million tonnes of crude oil, and exported 2.9 million tonnes of refinery products. About 60% of Sweden's total crude oil imports come from the North Sea. Overall, 38% of imports come from Norway, 18% from Denmark, 19% from Russia, 15% from Iran and about 4–5% each from the UK and Venezuela, as shown in Figures 29 and 30.

This substantial importation of oil is due to the fact that much of the oil is processed in Sweden before re-export. The export share of Sweden's production of oil products has increased from 25% in 1986 to about 47% in 2003.

In accordance with international agreements and its membership of the EU, Sweden is required to maintain stocks of oil as a buffer against crisis situations. The Agency is the surveillance authority for this, deciding who is required to maintain such stocks and how large they are to be.

Production and reserves

Crude oil is recovered from the earth's crust onshore or offshore, depending on where it is: costs differ between the two. The quality of the crude can also vary from one location to another, and it is generally more expensive to recover oil offshore than onshore. The oil cannot be used until it has been refined, which produces a range of petroleum products, primarily petrol, diesel fuel, aviation fuel and fuel oils. By far the greatest use of oil products is as motor fuels, with most of the transport sector now (and for a considerable time into the future) dependent on the use of oil. Oil products are also used for electricity and heat production, as a raw material for plastics, in other chemical industries and for many other products, such as asphalt. All this means that the oil market dominates the entire world economy. International trade in oil, which is largely organised through an international oil exchange, also accounts for the greatest volume of products transported by international maritime trade. This trade also represents a major environmental risk.

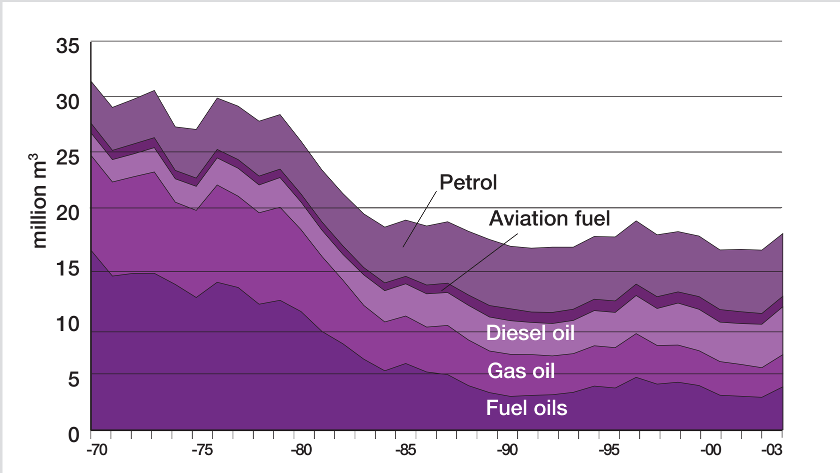
Production methods for crude oil have become more efficient, with technical development resulting in both improved prospecting for oil and improvements in bringing oil wells on line. New reserves can be found, thus increasing total known reserves. New technology has also made it possible to extract more oil from each well. This has reduced the cost of recovering the oil, thus giving a certain theoretical potential for lower oil prices. However, as long as output restrictions are applied by producers, oil prices are maintained at higher levels. It is difficult to put a figure on total oil reserves, and there are many different assessments thereof. The same applies to attempts to determine how long supplies will last with present technology and rates of use. (See also Chapter 6, 'The international perspective'.)

OPEC and other oil producers

OPEC (Organization of the Petroleum Exporting Countries) is an international organisation for cooperation between eleven oil-producing developing countries, the economies of which are strongly linked to their oil export revenues. The members of OPEC are Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela. Most of OPEC's production is in the Middle East. OPEC's purpose is to create stability on the international oil market, and to

FIGURE 28

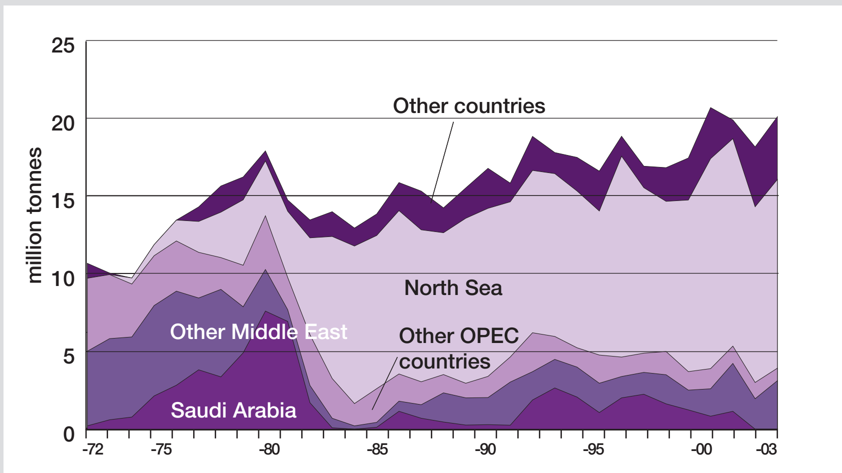
Use of oil products in Sweden, including international maritime trade, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 29

Swedish imports of crude oil, 1972–2003, by countries of origin



Source: Statistics Sweden, Swedish Energy Agency processing

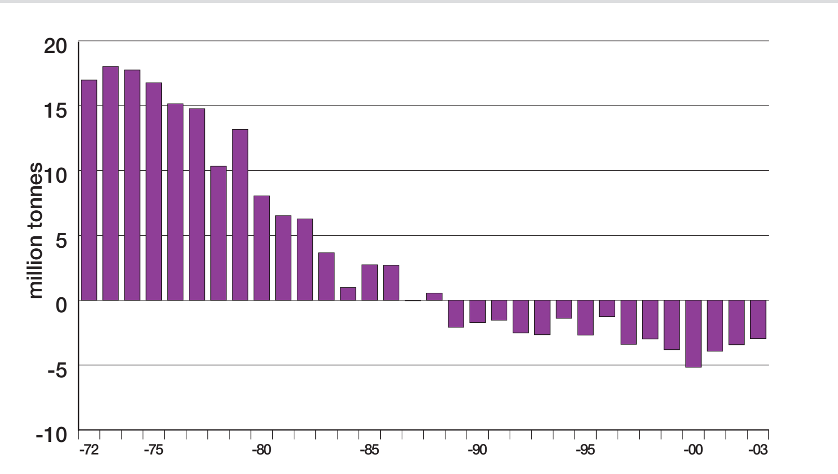
look after its members' economic interests. By controlling the amount of oil available on the market, OPEC attempts to achieve a balance between supply and demand, and to maintain prices at a level which is in the long-term interests of its members' economies. OPEC accounts for about 40% of world production of crude oil, and over 75% of world market net exports.

Outside OPEC, the largest oil-producing countries are Russia, the USA, Mexico, China, Norway, Canada, the UK and Oman, together accounting for most of the rest of the world's oil production. However, with the exception of Norway and Oman, these countries have large home markets, and therefore make little contribution to net world exports. Abstraction rates in the non-OPEC countries are high in relation to their remaining reserves, which means that the oil market will become more dependent on oil production from the OPEC countries in the longer term. In general, the cost of crude production is higher in non-OPEC countries, due to the size of the fields and their accessibility. Offshore production, for example, is more common in the non-OPEC countries. In 2003, Sweden imported 19% of its crude oil from OPEC countries.

Since the oil assets in the OPEC countries were nationalised during the 1970s, OPEC has acted as a cushion on the world market. Crude oil outputs are regulated by a quota system. OPEC has attempted to maintain price levels by persuading its member states not to utilise their full production capacity, although this policy has had somewhat varied success.

FIGURE 30

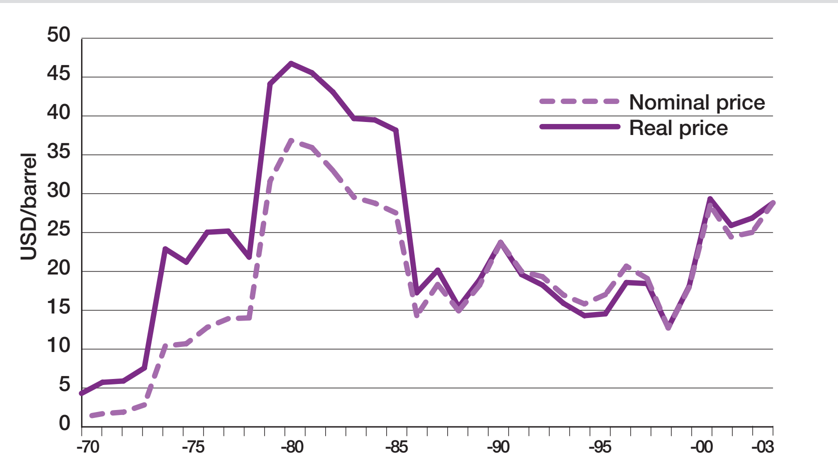
Net imports (+) and net exports (-) of refinery products, 1970–2003



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 31

Nominal and real prices of light crude oil, 1970–2003



Source: www.bpamoco.com and the World Bank

Oil prices

There are many factors that affect the price of oil: expectations of future economic trends, for example, political conditions in the Middle East, armed conflicts in high-output regions, terrorist threats and the strength or weakness of the dollar are some of the more important. In recent years, there have been substantial price changes on the international oil market as a result of these factors and of production restrictions by OPEC. Figure 31 shows the roller-coaster ride of oil prices over the last 30 years. OPEC has tried, for some years, to maintain the price level in the range USD 22–28 per barrel, aiming to achieve an average price of USD 25 per barrel. This price range represents a balance between a high price of oil, which gives high revenues for the producers, and the braking effect of this price on world economy and thus on the demand for oil.

The price of oil has risen from USD 13 per barrel in 1998 to between USD 25 and USD 29 over the period 2000–2002. In 2003, the average price was almost USD 29 per barrel which, in nominal terms, was the highest for 20 years. The upward trend has continued in 2004, with variations in the price and a peak of over USD 50 per barrel.

The coal market

Carbon is one of the elements, which occurs in nature in the form of combinations in various minerals. Some of these minerals can be burnt, and are referred to in everyday language as coal. By tradition, coal is divided into hard coal and brown coal, depending on its calorific value. This division is not particularly precise, as no two coalfields produce coal with exactly the same properties. They can differ with respect to properties such as ash content, moisture content, the proportion of flammable constituents (calorific value), volatile elements, sulphur content etc. Quality differences between coals vary on a continuous scale. Hard coal is a relatively high-value coal, while brown coal has a lower energy content and a higher moisture content. Sweden uses almost exclusively only hard coal, which is divided traditionally into two different categories: coking or metallurgical coal, which is used in the iron and steel industry, and steam coal, which is sometimes also referred to as energy coal, and is used for energy supplies.

Since 1991, the spot price of coal in north-western Europe has varied between 26 USD/tonne and 46 USD/tonne[57]. In August 2004, the price was 76.5 USD/tonne, which is a record.

The largest producers of hard coal are China and the USA, which together account for 58% of world production. The five largest exporting countries are Australia, China, Indonesia, South Africa and the USA, together accounting for over 74% of world trade in hard coal. Coal production in Europe is falling, while imports are rising somewhat. If production continues at the present rate, proven and economically recoverable reserves would last for over 200 years. The largest accessible reserves of hard 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.

Sweden's coal supply

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 oil crises of the 1970s meant that coal again became an interesting alternative fuel for reasons of price and security of supply. During the 1990s, the increasingly stringent environmental standards imposed on coal firing, together with rising taxation, meant that the use of coal for heat production stagnated. A total of 3.4 million tonnes of hard coal was used in Sweden in 2003. Of this, 1.8 million tonnes were coking coal, leaving 1.6 million tonnes for energy purposes. To this must be added a net import of 0.5 million tonnes of coke.

The use of coal in industry

Industry uses energy coal, metallurgical coal, coke and smaller quantities of other coal products such as graphite and pitch. Coke is essentially pure carbon, produced in coking plants from metallurgical coal. The country's two coking plants, at steelworks in Luleå and Oxelösund, also produce gas as a result of the process. The gas is used for heat and electricity production in the steelworks, and for district heating production. The coke is used in the iron and steel industry for reduction of the iron ore and as an energy input to the process. Some of the energy content of the coke is converted to blast furnace gas, which is used in the same way as the coke oven gas.

In addition to metallurgical coal and coke, ordinary energy coal is also used in industry. During the year, 1.8 million tonnes of metallurgical coal were used in industry, together with 0.9 million tonnes of energy coal and the country's entire net import of 0.5 million tonnes of coke. This quantity of energy coal provided an energy input of 6.7 TWh.

