INTERNATIONAL ENERGY AGENCY

Energy Policies of IEA Countries

Sweden 2000 Review

OECD

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SWEDEN 2000 REVIEW

INTERNATIONAL ENERGY AGENCY
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The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-four* of the OECD's twenty-nine Member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions;
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations;
- To operate a permanent information system on the international oil market;
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- To assist in the integration of environmental and energy policies.

** IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The European Commission also takes part in the work of the IEA.*

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- To achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- To contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- To contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

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Figure 1
Map of Sweden

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SUMMARY AND RECOMMENDATIONS

SUMMARY

Sweden has in place strong, market-based policies in some areas of the energy sector. Market-oriented policies include:

- The successful development of an international market in electricity.
- Co-operation in the Baltic Sea region on energy, climate policy and wider trade issues.
- Close consultation of government with industry, and a high level of industry awareness and voluntary activity.
- Tax measures to encourage, but not micro-manage, the development of the energy sector in an economically efficient and environmentally sustainable way. Even so, the structure of the system could be improved.

But there is a high level of government intervention in other areas. Energy policy in Sweden is influenced by several key decisions:

- The decision to phase out nuclear power.
- The commitment to reduce greenhouse gas emissions in line with the Kyoto Protocol.
- Limits to the further development of hydro resources.
- The aim to use renewables and energy efficiency as the principal means of replacing lost nuclear capacity.
- Requirement for a certain, but unquantified, degree of self-sufficiency in power generation.

Difficulties in achieving all these elements of energy policy have, together with conflicting views on the role of natural gas, given rise to uncertainty about the future direction of Swedish energy policy, and a degree of political intervention in the energy market. Mistakes could be costly to rectify. This could happen if large-scale applications of biofuels and renewables do not become economically competitive, or if the phasing-out of nuclear power generation is pushed too fast and replacement sources of electricity are insecure or too expensive.

Marked differences of view exist between the government and important areas of the industry. Low electricity prices following deregulation of the electricity market have reduced interest in investment in new generating capacity. There is also a marked difference of view between the government and industry on the future of the energy sector that may give rise to uncertainty affecting investment in the sector. Industry leaders believe that it will not be possible to make renewable forms of energy competitive for some time and are planning on the basis of the existing fuel mix. Moreover, they consider that market pressures on nuclear will eventually lead to the closure of reactors, starting with the least competitive. Industry leaders also believe that other energy sources, including imported electricity, will continue to be cheap and will maintain Sweden's energy security and overall competitiveness. Industry considers government ambitions for renewables may be unachievable except in the long term, and that government measures may result in distortion of the electricity market.

Energy policy formulation is complex. Certain inconsistencies reflect the different origins of policy initiatives, and need to be rationalised. Government consideration of the report of the Climate Commission may offer an opportunity to review government energy goals and priorities and, in consultation with industry and other stakeholders, to develop a set of achievable and cost-effective policy priorities.

As a result of successful policies, electricity prices are low and electricity is of fundamental importance to the economy. Swedish electricity prices are low, and the price of electricity is one source of competitive advantage for Sweden. On the other hand, the intensity of electricity use in Sweden is among the highest in the world (double the IEA Europe average and slightly higher than in the United States). This means that the price of electricity is disproportionately important for the Swedish economy. For these reasons, it is an explicit and essential priority of Swedish energy policy that electricity prices must remain at competitive levels, even if the fuel mix changes.

Energy taxation is a central policy instrument in Sweden: the tax regime needs to be simplified, the balance between revenue, environmental and energy policy goals needs to be clarified, and the tax regime kept stable over time. An energy tax, a carbon tax and a sulphur tax apply to the energy sector, as well as a number of other minor taxes. The tax system is complex and has undergone many revisions over time. Achieving a balance between revenue, environmental and specific energy policy goals should be one of the guiding principles in the review currently being conducted of the energy tax system. The present nuclear tax is not directly related to nuclear policy goals and impedes competition in the international electricity market. It should preferably be abolished, but it could be redesigned as part of a market-based package of measures to reduce the cost of phasing-out nuclear.

Taxes and environmental objectives need to be harmonised and the unintended effects of taxes addressed. Energy taxes require review in relation to their effects on fuel choice, and their impact on trade in electricity. Harmonisation of taxation is needed in the electricity market, including a clear choice between production or consumption taxes.

Harmonisation of environmental objectives, ideally in the wider European Union (EU) context, would be desirable as a starting point to rationalising the taxation system. Pending this development, consideration needs to be given to particular aspects of the Nordic electricity market. The approach to coal-based electricity production (principally from Denmark, but also from other countries) needs to be rationalised to avoid the clear inconsistency of developing carbon-free fuels domestically while importing low-cost coal-fired electricity.

Natural gas could emerge as a cost-effective option, but the investment climate could be improved. Energy policy should be based more broadly on market principles. The long-term objective of moving the energy sector to a renewables base is not questioned, provided electricity prices remain competitive. Natural gas could be a competitive alternative to nuclear, without the perceived safety and environmental problems of nuclear, but avoiding the high cost of a swift transition to renewables at their current state of development. In the case of Sweden, a move to gas would, however, mean accepting a higher level of carbon dioxide emissions.

Achieving a balance between environmental and economic goals is complicated by the policy of phasing-out nuclear. The Government of Sweden could take a more positive position on the development of gas. Measures underway, or which might be considered, include:

- Implementing, as planned, the EU Gas Directive with a view to opening the market as soon as possible.

- Addressing the influence of major suppliers in the gas and electricity markets on the development of the gas market.