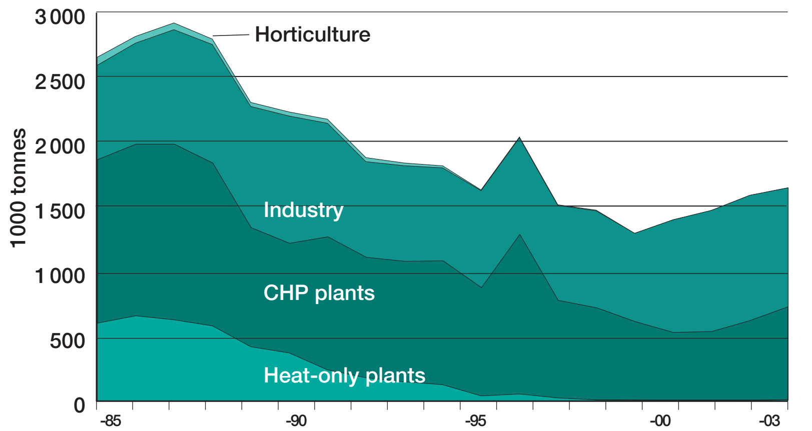
District heating and CHP production

The use of coal for district heating fell considerably during the 1990s, when the carbon dioxide and sulphur taxes were introduced. Plants that supply only heat have abandoned coal almost entirely as a fuel due to the high taxes, replacing it by biofuels. However, CHP plants still use some coal, as that proportion of the coal regarded as providing the energy for electricity production is exempt from energy and carbon dioxide tax. However, to improve the competitiveness of CHP production, this treatment has been changed with effect from 2004, so that the coal is taxed on the basis of the proportions of electricity and heat produced by the plant, with the heat production portion being exempt from energy tax and subject to a 75% reduction in carbon dioxide tax. SSAB's steel

[57] tonne, as used here, refers to a tonne with a standardised calorific value of 6000 kcal/kg = 6.98 kWh/kg

FIGURE 32

Use of energy coal in Sweden, 1985–2003



Source: Statistics Sweden, Swedish Energy Agency processing

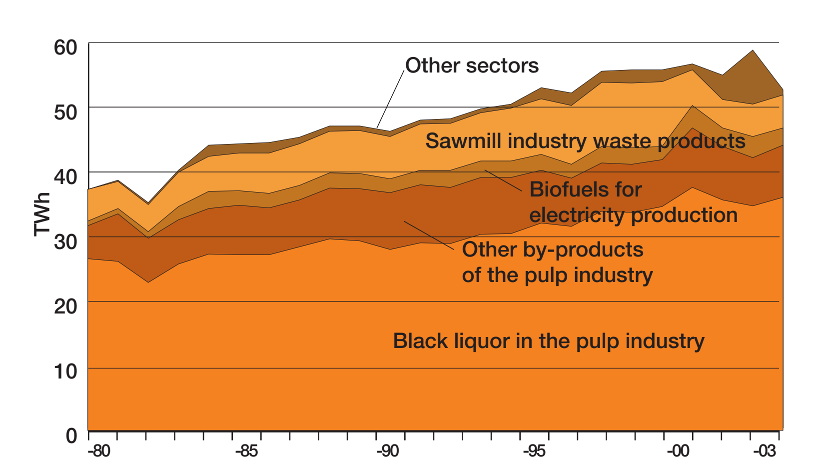
mill in Luleå supplies gas to the town's district heating cogeneration plant for the production of heat and electricity, while its mill in Oxelösund supplies heat from its coke oven gas and blast furnace gas to the town district heating system. In 2003, the district heating sector used 0.7 million tonnes of energy coal (5.1 TWh) and 2.1 TWh of coke oven and blast furnace gas for electricity and heat production.

Electricity production

0.54 million tonnes of coal (4.1 TWh), together with 1.9 TWh of coke oven and blast furnace gas, were used for electricity production in 2003, giving a total of about 3.8 TWh of electricity.

FIGURE 33

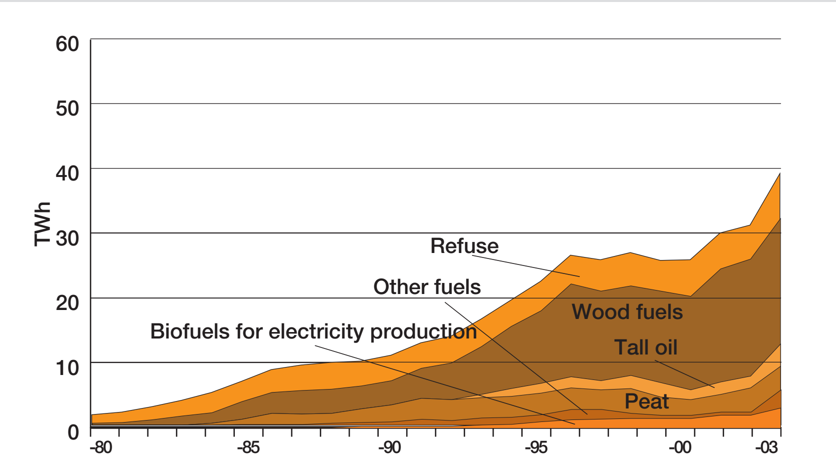
Use of biofuels, peat etc. in industry, 1980–2003



Source: Statistics Sweden, Swedish Energy Agency processing

FIGURE 34

Use of biofuels, peat etc. in district heating plants, 1980–2003



Source: Statistics Sweden, Swedish Energy Agency processing

Biofuels, peat and refuse

The proportion of bioenergy used in the Swedish energy system has steadily increased, from a little over 10% in the 1980s to about 17% in 2003. Most of the increase has been by industry and district heating plants.

The total use of biofuels in 2003 amounted to 103 TWh, of which about 62 TWh were as final use in the industry, residential and service and transport sectors, with over 41 TWh being used for electricity and heat production. The final use of biofuels amounted to about 49 TWh in the industry sector, over 12 TWh in the residential and service sector and almost 1 TWh in the transport sector. Biofuels for conversion amounted to 35 TWh in the district heating sector and about 6 TWh for electricity production.

With the exception of a certain import contribution, the biofuels used in the Swedish energy system are indigenous, consisting mainly of:

- Wood fuels
- Black and green liquors
- Peat
- Refuse
- Ethanol

They are used mainly in the forest products industry, in district heating plants, the detached house sector and for electricity production. Availability of raw materials for biofuels is good, due to the country's substantial forest areas. Large quantities of by-products and waste products are generated from wood raw materials by the long-established Swedish forest products industry. Most of the wood fuels used in the energy sector come directly from the forest in the form of felling residues, small branches and tops etc., from by-products from the sawmill industry and from the pulp and paper industry. Unprocessed biofuels are used mainly at regional and local levels, as their high bulk and low price means that it is not viable to transport them, Biofuels can be converted to pellets, briquettes or powder in order to improve their energy density, simplify handling and reduce the cost of transport. In 2003, the Swedish energy system used a total of about 1.1 million tonnes, or over 5 TWh, of pellets, making up about 0.9% of the country's total energy supply. The market for pellets grew by about 25% between 2002 and 2003[58].

Each year, there is a relatively extensive commercial importation of biofuels. However, no reliable import or export statistics are at present collected, and so it is difficult to estimate quantities. Imports are therefore included in

[58] Based on statistics from the Swedish National Association of Pellets Industries.

the country's energy balance as indigenously produced, calculated from the statistics of use. The investigations that have been carried out into the import quantities indicate a figure in the range 5–9 TWh, which means that the importation of biofuels represents a significant raw materials source. Most of the imported material is used for the supply of district heating.

The forest products industry

For economic reasons, the forest products industry[59] has long used the by-products from various manufacturing processes for the production of heat and electricity. Black liquors remaining after chemical processing of wood to produce wood pulp are burnt to recover chemicals. Black liquors are produced and used only within the pulp industry: in 2003, they provided over 35 TWh of energy (excluding electricity production). Wood fuels, in the form of raw materials residues, are used both in the pulp industry and in sawmills. They consist mainly of wood chips, bark and other waste products. In 2003, the pulp industry used a total of almost 8 TWh of wood fuels in the form of by-products for energy production, while sawmills and other woodworking industries used 5 TWh of wood fuels. Other industry sectors used almost 1 TWh of biofuels. In total, the forest products industry used about 51 TWh of various types of biofuels in 2003.

District heating plants

About 39 TWh of biofuels, peat etc. were used for heat production (i.e. excluding electricity production) in district heating plants in 2003. Of this, wood fuels accounted for over 19 TWh, refuse for almost 7 TWh, peat for almost 4 TWh, unrefined tall oil for over 3 TWh and other fuels for over 2 TWh.

The use of wood fuels by the district heating sector has increased by a factor of about five since 1990, as shown in Figure 34. The main form of these fuels is felling wastes and by-products from the forest products industry, although processed fuels such as briquettes and pellets have also been increasingly used in recent years.

Refuse has been used for district heating production since the 1970s. The quantity increased by about 3 TWh between 1990 and 2003, and is expected to continue to increase. Combustible refuse must now be separated from other refuse, and it has been prohibited since 2002 to dispose of unsorted combustible refuse in landfill. Refuse sent for combustion is exempted from the landfill disposal tax, but the ash is taxed. In 2003, the tax rate for landfill disposal was SEK 370/tonne[60]. A Commission has been appointed to evaluate the effect of the Landfill Tax, to put forward a proposal for a tax on refuse used as a fuel and to decide whether such a tax would be the most suitable economic guide measure. The Commission is due to report its results by not later than the end of 2004[61].

Some quantities of refuse, demolition timber and similar fuels have been imported in recent years, but the amounts are difficult to estimate. However, it is likely that the combustion of refuse will increase over the next few years. With effect from 1st January 2005, it will be forbidden to dispose of other organic refuse in landfill. There is at present a substantial capacity shortfall in ability to handle refuse in accordance with these requirements, and so new refuse incineration capacity is at present being built.

The use of peat amounted to 3.6 TWh in 2003. The harvest in 2003 was of normal amount, at about 2.6 million m^3. Imports continued to increase, so that they today provide about 30% of the use of peat for energy purposes. Peat is a substance that consists of dead plant and animal residues which, due to lack of oxygen in the decomposition process, have been incompletely broken down by the biological and chemical processes in peat bogs. The formation of peat started about 10 000 years ago as the inland ice from the last ice age retreated, and is still in progress. Sweden works peat partly for fuel purposes (energy peat), and also as a soil improver etc. (cultivation peat). Its properties when used as fuel are important when it is burnt together with wood fuels, particularly in reducing the risks of slag formation, sintering, the build-up of deposits and corrosion in boilers, and so increasing the availability and reducing the running costs of the plant[62].

With effect from 1st April 2004, the use of peat in approved CHP plants entitles electricity producers to electricity certificates. The EU Commission approved peat as an efficient CHP fuel for environmental reasons, and also because there was a risk that peat might be out-competed by coal in CHP plants. The role of peat in the Swedish electricity certificate system has been investigated by the Agency during the spring of 2004, as part of the evaluation of performance of the system. The final report from this evaluation was published on 1st November 2004. Today, energy peat is used primarily for hot water production in district heating plants, and only to a lesser extent for electricity production, which means that its entitlement to electricity certificates from April 2004 directly affects only a lesser part of the use of peat.

1st January 2005 sees the start of a trading system for emission rights. Although there is

59 Defined here as consisting of the pulp and paper industry and the sawmill and other woodworking industries.
60 SFS 1999:673.
61 Commission on Taxation of Combustible Refuse and Review of the Act (1999:673) Concerning Tax on Refuse (Dir. 2003:96).
62 Statistics Sweden Statistical Notice no. MI 25 SM 0401 (annual publication).

some uncertainty as to how peat should be classified in the trading system, the decision from the Climate Convention meetings of the parties, and guidelines from the UN Climate Panel, mean that emissions from the combustion of peat must be covered by the trading system. This affects the competitiveness of energy peat in Sweden, as it has previously been subject, when used as a fuel, only to sulphur tax.

The detached house sector

Over 12 TWh of biofuels, peat etc., were used in detached houses for heating in 2003.

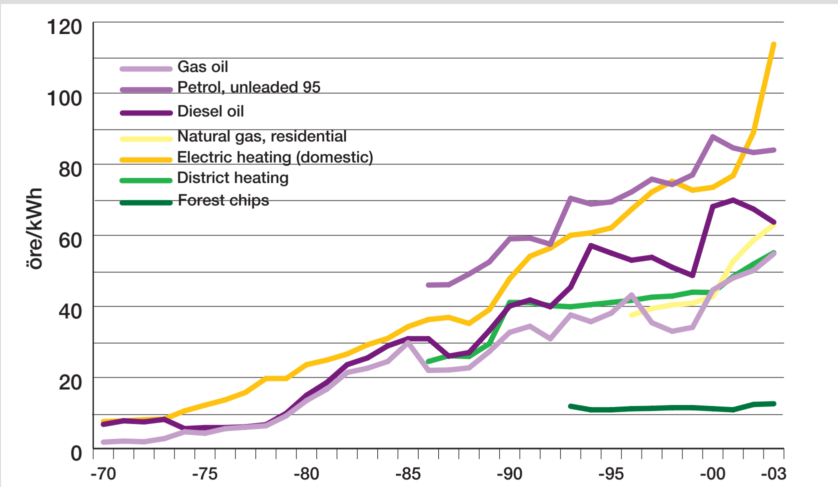
Most of this was in the form of logs, but a smaller proportion was provided by wood chips and a growing proportion by pellets and briquettes. Wood-firing is commonest among property-owners with good access to forests, e.g. in agricultural or rural areas. The use of pellets in the detached house sector has almost quadrupled since 1999, so that about 50 000 houses are today heated by pellets-fired boilers. The use of pellets in this sector increased by over 25% between 2002 and 2003.

An international context

About 17% of Sweden's energy is supplied by biofuels, which is a good level by European standards. It is difficult to find fully comparable details of biofuel use in other countries. In a global perspective, biofuels are the most important fuels for most of the Third World's populations. The following factors have a considerable effect on their use in energy systems: good availability of forests and raw materials, a developed forest products industry, wide existence of district heating systems and good transport systems. This explains why, of the European countries, it is Sweden and Finland that make use of the highest proportions of biofuels in their respective energy systems.

FIGURE 35

Commercial energy prices in Sweden, 1970–2003, including tax



Source: Swedish Petroleum Institute, Statistics Sweden, Eurostat, Swedish Energy Agency processing

Energy prices

At about USD 29 per barrel, the price of crude oil in 2003 was considerably higher than in 2002. Prices of refined products track the crude oil price, and therefore have a substantial effect on consumer prices. The import price of coal fell during the year, with an average price over the year of SEK 372/tonne. The average price of natural gas to domestic users has risen steadily over the last few years, reaching SEK 316/m³ in 2003. The price of forest chips also rose by 3% relative to the previous year: see Table 8.

Commercial energy prices consist of the price of the fuel, the price of electricity certificates, taxes and value-added tax. When trading in emission rights is introduced, the price of the rights will also be added to the fuel price in sectors affected by this trading. ■

TABLE 8

Fuel prices and price of electric heating in Sweden, excluding taxes and VAT, current prices

Energy carrier	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Crude oil, USD/barrel	23.73	20.00	19.32	16.97	15.82	17.02	20.67	19.09	12.72	17.97	28.50	24.44	25.02	28.83
Gas oil, SEK/m³	2 146	2 131	1 790	2 207	2 004	2 205	2 603	1 759	1 457	1 580	2 606	2 563	2 489	2 565
Coal, SEK/tonne	358	366	307	309	317	336	340	367	372	327	355	449	404	372
Petrol, 95 octane. SEK/l	2.23	2.19	2.06	2.23	2.10	2.02	2.10	2.25	2.01	2.29	3.18	3.12	2.88	2.86
Diesel fuel, SEK/l	2.88	2.87	2.68	3.03	2.83	2.55	2.21	2.19	1.84	2.16	3.83	3.92	3.61	3.18
Natural gas, residential, SEK/m³	-	-	-	-	-	-	214	217	221	216	229	285	311	316
Forest chips, SEK/m³				95.2	87.2	87.2	89.6	90.4	92.0	92.0	89.6	86.6	97.4	100.8
Electric heating, öre/kWh	31.5	36.1	37.9	40.0	39.7	40.7	43.6	45.2	45.0	43.0	42.2	43.3	51.3	68.32

Note: The 'Energy in Sweden: Facts and Figures' supplement gives the consumer price indices for 1970–2003, so the above prices can be converted to equivalent values.

Source: Statistics Sweden, Bank of Sweden, Eurostat, Swedish Petroleum Institute, BP.

The international perspective

Both EU and world energy supply are dominated by fossil fuels, with oil being the most important of them. However, there are major differences in the use of energy between countries and between regions, due largely to countries' economic situations, coupled with industrial structure and climate. Differences can also be partly explained by the fact that the countries are in different stages of development. An International Energy Agency forecast[63] expects world demand for energy to increase by 1.7% per annum until 2030, with most of this increase being accounted for by the developing countries.

Energy use in the EU-15

In 2002, energy use in the EU-15[64] amounted to 1057 million toe, equivalent to 12 300 TWh. This is dominated by oil, gas and electricity, with district heating, renewable energy and coal making up only a lesser part[65]. The primary energy supplied to the system is used at the end point either in its original form or as heat or electricity. The difference between energy supply and final energy use is accounted for partly by the losses that occur in connection with the production and distribution of electricity and heat, and partly by non-energy uses.

About 17% of world energy use, is in the EU-15. However, in recent decades, energy use in the EU-15 has been rising more slowly than in the rest of the world.

Oil is the dominating energy source in EU-15 energy supply, meeting about 50% of total final energy use. Although the greatest leap in oil consumption occurred during the 1960s, the increase has continued until today, although at a slower rate after the 1970s. It is the use of oil for transport that explains our continued dependence on oil.

The use of coal by end users has declined drastically, so that in 2002 it supplied less than 3% of final energy use, although it still an important fuel for the production of electricity and heat.

The use of natural gas continues to rise: since 1990, it has increased by 33%, so that it supplied over 22% of final energy use in 2002, although its use actually declined slightly in 2002. More than half of it was used by industry and domestic users, with about 15% being used for electricity production (which is an area with a considerable potential for growth)[66], and the remainder for heat production and transport. Some slight increase in the use of renewable energy sources has been discernable in recent years: in 2002, renewables provided 3.6% of final energy use in the EU.

Final use of electricity in 2002 amounted to almost 19% of total energy use. Since 1990, the use of electricity has increased by 27% (see also the Energy Markets chapter). Since 1970, its use has more than doubled.

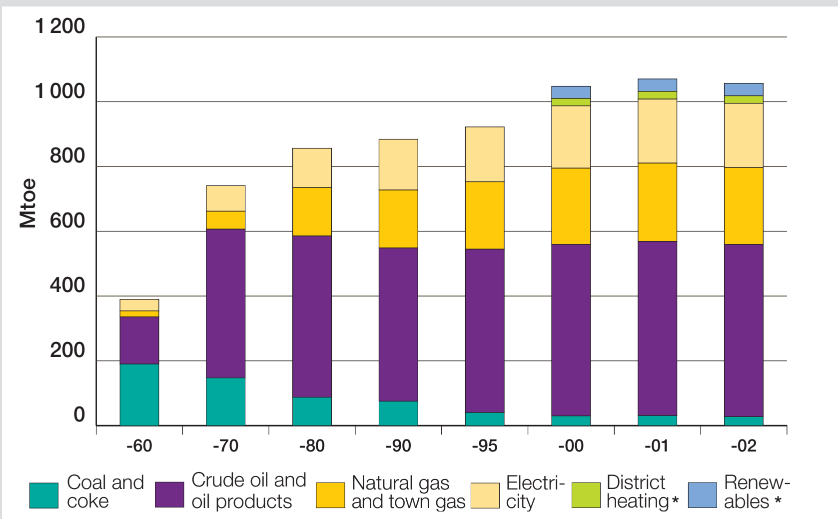
The use of district heating in EU-15 as a whole is relatively little, amounting to about 2.2% of final energy use. However, it is more widely used in the new member states: in Poland, for example, it provided about 12% of final use in 2001[67].

Energy supply in the EU-15

In 2002, the supply of primary energy in EU-15 amounted to 17 300 TWh (1489 Mtoe), in

FIGURE 36

Total final EU-15 energy use, by energy carriers, 1960–2002



* No data for renewables or district heating before 2000.

Source: IEA – Energy Balances of the OECD Countries 2001–2002, 2004 edition

63 IEA – World Energy Outlook 2002.

64 EU-15 consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Holland, Ireland, Italy, Luxembourg, Portugal, Spain, Sweden and the UK.

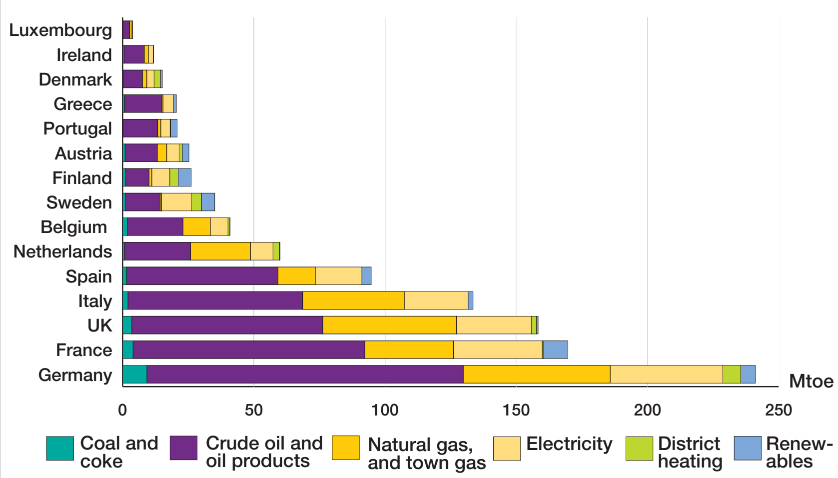
65 IEA Statistics – Energy balances of OECD countries 2001–2002, 2004 edition.

66 Green Paper – Towards a European strategy for a safe energy supply. COM (2000) 769, final.

67 IEA Statistics – Energy balances of non-OECD countries, 2000–2001, 2003 edition.

FIGURE 37

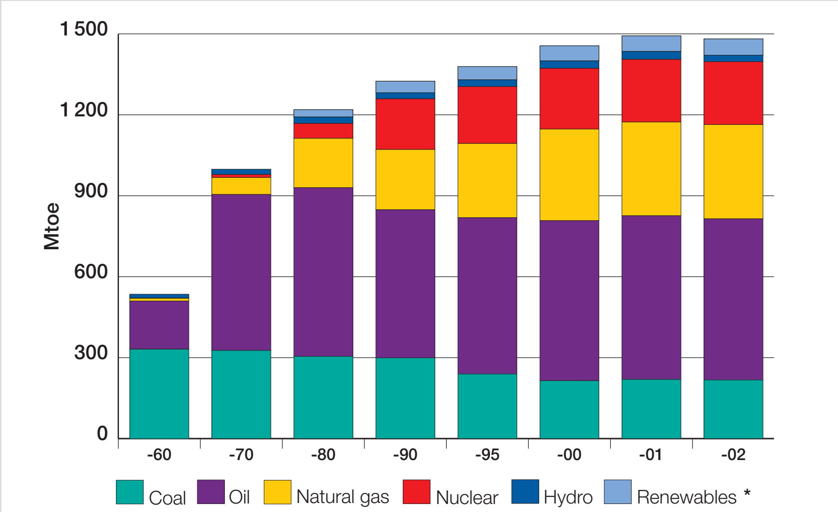
Total final energy use in the EU states, by energy carriers, 2002



Source: IEA statistics – energy balances of OECD countries 2001–2002, 2004 edition

FIGURE 38

Total supply of primary energy in the EU-15 states, by energy carriers, 1960–2002



*No data for renewables before 1980.

Source: IEA statistics – energy balances of OECD countries 2001–2002, 2004 edition

the form of 40% oil, 23% gas, 16% nuclear fuel, 15% coal, 2% hydro power and 4% renewable energy sources. Of this, about 3400 TWh were used for the production of electricity, 300 TWh for district heating and simultaneous production of heat and electricity in CHP plants.

From having dominated energy supply in 1960, when it accounted for more than 60% of energy supply, coal accounted for only 15% of energy supply in 2002. This relative reduction has also been accompanied by an absolute reduction of about 30% in the quantity of coal used.

Of the electricity produced in the EU, 34% came from nuclear power and 11% from hydro power. However, coal is still an important fuel for electricity production, supplying about 27% of electricity in EU-15 in 2002. Gas is also important for electricity production, supplying about 19% of the EU's electricity production, while renewable energy sources supplied somewhat less than 4%. However, in Finland, Denmark and Holland, 14%, 6% and 4% respectively of these countries' electricity were produced from biofuels in 2002. Since 1990, the proportion of renewable energy (excluding hydro power) in the EU's energy supply has increased by 17%. Fossil fuels account for over 60% of electricity production in Holland, Denmark, the UK and Germany.