- Establishing a stable tax regime.

- Facilitating access to the system network and the development of gas infrastructure by interested parties.

Rapidly phasing out nuclear will make it harder to achieve Sweden's greenhouse gas emissions target. The policies and measures adopted after consideration of the Climate Commission report should be cost-effective and realistic. If nuclear continues to be phased out, it is unlikely that renewables will be sufficiently developed in time to play a significant role in achieving Sweden's greenhouse gas emissions target. More extensive use of natural gas would raise the level of emissions. Current policy requires that the pace and manner of phasing out nuclear and introducing renewables should not damage Sweden's international competitiveness. But unreasonable expectations about the use of renewables to achieve the Kyoto target could lead to premature introduction of alternatives to nuclear, and jeopardise Sweden's competitiveness. It is essential that policies and measures are cost-effective, balancing economic and environmental goals in a realistic manner.

In Sweden, as in most IEA countries, market principles should encourage the use of the Kyoto flexible mechanisms. Sweden has undertaken important studies of the potential for the flexible mechanisms such as in its Baltic Sea region pilot programme. Baltic Sea regional co-operation is an important example to other IEA countries of how governments can develop the Kyoto flexible mechanisms. This should be further developed as a central goal of energy-environment policy.

Although Sweden has considered the use of a wide range of climate policies, little consideration has been given to the potential role of sinks. This is an area where studies might be usefully undertaken.

As in other IEA countries, progress in improving efficiency in transport is difficult. But it will become particularly important for energy-environment policy in Sweden, since opportunities for progress in reducing emissions in other sectors are limited. Development of alternative transport fuels to replace oil is a priority, but closer attention should be given to the commercial prospects of ethanol. Refiners are neutral on the issue because of their limited financial involvement to date. It is nevertheless important that they be involved from the outset if there is to be any prospect of commercial development of alternative fuels. Oil is also used in heating, as well as in transport, and it may be possible to cost-effectively reduce oil consumption in that sector for security and environmental reasons.

There is a need to clarify a policy for nuclear. Current policy on nuclear energy may impede developing a policy framework based on international markets and cost-effectiveness. Nuclear policy needs to be clarified. The electricity supply industry expects major reductions in nuclear capacity over the next 20 years because of competitive pressures. The government should consider allowing existing nuclear to be phased out on the basis of the economic life of existing reactors.

Even now, the closure of reactors can only be required by the government under certain conditions, including, for example, that closures do not damage industrial competitiveness. How the criteria are to be applied is not yet established. A good start has been made by commissioning independent consultants to evaluate Barsebäck 2 reactor against the statutory conditions (see Chapter 7). It is important that objective criteria be set out as well as a process established which is acceptable to all the parties for determining when the criteria are met. The criteria and the procedure for implementing Parliament's decision should be as transparent as possible, and allow independent organisations to study and analyse all relevant information. It would also be desirable to undertake a study, in consultation with industry, on the development of renewables. This study would provide an indication of the time-scale in which renewables might become competitive with other forms of energy and on a scale sufficient to replace existing nuclear reactors.

Existing nuclear capacity should be used productively pending any definitive policy on its future. A sufficient level of support must be maintained to ensure the continuing safe operation of reactors, the disposal of waste, and the attractiveness of the industry for competent new personnel.

Energy efficiency policy evaluation needs to be improved. It is planned that future reactor closures will be compensated, in part, by decreased electricity consumption. However, given the healthy growth of the Swedish economy in recent years and the optimistic outlook for future growth, the chances for reducing electricity consumption seem very limited in the short to medium term. The principal means of reducing electricity consumption is to promote the replacement of electrical space heating. Increased taxation of electricity may offer a more efficient and effective means of reducing electricity consumption, but the task is huge and difficult. Taxes on electricity are already quite high, and have been raised rapidly during the last couple of years.

The evaluation of efficiency programmes is at present inadequate. Current qualitative evaluation procedures need to be improved as a basis both for any future decision on nuclear power and for formulating future energy efficiency policies. Little has been achieved in improving energy efficiency since the late 1980s. Sustained improvements in energy efficiency over a number of years would need to be demonstrated to justify closure of nuclear plants. There is also a need to look for further effective energy efficiency measures in the transport sector since this is the main sector contributing to greenhouse gas emissions.

Regulation and performance of the electricity market require attention to some details. The Nordic electricity market and domestic liberalisation have worked well. The Nord Pool has become a leading example internationally of how to design a competitive electricity market. There is room for improvement in the following areas, discussed in detail in the report:

- Harmonising cross-border transmission tariffs.
- Addressing domestic transmission tariff issues, including congestion.
- Generation capacity constraints.
- Ownership issues in the gas and electricity markets.
- Independence of regulation.

RECOMMENDATIONS

The Government of Sweden should:

General Energy Policy

- ☐ Take the opportunity of the debate on the Climate Commission report to review energy policy goals, in consultation with industry and other stakeholders. The aim should be to formulate a set of consistent, achievable and cost-effective priorities based on market principles, and to establish a stable policy environment.

- ☐ Improve the structure of the energy tax regime to reflect more clearly the balance between energy policy, environmental and general revenue goals.
- ☐ Simplify and maintain stability in the energy tax regime to ensure investors are able to plan for the long term in a certain tax environment.
- ☐ Negotiate harmonised energy taxation in the Nordic region to remove distortionary effects on energy trade.
- ☐ Evaluate the cost of unintentional effects of the taxation system.
- ☐ Review the effects of the nuclear production tax, and consider the possibility of abolishing the tax as part of a tax reform.
- ☐ Consider strengthening the independence of energy sector regulators.
- ☐ Review the influence of ownership on the development of competition in the energy sector.