Dependence on imports

The EU is the world's largest net importer of energy. Both EU-15 and EU-25[68] are strongly dependent on imports in order to meet their energy requirements. In 1980, EU-15 was almost 48% self-sufficient. By 1995 this had increased to almost 54%, but only to fall thereafter, to somewhat over 51% in 2002[69].

About 80% of the oil supplied to the EU-15 energy system in 2002 was imported, as was about 53% of its coal and 47% of its gas. Importation of oil is forecast to remain high. Although EU reserves of coal increased with expansion of the EU, reduced mining of coal is forecast, which will lead to greater dependence on imports. Importation of natural gas, too, is expected to increase. In its energy strategy Green Book from 2002, the EU forecasts that, within 20–30 years, it will have to import about 70% of its energy requirements unless measures can be taken to break the rising trend[70].

25 countries with different conditions

Since 1st May 2004, the EU has expanded to consist of 25 countries, relatively varying in terms of size, geographical and economic conditions. Germany, the UK, France and Italy together account for 71% of EU-15 GNP, while smaller countries such as Luxembourg, Portugal, Greece and Ireland have GNPs that are less than 10% of that of Germany. Poland, the largest of the new member states, has a GNP amounting to about 6% that of Germany. Climates also differ between the countries, and this has a considerable effect on energy requirements. Together, Germany, France, Italy and the UK account for about 66% of total energy use in EU-15, although this proportion changes somewhat when converted to per-capita use. Finland and Sweden have high per-capita energy uses, partly due to high proportions

68 EU-25 consists of EU-15 and the new member states of Cyprus, Estonia, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, the Czech Republic and Hungary.

69 IEA Statistics – Energy balances of non-OECD countries, 2001–2002, 2004 edition.

70 Green Paper – Towards a European strategy for a safe energy supply. COM (2000) 769, final.

of energy-intensive industries and partly due to cold climates and historically low energy prices. The Benelux countries[71] also have high per-capita energy demands, and particularly in Luxembourg.[72] On the other hand, per-capita energy use is lower in the Mediterranean countries of Greece, Italy, Portugal and Spain. The new member states have an energy use which is equivalent to about one-tenth of that in EU-15. In comparison with EU-15, coal plays a more important part in their final energy use, with oil and gas being less important.

World energy use

At the end of the 1990s, total world energy use (excluding renewables) increased at an average rate of 1.4% per annum, with the greatest growth occurring in Latin America, the Middle East and Asia, and also in Africa. Energy use in the former Soviet Union and in non-OECD[73] eastern European countries fell during the 1990s, but started to rise again in many of these countries during the first years of the new century. Within the EU, energy use has increased by slightly over 1% per annum on average during the 1990s. The USA and Japan increased their total energy use in 2002. EU energy use decreased in 2002.

World per-capita energy use varies considerably between countries and between regions. The EU-15, for example, uses 10-15 times more energy per capita than does Africa or Asia, and four times more than in Latin America. Per-capita energy use in North America is 20 times greater than in Africa.

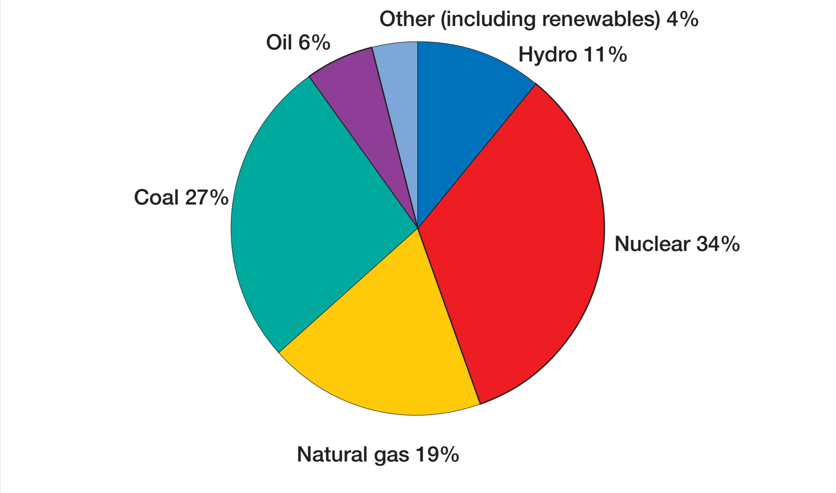
Table 9 shows the energy intensities (i.e. the amount of energy used per unit of GNP) for a number of groups of countries, in order to give an indication of the amount of energy used in proportion to economic production.

Asia and Africa use about twice as much energy per GNP dollar as does EU-15, while the former Soviet Union uses over ten times as much. These differences can be partly explained by the fact that these areas are at different stages of development. However, China, together with the European countries that are not OECD members, has shown a substantial reduction in its energy intensity during the 1990s. The North American and Western European countries have also improved their efficiency of energy use. Energy intensity in the world as a whole has fallen by almost 13% over the last decade.

After the break-up of the Soviet Union, the economies of the new republics are in a state of flux, with major problems in the energy sector, and this has been reflected by greater use of energy per unit of output during the 1990s. It is expected that, as energy prices in these countries are now more or less equal to world market prices, efficiency of energy use will improve. It is also expected that efficiency improvements will occur in China, Eastern Asia and Latin America.

FIGURE 39

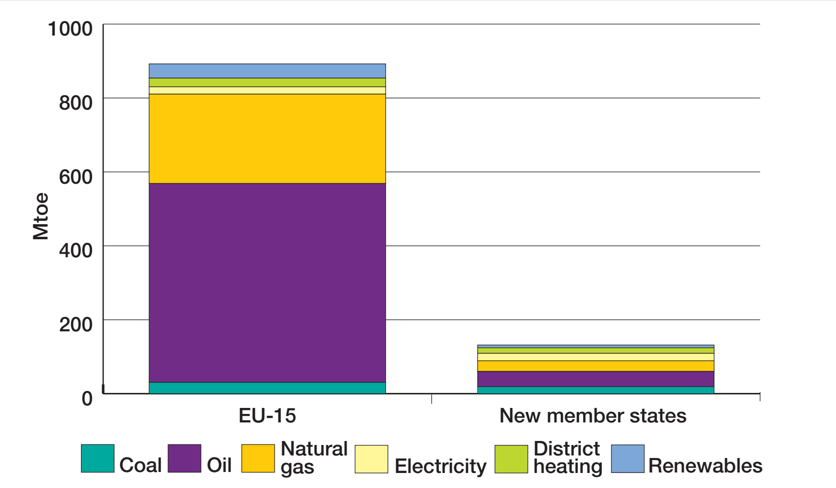
Electricity production in the EU-15 states, by primary energy source, 2002, 2 651 TWh



Source: IEA statistics – Energy balances of OECD countries 2001–2002, 2004 edition

FIGURE 40

Energy use in the EU-15 states and the new member states[1], by energy carriers, 2001



Anm. [1] The Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia

Source: IEA Statistics – Energy Balances of OECD Countries 2001–2002, 2004 edition, IEA Statistics – Energy Balances of non-OECD Countries 2000–2001, 2003 edition

World energy supply

World energy supply is dominated by fossil fuels, which account for about 80% of the total. Oil is the most important energy source, meeting 35% of demand, followed by coal at 23%

[71] Benelux: Belgium, Netherlands and Luxembourg.

[72] Luxembourg's high per-capita energy use is due partly to energy intensive industries and partly to low motor fuel prices, which result in substantial cross-border trade.

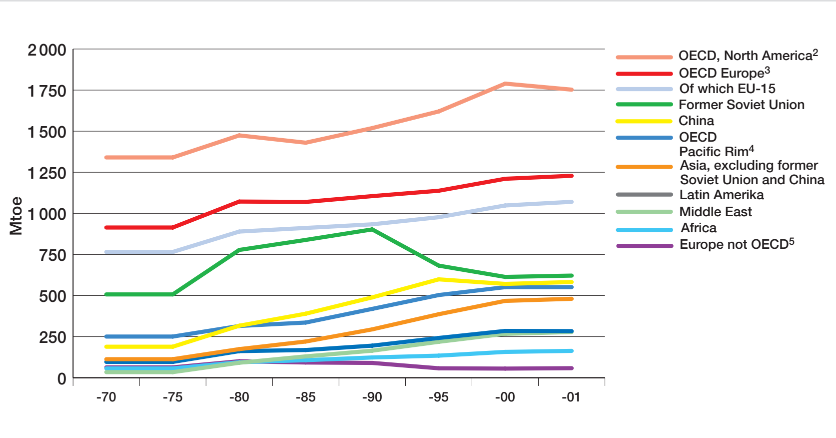
[73] OECD-members are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxemburg, Mexico, Holland, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, the UK and the USA.

and natural gas at 21%. Of the fossil fuels, it is the use of natural gas that has increased the most since the 1980s. The use of coal increased until 1990, but has since remained relatively stable. In 2001, hydro power account met about 2% of world energy needs, while nuclear power met 7%. Since 1990, supply of renewable energy[74] has remained on a stable level, contributing about 11% to world energy supply[75].

World electricity production is based primarily on coal, followed by gas, nuclear power and hydro power.

FIGURE 41

Total world final energy use[1], by regions, 1971–2001

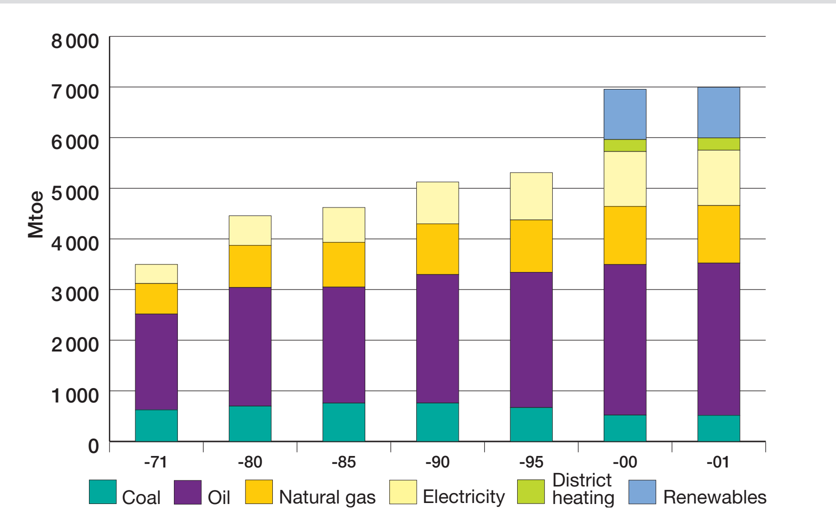


Note:[1] Energy use excludes renewable energy and energy from refuse. [2] USA, Canada and Mexico. [3] EU-15 plus Hungary, Czech Republic, Poland and Slovakia. [4] Australia, Japan, Korea and New Zealand. [5] Albania, Bulgaria, Cyprus, Gibraltar, Malta, Romania and former Yugoslavia.

Source: IEA Statistics - Energy Balances of non-OECD Countries 2000–2001, 2003 edition, IEA Statistics – Energy Balances of OECD Countries 2001–2002, 2004 edition.

FIGURE 42

Final world energy use, by energy carriers[1], 1971–2002



Note:[1] No data for renewables before 2000.

Source: IEA Statistics – Energy Balances of non-OECD Countries 2000–2001, 2003 edition

Resources and reserves

Reserves of fossil fuels – primarily oil, coal and natural gas – are estimates of the quantities that can be viably extracted under present economic and technical conditions. At the end of 2003, they amounted to:

- 192 years' production of coal
- 41 years' production of oil
- 67 years' production of natural gas.

The proven reserves consist of the known, discovered and developed fractions of the earth's total resources. They can be 'increased' by prospecting, or by rising prices making new and more expensive methods of recovery viable[76].

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 – primarily of oil – to the industrialised countries. The oil market is dominated by OPEC which, together with Russia, also dominates the gas market. EU-15 increased its oil production by over 1% in 2002, after a few years' decline, but it is expected that both oil and gas production in EU-15 will fall within a few years. (See also Chapter 5, Energy Markets.)

The greatest proportion of the world's energy production in 2001 came from North America[77] (23%), followed by Asia (21%), the Middle East (13%), the former Soviet Union (13%) and Western Europe (12%). As far as international trade is concerned, the Middle East, Africa, Latin America and the former Soviet Union are net exporters. Asia is the region in which energy imports are rising the most rapidly, and is expected soon to be second only to the EU in terms of imports[78].

Forecasts of world energy use and supply until 2020

According to a forecast from the International Energy Agency[79] in 2002, world energy demand is expected to continue to rise steadily, at about 1.7% per annum until 2030, which can be compared with an annual growth rate of 2.2% between 1971 and 1997. Much of this increase is expected to occur in the developing countries, as a result of economic growth and population increase, and will account for more than 60% of the increased demand. The proportion of energy use taken by the developing countries is expected to increase from 30% to

[74] Renewable energy is defined as hydro power, geothermal energy, solar energy, tide power, wind power, renewable domestic refuse, biofuels and biogas. The statistics of renewable energy are of doubtful quality and comparability, and should therefore be used with care.

[75] IEA statistics – Energy balances of non-OECD countries, 2000–2001, 2003 edition.

[76] BP Statistical Review of Word Energy, June 2004.

[77] The three major countries of North America; the USA, Canada and Mexico.

43%, with that taken by the OECD states falling from 58% to 47%. The remaining 10% of the world's energy use will be accounted for by the transition economies in the East, with this proportion declining somewhat.

The transport sector is that in which energy demand is increasing the most. By 2020, it is expected that this sector will have overtaken the industry sector as the largest user of energy.

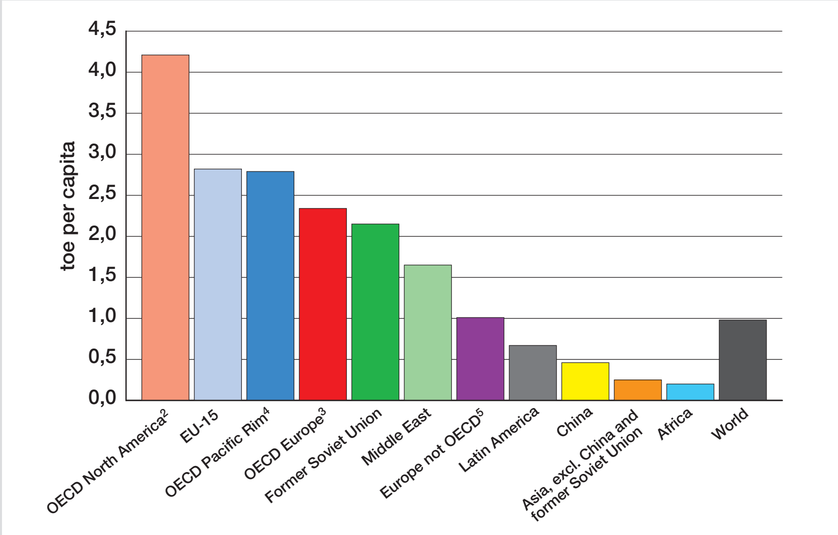
According to the forecasts, fossil fuels will continue to be the main source of energy, supplying more than 90% of the increase in demand. The demand for oil is expected to increase, with that for natural gas increasing at an even higher rate. The demand for coal, too, will increase, although not at the same rate. The part played by nuclear power is expected to decrease, partly as a result of fewer new reactors, and partly as a result of closure of existing reactors. The greatest increase in nuclear power generation is expected to occur in Asia, and the greatest decrease in Europe and North America.

According to the IEA, renewable energy will become increasingly important in world energy supply. As far as the production of electricity from renewable sources is concerned, hydro power is expected to continue to be the predominant source, although the rate of increase in the construction of new plants will be lower than that of expansion of other forms of renewable energy sources. The use of renewable energy sources other than hydro power is expected to increase by 3.3% per annum, which is more than any other primary energy source. The greatest growth will occur in the OECD states, although renewable energy will continue to provide only a small proportion of total energy supply.

World energy resources are regarded as sufficient to meet the expected increase in demand. Oil resources are sufficient, although more reserves need to be found. Reserves of natural gas and coal are particularly generous, and there is no shortage of uranium for nuclear power production. Much of the demand for oil and gas is expected to be met by production increases in the Middle East and the former Soviet Union. However, climate problems will bring new pressures to bear on the choice of energy sources that can be used for sustainable development. The physical potential for renewable energy is substantial.

FIGURE 43

Per-capita energy use, by regions, 2001[1]



Note: [1] Energy use excludes renewable energy and energy from refuse. [2, 3, 4, 5] ser figure 41.

Source: IEA Statistics – Energy Balances of non-OECD Countries 2000–2001, 2003 edition, IEA Statistics – Energy Balances of OECD Countries 2001–2002, 2004 edition.

TABLE 9

Energy intensity[1] by regions, toe/million USD

Region	1980	1990	1995	2000	2001	1990/2000	2000/2001
World	229	201	191	175	174	-13%	-0.5%
OECD, North America[2]	286	213	203	185	180	-13%	-2.4%
OECD, Europe[3]	159	126	120	112	112	-11%	0.2%
– of which EU-15	142	117	113	106	107	-9%	0.3%
OECD, Pacific Rim[4]	85	74	81	81	81	9%	-0.1%
Europe, not OECD[5]	694	613	486	419	420	-32%	0.3%
China	1 436	968	713	476	454	-51%	-4.6%
Former Soviet Union	936	1 156	1 472	1 235	1 179	7%	-4.5%
Asia, excl. former Soviet Union and China	299	283	273	271	272	-5%	0.6%
Africa	233	260	269	265	267	2%	0.8%
Middle East	140	358	459	459	473	28%	3.0%
Latin America	154	182	170	178	177	-2%	-0.9%

[1] Excluding renewable fuels and refuse. [2, 3, 4, 5.] see figure 41.

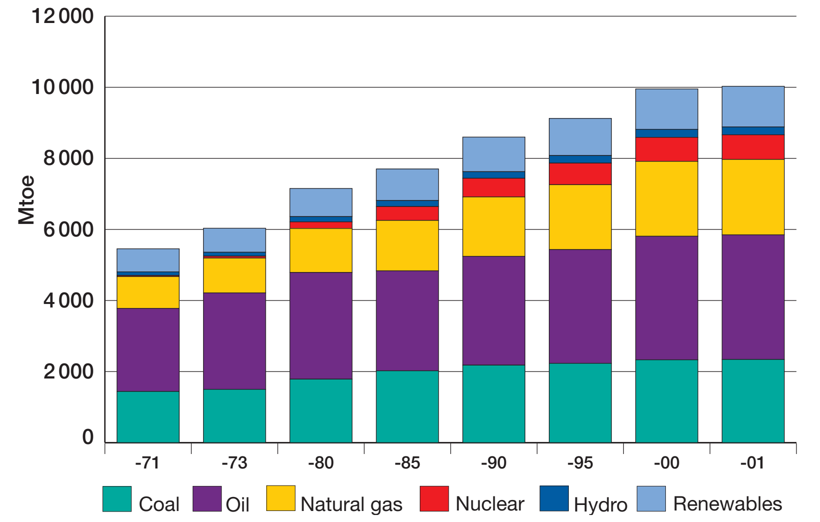
Source: IEA Statistics – Energy Balances of non-OECD Countries 2000–2001, 2003 edition, IEA Statistics – Energy Balances of OECD Countries 2001–2002, 2004 edition.

New energy sources and advanced technology are expected to be developed during the period, e.g. unconventional oil sources and fuel cells. It is expected that world trade in energy (which consists almost exclusively of fossil fuels) is expected to increase dramatically. ■

[78] IEA statistics – Energy balances of non-OECD countries, 2000–2001, 2003 edition.
[79] IEA – World Energy Outlook 2002.

FIGURE 44

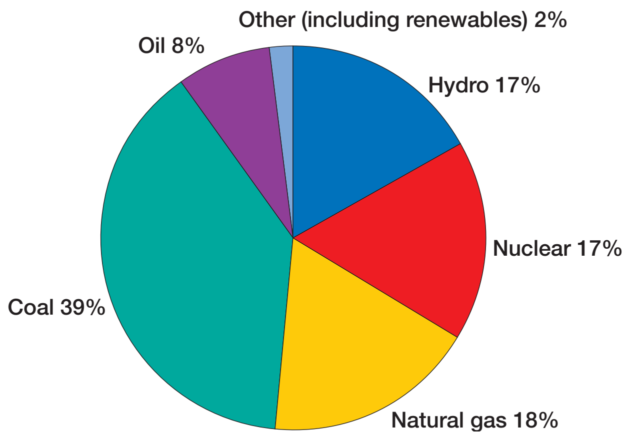
Total supply of primary energy, world, by energy carriers, 1971–2001



Source: IEA Statistics – Energy Balances of non-OECD Countries 2000–2001, 2003 edition

FIGURE 45

World electricity production, by primary energy source, 2001, 15 476 TWh



Source: IEA Statistics – Energy Balances of non-OECD Countries 2000–2001, 2003 edition

The environmental situation

Almost all abstraction/recovery, conversion and use of energy gives rise to some form of environmental impact. The most significant environmental effects are those related to emissions from combustion of fuels. They include increasing the concentration of greenhouse gases in the atmosphere, precipitation of acidifying substances and emissions of health-hazardous or environmentally harmful compounds in flue gases and vehicle exhaust gases. Even less environmentally harmful energy processes, such as hydro or wind power generation, do have an environmental impact in the form of their effects on nature and the landscape. Although much has been done to reduce the impact of energy systems on the environment, much still remains to be done.

Environmental impact occurs at local, regional and global levels. The boundaries between these levels are fluid, determined not only by the type of impact (e.g. emissions), but also by how far it spreads. There are several working areas at regional and global levels where countries are working together to attempt to tackle environmental problems.

Local and regional environmental problems

Local environmental problems are regarded as being those that are restricted to the most immediate environment. They include emissions of pollutants to air or water, examples of which are those resulting from various forms of combustion, such as particulates, volatile organic compounds and ground-level ozone. Problems of this type generally have an immediate effect on their surroundings and are easy to detect, so steps to deal with them can generally be taken at an early stage.

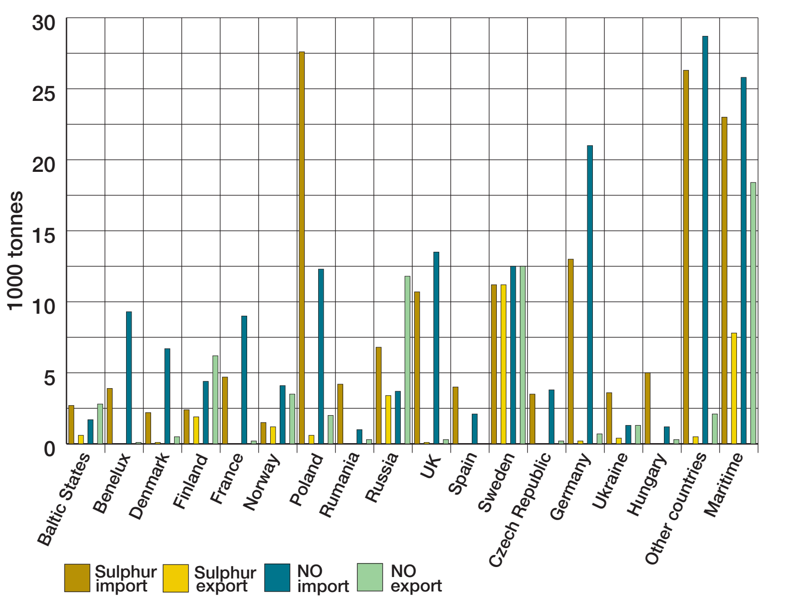
Environmental problems are regarded as being regional if they afflict large areas, countries or, in some cases, continents. They include acidification and eutrophication. Problems of these types are akin to the fatigue of metals, as the damage that they cause becomes apparent only after a longer time. They are generally more difficult to deal with than local environmental problems. They often have many different sources, and spread over large areas.

Acidification

At the beginning of the 1970s, acidification was one of the environmental problems in Scandinavia to which the most attention was paid. As the ability of the ground and water to neutralise acidity is less in these countries than in most other parts of Europe, it was in the Scandinavian countries that the problem was first noticed, with the result that it was long regarded as an essentially Scandinavian problem. One of the effects of acidification is the precipitation of metals such as aluminium in the ground and water, making it available for uptake by plants and aquatic organisms. This adversely affects the growth of forests and leads to damage to many sensitive species of plants and animals, both on land and in the water.