Environment

- ☐ Move quickly to settle a package of cost-effective policies and measures to meet Sweden's greenhouse gas target.
- ☐ Integrate environmental concerns (local, regional and global) into energy policies, while also maintaining the objectives of security of supply and competitiveness.
- ☐ Continue the pilot development of the Kyoto flexible mechanisms in the Baltic Sea region in anticipation of international agreement on the implementation of the mechanisms.
- ☐ Take into account the role of sinks as a potentially important measure for use by Sweden.

Efficiency

- ☐ Clarify existing qualitative goals for efficiency improvement programmes to ensure an objective assessment can be made of their cost-effectiveness and, in particular, the contribution energy efficiency programmes may make to offsetting any further reductions in nuclear capacity.
- ☐ Consider increasing taxes on household electricity consumption as an alternative to promoting the expansion of district heating as a means of reducing electricity consumption.
- ☐ Harmonise taxation of heat and electricity production from combined heat and power plants.

Electricity

- Consider the influence of the present major players in the gas and electricity markets on the development of gas-fired electricity generation and ensure that there is no discrimination in the gas market against gas-fired energy production.
- Review transmission congestion and pricing mechanisms to identify potential improvements such as pricing methods that better reflect costs and enhanced co-ordination between Nordic system operators in the management of reserves.
- Introduce, as planned, a scheme to support market entry of renewables that does not distort competition.
- In the context of the EU's "Florence process", consider reforms to the cross-border tariff system to facilitate trade with EU countries outside the Nordic countries.
- In the context of the ongoing review of distribution tariffs, identify options to provide stronger incentives for efficiency in distribution and to ensure that distribution tariffs are cost-reflective and do not cross-subsidise supply activities.

Nuclear

- Assess the economic advantages of allowing existing nuclear to be phased out on the basis of the economic life of existing reactors.
- Ensure full transparency and independence of the evaluation to be made to determine when the criteria established by the Parliament for the closure of reactors have been met.
- Pending any further government decisions on nuclear reactor closures, ensure the continuing safe and economic operation of existing reactors.
- Continue progress towards the selection and construction of a final repository for high-level wastes; review the adequacy of the present low- and medium-level waste repositories and facilitate their expansion, if necessary for decommissioning waste.

Gas

- Further develop the policy framework for the use of natural gas, including the following elements:
- Implementing, as planned, the EU Gas Directive with a view to opening the market as soon as possible.

- Addressing the influence of the present major players in the gas and electricity markets on the development of the gas market.

- Establishing a stable tax regime.

- Adopting measures to facilitate access to the system network and the development of gas infrastructure by interested parties.

- Take into account the supply security implications for Sweden if any proposal for a second gas pipeline is submitted for approval.

Renewables

- Keep government support for renewables under continuous review, with the objective of ensuring that satisfactory progress is being made towards the goal of competitiveness with other fuels.

- Ensure that policy on the use of biofuels does not give rise to support for indigenous fuels principally for reasons of supply security, or for social, regional or industry policy purposes.

- Continuously update assessments of the capacity of forest-based industries to supply sufficient biomass at acceptable cost to meet the requirements for biomass in electricity generation.

Research and Development

- Further streamline the administration of energy research and development; and ensure that the goals of programmes and criteria for project selection are determined by government energy policy objectives, and evaluated against these objectives.

- Review the research and development programme to ensure that projects undertaken are justified on grounds of their outcomes, and that they give rise to cost-effective energy technologies within targeted time periods; work closely with industry programmes to ensure harmony of objectives and complementarity of outcomes.

CONDUCT OF THE REVIEW

REVIEW TEAM

The 2000 International Energy Agency (IEA) in-depth review of the energy policies of Sweden was undertaken by a team of energy policy specialists drawn from the Member countries of the IEA, which visited Sweden 31 January – 4 February 2000 for discussions with government officials, energy suppliers and energy consumers. Information provided during the visit has been supplemented by published sources and IEA statistical analysis of data provided by the Swedish Ministry of Industry, Employment and Communications.

Members of the team were:

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John Cameron managed the review and drafted the report, except for Chapter 6, which was drafted by Carlos Ocaña. Monica Petit and Bertrand Sadin prepared the figures.

The team held discussions with the following organisations:

Elforsk AB (research and development organisation of the electricity supply companies)
Federation of Swedish Industry
Ministry of Industry, Employment and Communications
Ministry of Environment
Parliamentary Standing Committee on Industry and Trade
Svenska Kraftnät (the Swedish National Grid)
Swedish Association of Local Authorities
Swedish Bioenergy Association, SVEBIO
Swedish Council for Vehicle Research
Swedish District Heating Association
Swedish Environmental Protection Agency
Swedish Gas Association
Swedish National Energy Administration
Swedish Nuclear Power Inspectorate
Swedish Petroleum Institute
Swedish Power Association
Swedish Transport and Communications Research Board
Sydkraft AB
Vattenfall AB

The assistance and co-operation of all participants in the review are gratefully acknowledged.

REVIEW CRITERIA

The *Shared Goals* of the IEA, which were adopted by IEA Ministers at their 4 June 1993 meeting, held in Paris, provide the evaluation criteria for in-depth reviews conducted by the Agency. The *Shared Goals* are set out in Annex B.