FIGURE 46

Swedish import and export of sulphur and NO_x (as NO_2), 2000

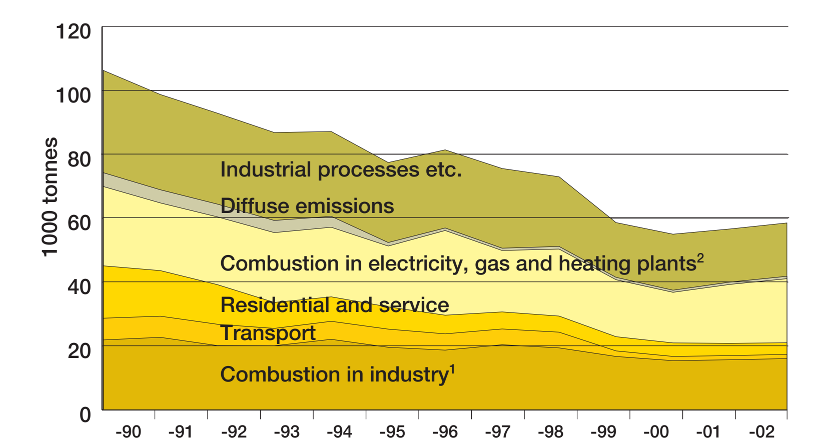


Source: Environment Protection Agency – Basic data from Trans-boundary acidification and eutrophication and ground-level ozone in Europe, EMEP Status Report 1/2003

The main source of acidification is the emission of sulphur in the form of sulphur dioxide, with ammonia and oxides of nitrogen (NO_x) also contributing to the effect. The sulphur dioxide is oxidised in the atmosphere to sulphuric acid, which is then brought down to the surface of the earth in precipitation, and thus referred to as 'wet deposition'. Sulphur emissions can also be deposited directly in the form of sulphur dioxide, known as 'dry deposition'. As the conversion process of sulphur dioxide in the atmosphere for wet deposition takes a few days – sometimes up to a week – it means that precipitation over Sweden originates primarily from sources in other countries. In 2002, Swedish emissions of sulphur dioxide amounted to about 59 000 tonnes in total. Sweden's 'import' of sulphur on wind streams from other countries is therefore very much greater than the contribution from indigenous sources. On the other hand, we 'export' about 60% of our own emissions to other countries: only about 11 000 tonnes fell back to Swedish soil in 2000. The export and import quantities shown in Figure 46 are expressed as quantities of pure sulphur: each tonne of sulphur produces about two tonnes of sulphur dioxide.

FIGURE 47

Sulphur dioxide (SO_2) emissions in Sweden, 1990–2002

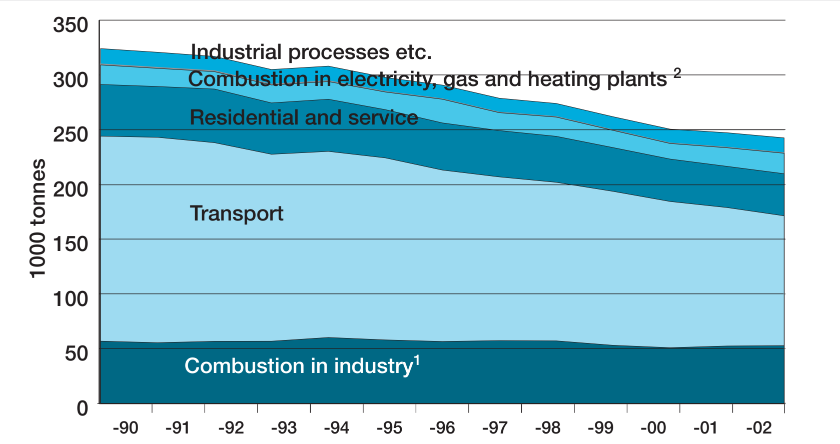


Note: [1] Including industrial back-pressure generation. [2] Including coking plants and refineries.

Source: Sweden's status report to the UN Climate Convention, Environment Protection Agency, 2004

FIGURE 48

NO_x emissions (as NO_2) in Sweden, 1990–2002



Note: [1] Including industrial back-pressure generation. [2] Including coking plants and refineries.

Source: Sweden's status report to the UN Climate Convention, Environment Protection Agency, 2004

Reduced sulphur emissions

Emissions in both Sweden and the rest of Europe have fallen considerably since 1980, partly as a result of reduced use of oil and partly because of lower sulphur contents in the oil. Sweden has fulfilled ambitious targets of, for example, reducing its sulphur emissions in 2000 by 80% relative to those of 1980.

Some of the most important factors in international work on reducing sulphur emissions have been the Convention on Long-Range Transboundary Air Pollution (CLRTAP), EU acidification strategy and various directives and political and structural changes in Europe. A number of protocols have been developed as part of the work of the Convention, including the Oslo Protocol and the Gothenburg Protocol. The objective of the latter is to reduce the problems of acidification, eutrophication and low-level ozone. In addition, the EU's National Emission Ceiling Directives, which must be met by 2010, sets emission limits for sulphur dioxide, NO_x, VOCs and ammonia for each individual member state.

Eutrophication

The main reason for eutrophication is an excess of nitrogen. Much precipitation of nitrogen compounds falls on land, but if plants cannot utilise it all, the surplus is leached off into waterways where it contributes to excessive aquatic plant growth, algae blooms and oxygen-free sea or lake bottoms. Most of the nitrogen run-off comes from the use of artificial fertilisers in agriculture, but the energy sector is the origin of most of the excess nitrogen in precipitation.

Reduction in NO_x emissions

By far the greatest proportion of NO_x emissions comes from road traffic. Although emissions of nitrogen have not been reduced as much as emissions of sulphur dioxide, they are being reduced, mainly due to the introduction of catalytic exhaust cleaning on petrol-driven vehicles. Emission requirements for both petrol and diesel cars and for heavy vehicles were progressively tightened up during the 1990s. Emissions of NO_x have been reduced by 25%, to 243 000 tonnes/year, between 1990 and 2002, despite a rise in transport work. Under the 'Zero Eutrophication' banner, there is a sub-objective of reducing airborne emissions of NOx in Sweden further to 148 000 tonne/-year by not later than 2010.

The largest contributors to NOx precipitation in Sweden from other countries are Germany, the UK and Poland. Solving eutrophication problems requires international cooperation, and it is here that the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and various EU directives have an important part to play. Emissions of NO_x are treated in the same way as those of sulphur dioxide in the Convention, in the Oslo Protocol and the Gothenburg Protocol (the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone) and elsewhere. The EU Directive on National Emission Ceilings has also set emission ceilings for NO_x and ammonia by 2010. are treated in the same way as those of sulphur dioxide in the Convention, in the Oslo Protocol and the Gothenburg Protocol (the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone) and elsewhere. The EU Directive on National Emission Ceilings has also set emission ceilings for NO_x and ammonia by 2010.

Global environmental problems

"The solution to pollution is dissolution" was still regarded as a truth at the beginning of the 1960s. It was thought that the oceans and the atmosphere could absorb and dilute all our emissions to levels so low that they would not be noticed. Nowadays, we know that some of the emissions that we generate result in global environmental problems, which is most clearly exemplified by the increase in the greenhouse effect and by depletion of the ozone layer. The extent of global environmental problems is such that they afflict the entire globe. They are therefore difficult to tackle, as they require international cooperation.

Depletion of the ozone layer

The ozone layer, in the stratosphere, protects life on earth from the sun's damaging ultraviolet radiation. In the middle of the 1970s, it was discovered that the ozone layer was being depleted, as chlorine and bromine atoms reacted with the ozone. Their source was chemicals released by industrial and energy processes. In the energy sector, ozone-depleting substances are used for applications such as air conditioning and heat pumps, and in end-user applications such as refrigerators and freezers. Today, ozone-depleting refrigerants have been largely replaced by less harmful, chlorine-free refrigerants, or in many cases by natural refrigerants such as hydrocarbons (propane and butane), or ammonia. However, the rate of replacement of the earlier refrigerants by these less harmful refrigerants varies from one part of the world to another.

Tackling depletion of the ozone layer is the first global environmental problem that has been successfully reduced by strong measures at international level. The use of ozone-destructive chemicals has been regulated by a number of international agreements (the Vienna Agreement and the Montreal Protocol). Production is declining, and it is expected that the ozone layer will be back to normal by about the middle of the century.

The greenhouse effect

Strictly, the greenhouse effect is not an environmental problem: it is, in fact, an essential factor for the existence for life on earth. Without carbon dioxide and water vapour in the atmosphere, the average temperature of the earth would be about 33°C lower than it is today (i.e. about –18°C), and the planet would be frozen. It is, however, the increase in the greenhouse effect, resulting from the emission of greenhouse gases, that is an environmental problem. Over the last 150 years, anthropogenic activities have increased the concentration of carbon dioxide in the atmosphere by about 30%: if the oceans were not also a major sink for carbon dioxide, this increase would have been closer to 60%. The average temperature of the earth has risen by about 0.5°C during the 20th century, but has accelerated particularly during the last 25 years.

The most important anthropogenic greenhouse gas is carbon dioxide. Other gases that contribute to the effect include methane, nitrous oxide (laughing gas – N2O), ground-level ozone, HFCs (refrigerants), PFCs (from industrial processes) and sulphur hexafluoride (an electrical insulator). Per molecule or per kilogram, these gases actually have a more powerful greenhouse effect but, due to their low concentrations in the atmosphere, they represent less of a problem than does carbon dioxide. The following text therefore concentrates primarily on carbon dioxide emissions.

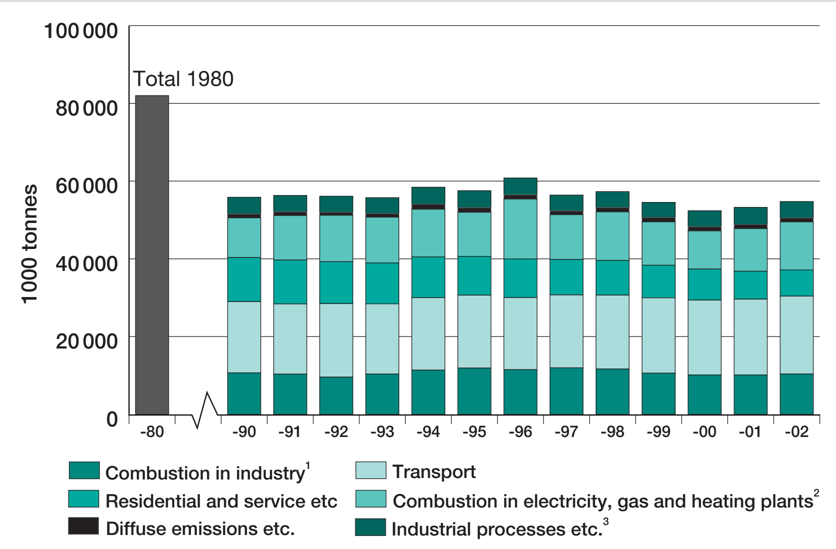
The OECD countries emit over half of the total global carbon dioxide emissions, with the USA being responsible in turn for by far the greatest amount, of over 45%. Other countries with high emissions include Japan, the UK and Germany. In terms of highest per-capita emissions, the USA is in top place, followed by Luxemburg, Australia and Canada. These countries also have high emissions in relation to their GNPs, although the old Eastern Bloc countries such as Poland and the Czech Republic have even higher levels. (See Figure 50.)

Sweden contributes a few parts per thousand to the world's carbon dioxide emissions, with per-capita and GNP-proportionate emissions being below the average both for the OECD countries and for the EU. Carbon dioxide emissions in 2000 were less than in 1990. The reason for the low emission level is that much of its electrical energy system is based on nuclear power and hydro power, which have no net emissions of carbon dioxide.

According to the IEA reference scenario , carbon dioxide emissions will continue to increase steadily, at a rate of somewhat over 1.8% per annum until 2030. Of this, about two-thirds will come from the developing countries. By 2030, emissions are expected to have increased to about 38x109 tonnes, which is 70% more than today. Electricity production and transport are expected to contribute to more than three-quarters of the increase in emissions. Geographically, it is expected that the proportion of global CO_2 emissions from the developing countries will have increased from 34% to 47%, while that of the OECD states will have declined from 55% to 43%. China is expected to account for a quarter of the increase in emissions. The IEA points out in its forecast that the OECD states will have difficulty in fulfilling their Kyoto commitments, particularly if it is assumed that the USA does not intend to ratify the Kyoto Protocol.