GENERAL ENERGY POLICY

BACKGROUND

Sweden is the fourth largest country in Europe (total area 450 000 square kilometres), extending from the southern Baltic to north of the Arctic Circle. Nearly 90% of the land area is under forest or other woodland, bogs, fens and lakes. Some 8% is farms and 3% built-up areas. Most of the population of 8.8 million lives in the southern half of Sweden, and about 90% in urban areas. About one-third of the population is in the three main metropolitan areas of Stockholm, Göteborg and Malmö.

Sweden has an urban industrialised economy in which traditional industries based on domestic resources of iron ore and wood still play an important part, coupled with low-cost electricity. Exports, principally industrial products, account for over 30% of GDP. After moderate growth in the 1970s and 1980s, the Swedish economy went into recession in the period 1989 to 1993. Following extensive adjustment of economic and social policies, economic growth resumed in 1994 and the economy grew strongly during 1997-1999 at about 3% each year. Economic growth is expected to be about 2.75% over 2000[1].

Sweden, offically Konungariket Sverige (Kingdom of Sweden) is a constitutional monarchy. The Riksdag (Parliament) consists of a single chamber directly elected by proportional representation. Executive power is vested in the cabinet, which is responsible to the Parliament. Important decisions affecting policy, including energy policy, may arise directly from the Parliament. In addition to cabinet ministries, there are central government agencies administering government policies and services. Government agencies, including for energy, administer government policy with a high degree of independence from the ministries. There are three major political parties and several other influential parties. Governments are invariably formed by coalitions of several parties. In addition to the central government, Sweden is divided into 24 counties, each with a governor appointed by the central government, and a popularly elected council.

GENERAL ENERGY POLICY

Objectives

The objectives of energy policy are to secure the short- and long-term electricity supply, as well as the supply of other energy, on competitive terms. Energy policy should:

1. *OECD Economic Surveys – Sweden 1999*, OECD Paris, 1999.

- Create the conditions for efficient energy use and a cost-efficient Swedish energy supply with a low negative impact on health, the environment and the climate.

- Facilitate the transformation into an ecologically sustainable society, promoting sound economic and social development in Sweden.

- Contribute to the creation of stable conditions for a competitive business sector, and to the renewal and development of Swedish industry.

- Contribute to broadening co-operation within the Baltic region with regard to energy, the environment and the climate.

More specifically, objectives of energy policy include:

- Basing the national electricity supply on cost-efficient, lasting, preferably indigenous and renewable energy resources.

- Fixing the use of fossil fuels at a low level.

- Protecting specified rivers and river stretches from exploitation.

MAJOR DEVELOPMENTS

In 1997, following an inter-party agreement, Parliament took a major energy policy decision concerning the future of nuclear power and the development of the energy system. The government stated that problems would arise regarding employment, welfare, competitiveness and the environment if all nuclear power plants were phased out by the year 2010. The final year in which the last nuclear reactor should be taken out of service was not specified in order to allow sufficient time for the transformation of the energy system. The Barsebäck nuclear energy plant, with two reactors, was deemed inappropriately located. The Barsebäck 1 reactor was closed in November 1999. Conditions for further closures were included in legislation on sustainable energy supply (Government Bill 1996/97:84). More efficient energy use, electricity conservation, conversion from electricity and an increased electricity supply from other energy sources should compensate the electricity loss in the event that reactor closures took place. Provided the conditions are met, Barsebäck 2 is planned for closure by 1 July 2001. Before the end of the government's current term of office, Parliament requires that a decision be taken concerning the future of the remaining reactors.

Following Parliament's decision, an extensive energy policy programme with total funding of SKr 9.1 billion[2] is being implemented in two parts.

2. On average in 1999, SKr 1 = US$ 0.121. In 1999, SKr 1 = € 0.1166.

- A long-term (seven-year) research, development and demonstration programme (SKr 5.6 billion) to develop renewable energy sources and new energy technology, focusing on developing new technology for biofuels, ethanol, wind, solar and others. The programme provides for substantial research to develop technology relating both to the supply of renewable energy and to improving the efficiency of energy use.

The programme is intended to provide a foundation for the long-term development of an ecologically sustainable society. The main target of the programme is to reduce the costs of the use of renewables so as to make them economically viable alternatives to nuclear power and fossil fuels. Effort is primarily directed at increasing the supply of biofuels, and developing technology for wind power, hydropower, heat storage, etc. In the longer term, effort will be directed towards fuel cell and battery technology, artificial photosynthesis, photovoltaics and solar heating.

- A short-term (five-year) subsidiary programme (SKr 3.5 billion) to promote energy efficiency and electricity production from renewable energy sources such as biofuels, wind and small hydropower plants. The support for energy efficiency includes conversion of electrical heating to district heating, technology procurement, information, labelling, etc. The use of electric boilers in district heating is to be reduced.

The programme is intended to meet the conditions for closure of further reactors by compensating for loss of nuclear electricity production with electricity produced from renewable energy resources, and with a decreased use of electricity.

ENERGY POLICY DEVELOPMENT

1980

- A government bill declared that nuclear power was to be phased out at a rate compatible with electrical power requirements for the maintenance of employment and national well-being. The Parliament recommended a commitment to closing Sweden's last reactor no later than 2010.

1991 Energy Policy Bill

- Energy Policy Bill with the purpose of creating the conditions for long-term sustainable political decisions on energy policy, whose goal was defined as securing the availability of electricity and other energy in the long and short term at prices that are competitive on the world market.

- The commencement and pace of the phase-out to be determined by the results of electricity conservation efforts, the availability of electricity from environmentally acceptable power production, and the ability to maintain internationally competitive prices.

- From a climate viewpoint, it was essential to avoid burning fossil fuels wherever possible, by means of active energy conservation and by utilising renewable energy sources. Taxes and prices were recognised as having a crucial bearing on production costs and influencing energy consumption.