FIGURE 49

Carbon dioxide (CO_2) emissions in Sweden 1980, 1990–2002

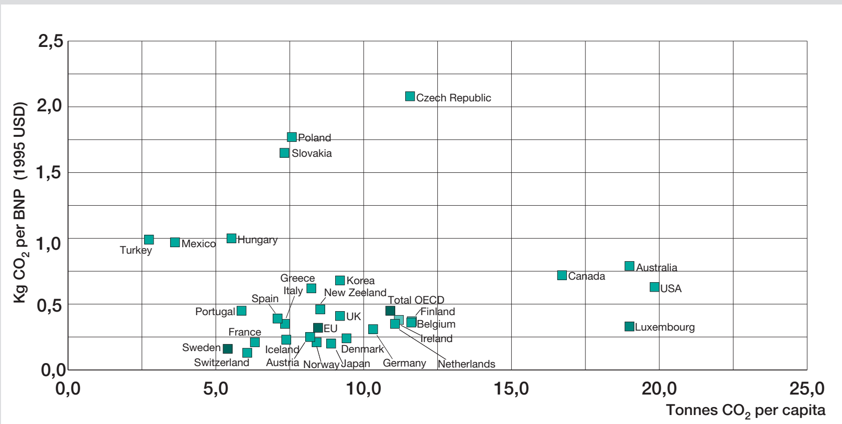


Note: [1] Including industrial back-pressure generation. [2] Including coking plants and refineries. [3] Including solvents and use of products

Source: 1980: Statistics Sweden 1990–2002: Sweden's status report to the UN Climate Convention, Environment Protection Agency, 2004

FIGURE 50

Carbon dioxide emissions in 2001 from combustion, per-capita and in relation to GNP, in the EU states and the OECD countries



Source: OECD in Figures, 2003 edition

International climate cooperation

An outline convention on climate changes was signed at the 1992 UN Conference on the Environment and Development (UNCED) in Rio. It came into force in 1994, when it had been ratified by a sufficiently large number of countries. Sweden ratified the Convention in 1993, at which time it also adopted guidelines for Swedish climate policy. One of the contents of the Convention is that all industrial countries should take steps to reduce their emissions of greenhouse gases and to increase the uptake and storage of the gases. The countries should also regularly report details of their progress and the steps that they have taken to the UN.

At the meeting of the parties in Berlin in 1995, it was noted that work to date was inadequate, and a process was started to produce a legally binding document. At the third meeting of the parties in Kyoto in 1997, agreement was reached on a document regulating emissions of carbon dioxide and five other greenhouse gases. The document sets out reductions for all Annex 1 countries, i.e. the OECD states and the previous Eastern European states, for the period 2008–2012. The reductions are expressed in relation to the 1990 emission levels. The EU, which negotiates as a single group, is required to reduce its emissions by 8%. The EU states have reached agreement on the internal apportioning of this aggregate reduction, based on factors such as per-capita emissions and the structure of energy and industry sectors, and this agreement will become legally binding when the Protocol has been ratified by the necessary number of signatories and therefore come into force. Sweden has in fact been permitted actually to increase its emissions by 4%, but has unilaterally adopted a more ambitious target, of reducing its emissions by 4%.

The Marrakech Accords

Since the third meeting of the parties in Kyoto in 1997, negotiations on the final form and interpretation of the Kyoto Protocol have continued. The points on which agreement was sought at the negotiations in Den Haag, Bonn and Marrakech related primarily to the conditions and rules for flexible mechanisms (see below), carbon dioxide absorption in forests and the ground (carbon sinks), assistance to developing countries and means of cooperation between industrialised countries and developing countries, and the drafting of sanctions and other responses against countries failing to fulfil their obligations.

However, agreement was reached between the remaining states at the Marrakech meeting in the autumn of 2001, converting the Kyoto Protocol to a legally binding text, known as the Marrakech Accords.

’Flexible mechanisms’, in the form of Emission Trading, Joint Implementation and Clean Development Mechanisms, are included in the Marrakech Accords in order to facilitate more cost-efficient reductions. (See the panel in Chapter 1, ’Current energy and climate policy areas’ for further details.)

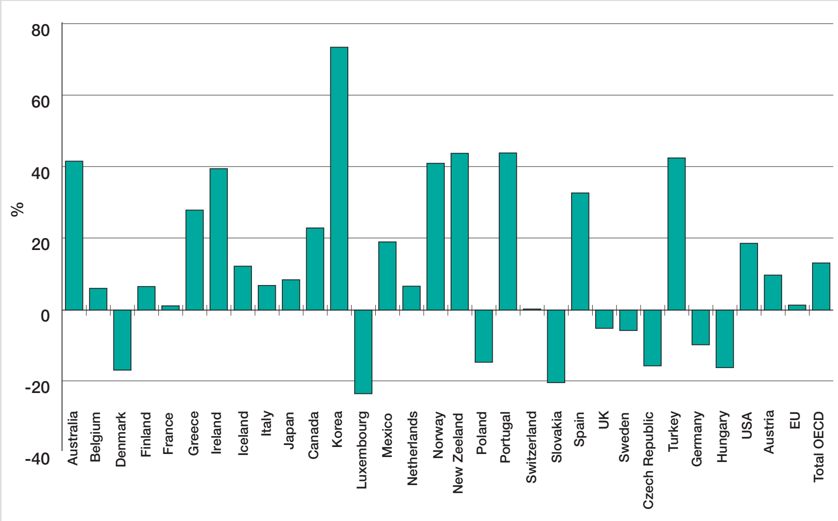
A major blow occurred to the process of international climate cooperation when the USA withdrew from the negotiations in 2001 and announced that it did not intend to ratify the Protocol. A requirement for the Protocol to come into force is that it must be ratified by at least 55 countries. A further condition is that carbon dioxide emissions from the Annex 1 states that have ratified the Protocol must be less than 55% of 1990 emissions from all Annex 1 states. As the USA has now withdrawn, the Protocol must be ratified by the EU, Japan and Russia in order to come into force. The EU states jointly submitted their ratification documents in May 2002, and Japan has also ratified the Protocol. At the end of September 2004, the Russian government announced that it would ask the Duma to confirm ratification of the Protocol. The protocol has now been ratified by both the Duma and the Russian President, which means that it can win legal force in the spring of 2005.

The tenth meeting of the parties will be held in Buenos Aires in December 2004. With the expectation that the Protocol will come into force, the meeting will be concerned primarily with technical and other matters of detail that are important for implementation of the Protocol. Even if coming into force of the Protocol is delayed for any reason, the EU is hoping that emission rights trading will become an important international means of influencing climate protection measures.

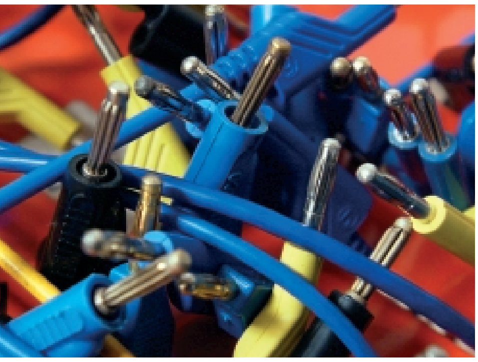
■

FIGURE 51

Changes in carbon dioxide emissions in the EU and OECD countries between 1991 and 2001



Source: OECD in Figures, 2003 edition



Energy facts

This chapter explains some energy terms that are used in Energy in Sweden. Units and conversion factors are described: the conversion factors have been used by Statistics Sweden (SCB) and the Swedish Energy Agency to convert physical quantities to energy quantities. Relationships between various energy units are also given, in order to make it possible to compare statistics with other international statistics.

Information on statistics and conversion factors

Statistics in the 2001 edition of Energy in Sweden and Energy in Sweden in Figures were revised relative to those given in earlier editions. The changes related primarily to the years 1983–1999, but entire time series in some tables were updated. Conversion factors are shown when changes in fuel energy contents have occurred. During the latest such revision, for statistics from and including 2001, the specific energy contents of petroleum coke, petrol, diesel fuel, gas oil, all grades of heavier fuel oils and natural gas were changed. Note that these conversion factors are averages for various fuels, and that there are differences between qualities, not least for various wood fuels and coal.

The international standard unit for energy is the joule (J). However, this is a small unit (1 J = 1 watt-second), and so for convenience the watt-hour (Wh) or kilowatt-hour are generally used. International comparisons and statistics often use the unit of toe (tonne of oil equivalent). In some applications, calories (cal) are still used.

All these units are impractically small for dealing with large energy quantities in national contexts. Instead, larger units are used through the additions of prefixes, such as petajoule (PJ) or terawatt-hour (TWh). ■

TABLE 10

Conversion factors for effective calorific values, as used by Statistics Sweden and the Swedish Energy Agency.[1]

Fuel	Physical quantity	MWh	GJ
Wood chips	1 tonne	2.0–4.0	7.2–14.4
Peat	1 tonne	2.5-3	9–11
Pellets, briquettes	1 tonne	4.5-5	16–18
Coal	1 tonne	7.56	27.2
Coke	1 tonne	7.79	28.1
Nuclear fuel	1 tonne	11.6	41.9
Crude oil	1 m^3	10.1	36.3
Topped crude oil	1 m^3	11.1	40.1
Petroleum coke[2]	1 tonne	9.70	34.9
Asphalt. road dressing oils	1 tonne	11.6	41.9
Lubricating oils	1 tonne	11.5	41.4
Road fuel petrol[3]	1 m^3	9.04	32.6
Virgin naphtha	1 m^3	8.74	31.5
Light virgin naphtha	1 m^3	7.91	28.4
Aviation petrol	1 m^3	8.51	30.6
Other light oils	1 m^3	8.74	31.5
Petroleum naphtha	1 m^3	9.34	33.6
Aviation paraffin	1 m^3	9.58	34.5
Other paraffin and intermediate oils	1 m^3	9.54	34.3
Diesel fuel[4] and gas oil	1 m^3	9.96	35.9
Heavy fuel oils[5] and bunker oil	1 m^3	10.6	38.1
Propane and butane	1 tonne	12.8	46.1
Town gas, coking oven gas	1000 m^3	4.65	16.7
Natural gas[6]	1000 m^3	9.99	36.0
Blast furnace gas	1000 m^3	0.930	3.35

Notes:[1] The table shows three values of conversion factors. Further values have been used in the calculations.
The following values were used prior to 2001:
[2] 9.67 for conversion to MWh and 34.8 for conversion to GJ. [3] 8.72 for MWh and. 31.4 for GJ. [4] 9.89 for MWh and 35.6 for GJ. [5] 10.8 for MWh and 38.9 for GJ. [6] 9.72 for MWh and 35.0 for GJ.
The value for natural gas is the net (lower) calorific value. The gross (upper) calorific value for conversion to MWh is 11.1 from and including 2001: prior to 2001. it was 10.8.

TABLE 11

Conversion between energy units as used in Energy in Sweden

	GJ	MWh	toe	Mcal
GJ	1	0.28	0.02	239
MWh	3.6	1	0.086	860
toe	41.9	11.63	1	10000
Mcal	0.0419	0.00116	0.0001	1

TABLE 12

Prefixes used with energy units in Energy in Sweden

PREFIX		FAKTOR	
k	Kilo	10^3	thousand
M	Mega	10^6	million
G	Giga	10^9	billion
T	Tera	10^{12}	trillion
P	Peta	10^{15}	thousand trillion

A little energy reference book

Ash

Ash is the unburnable residue from a fuel. Combustion oxidises the carbon and hydrogen in the fuel to carbon dioxide and water respectively, leaving the minerals behind as ash. Solid fuels contain more ash than do liquid fuels, while gases leave no ash at all. Heavy oil products, which contain more ash than light oil products, can contain up to about 1% of ash. Common ash contents of hard coal are 5–15%. Peat contains 1–15% ash, while logs contains 1–5%. Light ashes tend to be carried away in the flue gases as dust (fly ash). Dust separators can trap over 99% of fly ash for disposal. As greater quantities of fuel are taken from forests, it is important to return the minerals that they contain, and so research into how the ash can be safely and effectively returned to the forest is in progress.

About 10 % of the ash constituents melt during combustion, forming slag at the bottom of the combustion chamber (bottom ash or molten ash). Combustion of coal and refuse produce the greatest quantities of bottom ash and slag. Ash may be disposed of in landfill, or be used in building materials or as bulk filling material. Before disposing of it in landfill, the risks of leaching or enrichment of heavy metals must be dealt with.