1994 Energy Commission

- A Parliamentary Energy Commission was appointed to examine the ongoing programmes for transformation of the energy system and analyse the need for changes and additional measures.

1997 Sustainable Energy Supply Bill

- On the basis of the report of the Energy Commission, in spring of 1996 the government invited the parliamentary parties to formulate the basis for sustainable long-term energy policy decisions. These deliberations resulted in an agreement in the Parliament regarding guidelines for energy policy.

- The guidelines set down in the 1991 Energy Policy Bill remain unchanged. Two nuclear reactors at Barsebäck to be shut down; the first before 1 July 1998 and the second before 1 July 2001. However, closure of the second reactor is conditional upon its electricity production being compensated by new electricity production from renewable sources and reduced use of electricity.

- The previous commitment to closing Sweden's last nuclear reactor no later than 2010 was revoked.

- The launching in January 1998 of a seven-year programme for an ecologically sustainable energy system. The programme includes work intended to reduce electricity use and also to provide new electricity production.

1998

- The creation on 1 January 1998 of a new central energy authority, the Swedish National Energy Authority, responsible for implementing the greater part of the country's energy policy programmes, and with responsibility for co-ordinating the various energy policy change-over and introductory measures. The Energy Administration will monitor the implementation of the energy policy programme.

Government Energy Organisation

The lead responsibility for developing energy policy rests with the Minister of Industry, Employment and Communications. The Swedish National Energy Administration, which was established on 1 January 1998 to replace the energy policy administration functions of the National Board for Industrial and Technical Development, is the central government body responsible for most functions within the energy area. The National Energy Administration has responsibility for implementing most of the energy policy programme, and for co-ordinating the programme as a whole.

The Minister of Industry, Employment and Communications is appointed by the Prime Minister, and is responsible to the Parliament. The Ministry is one of ten ministries which form, together with the Prime Minister's Office and the Office for Administrative Affairs, a single authority known as the Government Offices. The ten ministries conduct government business within their spheres of responsibility. In 1999, the Ministry of Industry, Employment and Communications had an allocation of approximately SKr 115 billion (SKr 1.7 billion for energy-related measures), corresponding to 15% of the national budget and employed 370 people.

The Ministry of Industry, Employment and Communications has overall charge of the activities of 42 central government agencies, including four public utilities. The Swedish National Energy Administration is one of the central government agencies reporting to the Ministry of Industry, Employment and Communications. The central government agencies are responsible for the day-to-day running of the central government administration. The nature and scope of their activities are defined by government objectives and guidelines and further determined by the allocation of funds for their operations.

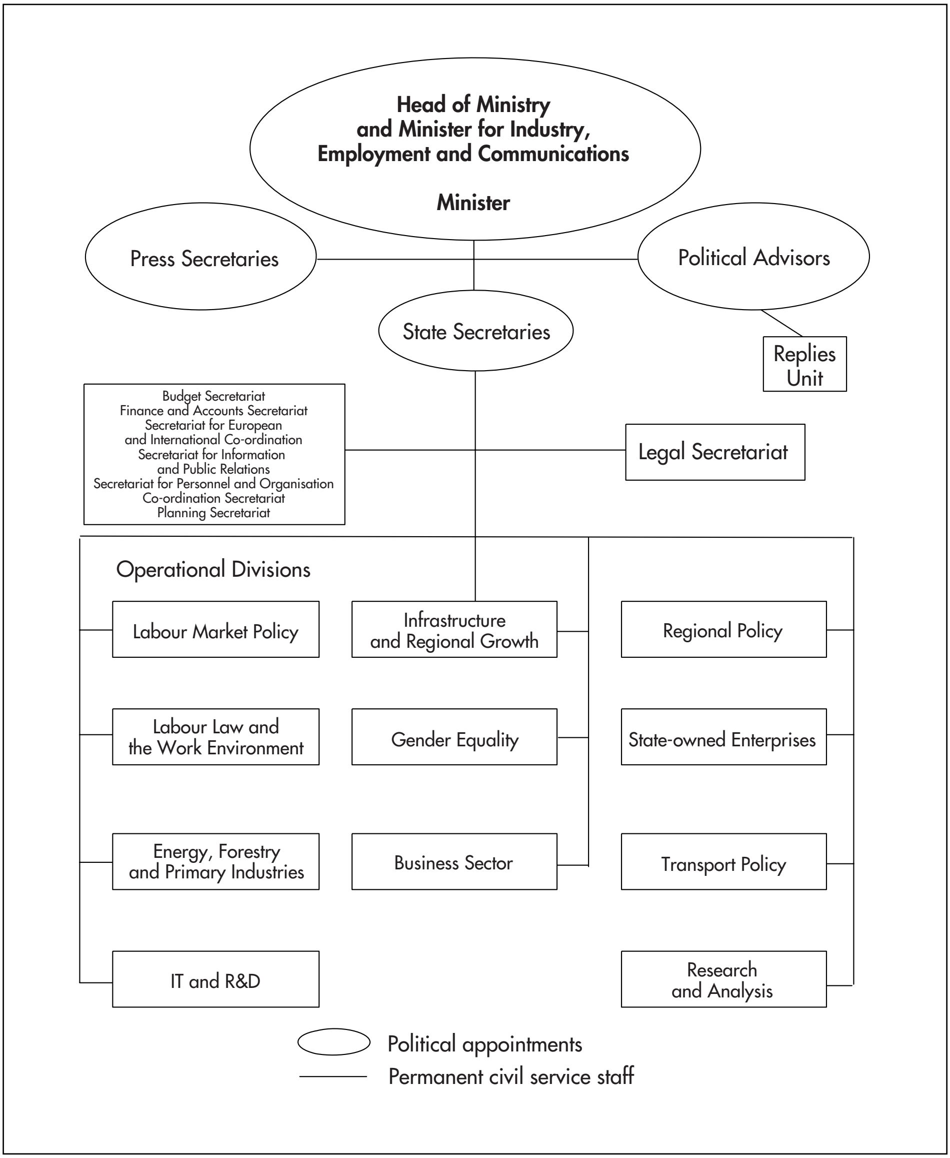
Fifty-five companies and four public utilities are owned, either wholly or in part, by the Swedish state. Of these, 26 are within the responsibility of the Ministry of Industry, Employment and Communications, including Vattenfall AB (100% state-owned).

A number of organisations have a role in implementing the energy policy programme:

- The Swedish Council for Building Research is responsible for energy-related building research.
- The Swedish Board of Housing, Building and Planning is responsible for the sub-programme for reduction of peak load in households as well as the sub-programme for substitution of electrical residential heating with other heating methods.
- The Swedish Consumer Agency is responsible for testing, labelling and certification of energy use in household equipment, etc.
- The Swedish Environmental Protection Agency is responsible for the supervision of environmental issues under the energy policy programme.

Figure 2

Ministry of Industry, Employment and Communications



Source: Ministry of Industry, Employment and Communications.

- The Swedish Natural Science Research Council and the Swedish Research Council for Engineering Sciences are responsible for energy-relevant basic research.

- The Swedish Transport and Communications Research Board (KFB) is responsible for energy-related transport research. The transport authorities (Vägverket, Sjöfartsverket, Luftfartsverket, Banverket) have responsibility within their sectors to promote efficient use of energy.

- The regional authorities are responsible for the implementation of the parts of the sub-programmes concerning private households on behalf of the Swedish Board of Housing, Building and Planning.

- The state-owned utility Vattenfall, which produces 50% of Swedish electricity, is expected to play an active role in the conversion process of the Swedish energy system on competitive terms.

In addition, the Swedish Nuclear Power Inspectorate (SKi) is responsible for regulation of nuclear activities with regard to safety, nuclear waste management and nuclear non-proliferation. SKi is also responsible for government-funded nuclear safety research. Moreover, SKi manages a special government-funded programme for co-operation and support to Eastern and Central Europe in nuclear safety and related radiation protection areas.

Energy Taxation

There are three different levies on energy products: energy tax, carbon dioxide tax and sulphur tax. The energy tax is levied on fossil fuels and electricity and has been collected for several years. The carbon dioxide and sulphur taxes were introduced in 1991. The energy tax on gasoline and diesel oil is differentiated with respect to "environmental class". The carbon dioxide tax rates correspond at present to approximately SKr 0.37 per kilogram of carbon dioxide released. The sulphur tax is levied on the sulphur content in the fuels and is based on a tax rate of SKr 30 per kilogram. In addition, an environmental fee on nitrogen oxide emissions has been levied since 1992.

VAT is levied on all kinds of energy consumption, with the exception of fuels used for air navigation. The tax rate is 25 %.

In the calculation of energy tax on fuels, rules are applied to avoid double taxation. Under the principal rule, deductions are permitted for fuel used in electricity production, while the electric power produced is taxed at the consumer level. Nuclear power production is taxed at a rate of SKr 0.022 per kWh. For district heat, input taxes are applied, that is taxes are levied on the fuels used in heat production and not at the consumer level. There are special rules for combined heat and power.

Energy products used in the manufacturing industries are exempt from the energy tax and the carbon dioxide tax is levied at a reduced rate of 50% of the general rate. Further tax reductions are admitted for energy-intensive activities. Electricity production is exempt from energy and carbon dioxide taxes.

A government committee is reviewing the energy tax system. The work is based on a model for reformed energy taxation presented in the report from the Swedish

Green Tax Commission *Taxes, Environment and Employment*. The purpose of the review is to create a simpler and clearer energy taxation system.

ENERGY SUPPLY AND DEMAND

Primary Energy Supply

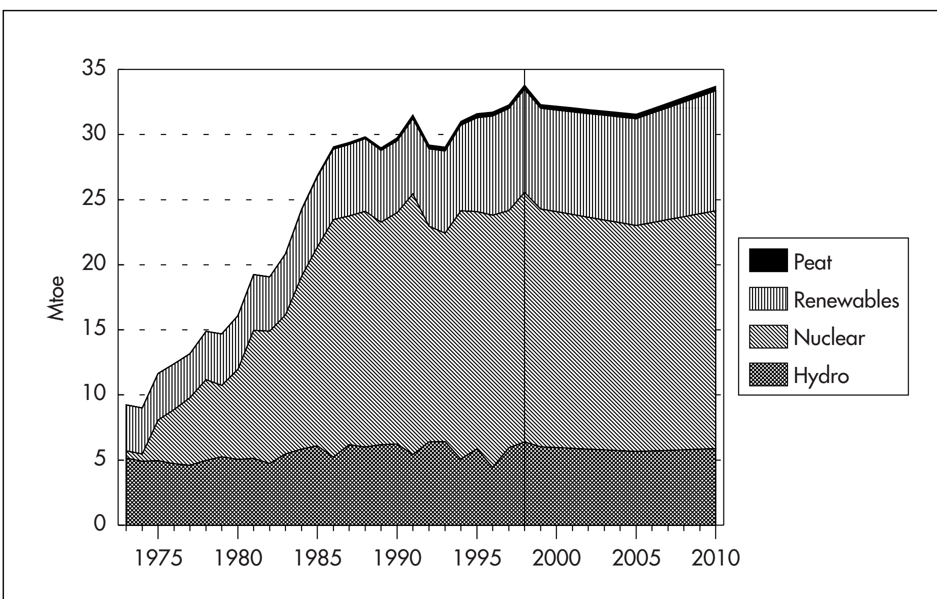
Annex A contains information on Sweden's energy balances and key statistical data. About two-thirds of Sweden's energy supply is accounted for by oil and nuclear. Combustible renewables and wastes (principally wood and forest wastes) account for about 15%, and hydro about 12%. Coal, gas and peat account for the remainder. Sweden imports about 35% of its energy supply, mostly oil.