Calorific value

The calorific value of a fuel is the amount of heat released per unit quantity of the fuel when completely burnt, expressed in the SI units of J/kg or J/m^3. We distinguish between the gross or upper calorific value and the net or lower calorific value. The former measures all the heat released by burning the fuel, while the latter does not include the heat needed to evaporate the water either formed in the combustion process itself through combustion of the hydrogen in the fuel, or accompanying the fuel (i.e. as inherent dampness). Until the beginning of the 1980s, it was felt in Sweden that only the lower calorific value was relevant for practical purposes. However, with the development of condensing boilers, which utilise the latent heat of condensation of the water (e.g. by condensing the flue gases in a heating plant), the upper calorific value has also become of interest.

Coal

Coal is an umbrella name for brown coal, hard coal and anthracite. It is the world's most abundant fossil energy resource, although also that which produces the greatest carbon dioxide emissions. Both physically and chemically, it is a complex and heterogeneous substance, with considerable differences in quality and properties from one deposit to another. For trading purposes, coal is divided into essentially the following energy content groups:

- Brown coal, with a calorific value of 10–28 MJ/kg
- Hard coal, with a calorific value of 28–36 MJ/kg
- Anthracite, with a calorific value of about 34 MJ/kg.

Brown coal is normally utilised at the place of extraction, while the higher energy content of hard coal makes it worth while to transport or export it. It is divided into special grades depending on application, such as flame coal, steam coal, coking coal or forging coal.

Efficiency, coefficient of performance

Efficiency can be defined as useful energy output, divided by the energy input needed to provide it. However, for heat pumps and refrigerators we use instead what is known as the coefficient of performance. For heat pumps, this is defined as the amount of heat delivered, divided by the input drive energy. For refrigerating machinery, it is defined as the amount of heat absorbed (i.e. the amount of cold produced), divided by the input drive energy. Efficiency can never exceed 100%, but the coefficient of performance should exceed unity (1) for most types of heat pumps / refrigerating machinery. The efficiency of a nuclear power station is about 30%, while that of a cold condensing power station fuelled by fossil fuel is about 40%, and that of a CHP power station is about 70–80%. A combined cycle power station (producing only electricity, and not district heating) has an efficiency of about 60%. Typical coefficients of performance of compressor-driven heat pumps are about 3–5 (i.e. 300%–500%), while those of compressor-driven refrigerating machines are about 2–4 (i.e. 200%–400%). A thermally powered absorption heat pump typically has a coefficient of performance of about 1–2.

Efficiency improvement

All energy use processes (e.g. lighting, electric motor drive, petrol motor drive etc.) involve some loss, i.e. not all of the energy supplied is turned into the desired form.

In the case of lighting (for example), some of the electrical energy ends up as heat, rather than light. If we can improve the process, we can get more light and less heat for the same amount of energy: i.e. we have improved the efficiency. Progressive improvements in the case of lighting are from incandescent bulbs (hot wire filaments), to fluorescent tubes, to high-frequency fluorescent lamps. The next stage is still under development: to white light-emitting diodes.

Electricity certificate system

The electricity certificate system is a market-based support system to assist the growth of renewable electric power production (electricity from solar energy, wind power, hydro power and biofuels) in Sweden. The target is to increase the amount of such power by an additional 10 TWh/year by 2010. All producers of such renewable power receive one certificate unit per MWh of electricity. These certificates can then be sold, as the system requires all electricity users (with a few exceptions) to buy a certain number of certificates, determined by their quota obligation. By raising this quota each year (i.e. by requiring users to buy a greater proportion of electricity from renewable sources), demand for such electricity will be increased, thus stimulating the expansion of production from renewable energy sources.

Energy

Is measured in joules, which equal 1 watt-second. One kilowatt-hour (kWh) therefore equals 3600 joules, as there are 3600 seconds in an hour.

Energy carrier

A substance or a state that can be used to store, convey or transmit energy.

Fuels are energy carriers containing chemically bound energy. Electricity is an energy carrier that, to be of practical use, needs to be supplied at a defined, known and controlled voltage, capable of supplying a useful current. It has to be produced from other energy sources. Water reservoirs store energy in potential form, i.e. capable of delivering energy if the water is discharged to a lower level through a water turbine. Hot water as used in district heating is an energy carrier that delivers heat to users. Cold water in district cooling systems is an energy carrier that carries away heat from buildings, processes etc. Hydrogen is an energy carrier belonging to the fuels group, i.e. carrying energy in chemically bound form. It needs to be produced from other energy sources.

Energy gas

A fuel in gaseous form at normal pressures and temperature. The most important energy gases are natural gas, LPG (liquefied petroleum gas), town gas, generator gas, hydrogen and biogas. Natural gas (which is mostly methane) and LPG (mostly propane or butane) are fossil gases found in the crust of the earth. The others are produced from energy-rich raw materials by various technical processes, Biogas (methane) is formed by the organic decomposition of organic materials by bacteria, and can be produced by digestion of sewage sludge or other biological waste.

Energy plants: **Thermal power stations, combined heat and power stations (also called cogeneration power stations), combined cycle power stations and heating plants**

An energy plant is one that produces electricity and/or heat.

A thermal power station produces only electricity. In practically all cases, they use a steam turbine to drive a generator, with the steam from the turbine being discharged to a condenser, where it is condensed back into water by giving up its heat to the surrounding air or to some source of cold water, such as a river or the sea . This is the origin of the name, cold condensing power station. Cold condensing power stations can be either nuclear-fuelled or fossil-fuelled.

Combined heat and power (CHP) stations produce both heat and electricity. The amount of electricity that they produce, per unit of fuel input, is less than that of a cold condensing power station, but the overall efficiency is considerably higher, as the steam leaves the turbine at a higher temperature than is the case for the steam leaving a cold condensing turbine, and is used to heat water for a district heating network. The fuel therefore produces both electricity and useful heat. In industry, this form of power generation is generally referred to as back-pressure power generation. The only difference is that, instead of the exhaust steam being used to supply heat to a district heating system, it is used instead as process steam in the industry.

Combined cycle power stations have two turbines: a gas turbine, which drives an electrical generator, with the hot gases leaving the turbine being used to raise steam to drive a steam turbine, which in turn drives a second electrical generator. The exhaust steam from the steam turbine can be used to supply district heating, or it may be condensed in the same way as in a cold condensing steam power station. Electricity yield is higher than in a cold condensing power station, but the initial plant cost is considerably higher.

Heating plants are simply boiler plants that supply only heat. For a district heating system, this is delivered as hot water, not as steam.

Energy source

These are natural resources or natural phenomena that can be converted into useful energy forms such as light, motion or heat. Examples of fossil energy sources are natural gas, crude oil and coal. They occur in finite, although very large, quantities, and are renewed only extremely slowly. Another relatively plentiful energy source, but which is not renewed, is uranium, the raw material for nuclear fuel. Renewable or flowing energy sources are constantly renewed by energy input to the earth and to nature from the sun. Water, wind and wave power are flowing energy sources. Tidal power is another, but derives from the interaction of the earth and moon. Biomass is also regarded as a solar-derived energy source, and is therefore a renewable energy source. In addition to these primary energy sources (solar, nuclear or fossil), there is also geothermal energy, originating from the earth's hot interior.

Evaporation

Evaporation is the process of changing a liquid to a gas by the addition of heat. It occurs when a liquid becomes a gas without any turbulence or violent disturbance. Boiling occurs when the liquid is raised to the temperature at which the liquid can no longer exist as a liquid, but must become a gas. The evaporation process is the most important process in energy technology, forming the basis for more or less all electricity production apart from hydro power, wind power and solar cell power, i.e. in cold condensing power stations, nuclear power stations and combined heat and power stations. All use water as the medium that is evaporated. Heat pumps and refrigerators, however, in which the evaporation processes are used in order to absorb energy, rather than to release it, use different working fluids, such as propane, ammonia or fluorocarbons, and at lower temperatures than for water. In this way, they can absorb heat from their surroundings.

Fuels

Substances or materials with chemically-bound (or fissile) energy. Fuels are usually regarded as being organic compounds or organic materials which release heat when burnt. Nuclear fuels, however, are those that release heat as a result of nuclear fission or (not yet realised on a practical scale) by nuclear fusion. The most important elements in fuels are carbon and hydrogen, and it is the reaction of these two with oxygen to form carbon dioxide and water respectively that releases heat. In addition to the combustible elements of carbon and hydrogen, most fuels (apart from energy gases) contain many other elements, in the form of non-combustible minerals that form ash.

Gasification
Gasification is a very important process in energy technology, as no fuel can burn without first being converted to gas. Gasification of a fuel generally occurs when the fuel is actually burnt. However, combustion losses can be reduced by first gasifying the fuel before combustion, and then delivering it in gaseous form. Another reason for doing this is that it makes it easier to remove various contaminants. Solid fuels can be converted to gaseous form either by pyrolysis or by partial combustion. In addition, organic non-fossil materials can be gasified by biological processes, to produce biogas. Pyrolysis (dry distillation) involves heating the solid organic material in the absence of oxygen, causing it to release volatile substances (mainly various hydrocarbons) without burning them. Light hydrocarbons released in this way (e.g. methane) remain in the gas phase even if they are then cooled, but other hydrocarbons condense to pyrolysis oil, leaving most of the fuel in solid form as carbon powder or sinter and ash.

Partial combustion involves supplying steam and limited quantities of air to glowing carbon in a special reactor vessel, to produce a gas consisting of a mixture of hydrogen, carbon monoxide, carbon dioxide and nitrogen. The combustible constituents of this gas, known as water gas, are hydrogen and carbon monoxide. Generator gas consists mainly of carbon monoxide, carbon dioxide and nitrogen. Water gas is widely used in the chemical industry as a feedstock for the production of more high-value fuels and chemical products, such as methanol.

Oil
Crude oil, or petroleum, is a mixture of various hydrocarbons, ranging from the lightest that consist of just a few carbon atoms to long, heavy molecular chains containing a score or so of carbon atoms. Crude oil can be used directly in some types of plant, but is considerably more valuable, and has a wider range of uses, if it is first refined into a range of petroleum products. This is done is refineries which, in principle, are large and sophisticated distillation plants. The hydrocarbons in the crude oil have different boiling points, and can therefore be separated from each other by appropriate control of the temperatures and pressures in the distillation process. This produces the various common oil products of LPG (liquefied petroleum gas), petrol, paraffin (am. kerosene), diesel oil, gas oil and heavy fuel oils, together with various special products. The composition of the crude oil, which varies depending on its source, determines how much of a particular product can be obtained. However, the thickest products can be further processed by cracking, which breaks the long carbon chains into shorter chains, so increasing the yield of lighter products such as petrol and diesel fuel.

Oil equivalent
A common unit for comparing the energy contents of various fuels with each other and with a standardised measure of the energy content of fuel oil. The unit is generally that of tonne of oil equivalent (toe), which provides 41.9 GJ or 11.63 MWh.

Peat
An organic type of soil, formed under damp and oxygen-deficient conditions by the bacterial and chemical decomposition of dead plant and animal matter. Peat is renewed relatively slowly, and is therefore somewhere between renewable and fuels and non-renewable fossil fuels.

Power
Energy and power are not the same. Power is the rate of delivering energy. It is measured in joules per second, which is the same as the traditional watt. Power shortage is the state when an energy system, such as an electrical power system, is unable to supply the amount of energy required at the rate at which it is required.

Statistically average year
A statistically average year is one that is statistically average in terms of its meteorological and/or hydrological data. It provides a means of making fairer comparisons of energy supply and energy use between one year and another, eliminating the effects of weather conditions in varying the statistics.

Waste heat
Waste heat is heat discharged from industrial processes, when it has fallen to a temperature that is no longer useful in the process. It can be used by district heating systems, either by direct distribution in the mains or, if it is at too low a temperature, by raising its temperature in a district heating plant or by using it as a heat source for heat pumps. Refineries, cement factories, steel mills and pulp mills are major sources of such waste heat. Sewage effluent treatment plants also produce waste heat, but at a relatively low temperature.

An efficient and low – environmental – impact energy system

The Swedish Energy Agency is the central Swedish public authority for energy. Our work is aimed at assisting the strategic transformation of the Swedish energy system to an environmentally benign, reliable and efficient energy system. Although Sweden's energy system is our prime objective, we also extend this work to other countries as appropriate.

We promote efficient energy markets, with increased production from renewable energy sources. We are the regulatory authority for Sweden's gas and electricity grids, and are also responsible for strategic energy preparedness for crisis situations. We support a large number of research and development programmes in the energy sector in conjunction with universities, research institutes and industry

Energimyndigheten

Statens energimyndighet, Box 310, 631 04 Eskilstuna. • Besöksadress: Kungsgatan 43
Telefon 016-544 20 00 • Telefax 016-544 20 99 • stem@stem.se • www.stem.se