Final Energy Consumption

Total final energy consumption in 1998 was 35.3 Mtoe, a decrease of 0.5% from 1997, compared with an annual rate of growth in Gross Domestic Product in 1997-98 of 2.9% and 0.8% 1990-97. In 1998, oil accounted for nearly 40% of final consumption, electricity about 30%, combustible renewables and wastes nearly 15%, and heat about 10%.

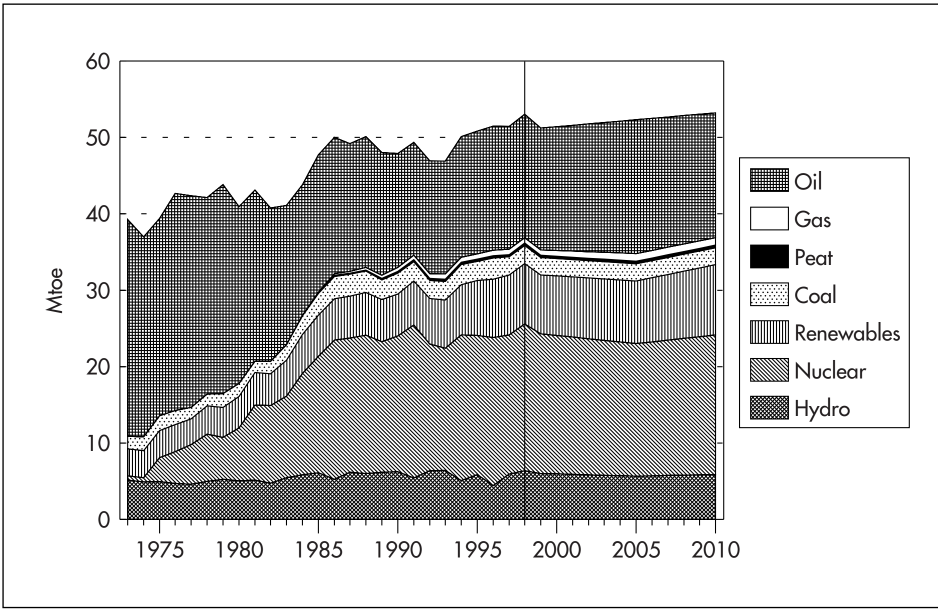
Figure 3

Energy Production, 1973-2010



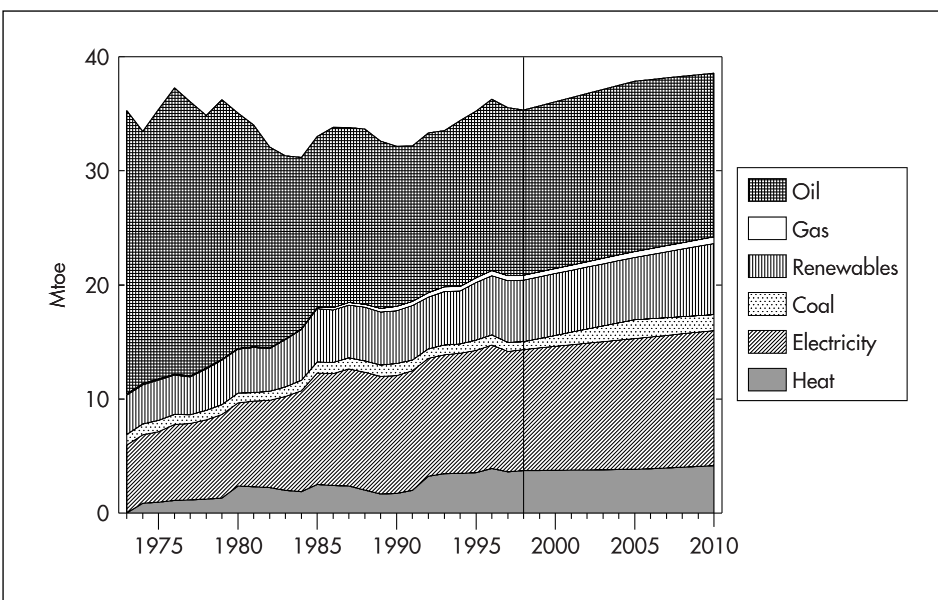
Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and country submission.

Figure 4
Primary Energy Supply, 1973-2010



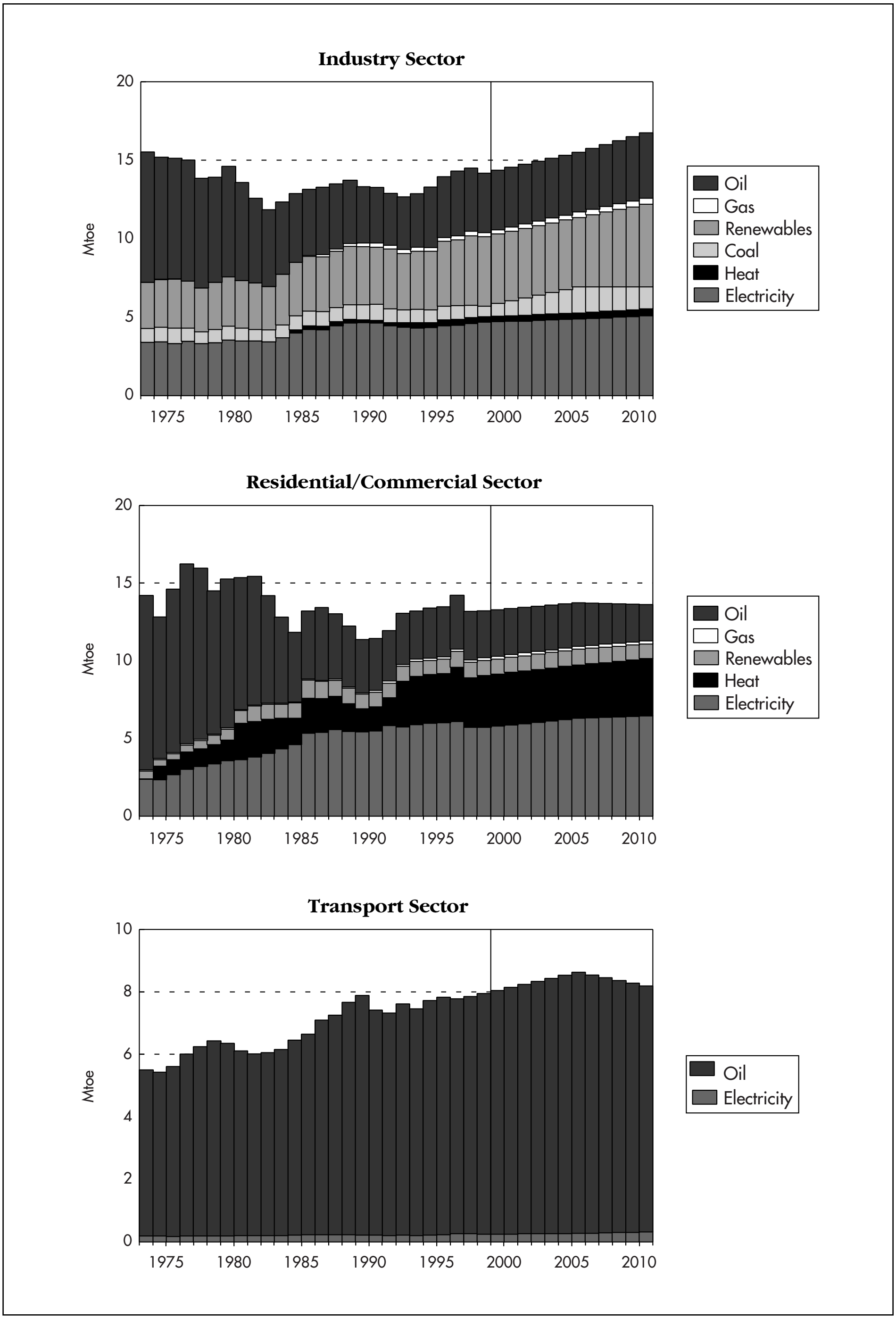
Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and country submission.

Figure 5
Total Final Consumption by Fuel, 1973-2010



Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and country submission.

Figure 6
Final Consumption by Sector, 1973-2010



Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and country submission.

In 1998, industry accounted for about 42% of final energy consumption, and transport accounted for about 22%. Industrial demand for energy in Sweden has risen by about 7% since 1990, but has fallen by nearly 9% since 1973. Transport demand for energy has risen by just over 7% since 1990, and by 45% since 1973.

CRITIQUE

Energy policy objectives are complex and could be clarified. Swedish energy policy objectives are a web of general and specific instructions from the Executive and the Parliament that the Ministry of Industry, Employment and Communications and the National Energy Administration have sought to bring together in a consistent and coherent energy policy.

Two overriding concerns are evident in Swedish energy policy: to keep down electricity prices to maintain industrial competitiveness and economic growth, and to achieve Sweden's target for greenhouse gas emissions. Very effective use has been made of energy taxation as a principal means of achieving both objectives consistently and at least cost. The successful development of the Nordic electricity market has been important in maintaining low electricity prices through competition.

Current and prospective policies and measures to achieve Sweden's greenhouse gas emissions target are discussed in Chapter 4. Consideration of the report of the Climate Commission on additional polices and measures will provide an opportunity for reviewing energy policy goals generally and to ensure they are consistent and achievable. The latter point is important since Sweden has already established a costly set of programmes to promote renewable energy and energy efficiency as substitutes for nuclear power. These policies are expected to have an impact on the level of emissions and the Climate Commission will be proposing additional measures. Judgement will need to be exercised as to what might be achieved during the life of the existing programmes, and what supplementary measures are needed that will realistically help achieve Sweden's greenhouse gas emissions target at acceptable cost.

Formulation and administration of energy policy are complex in Sweden and many organisations are involved besides the ministry and the National Energy Administration. Consistent outcomes will depend in part on ensuring efficient co-ordination of all the organisations involved, particularly once greenhouse gas emissions policies and measures are settled and integrated with economic and other environmental objectives of energy policy.

Energy tax reform should seek to establish a stable system balancing economic and environmental goals. The system of energy and environmental taxation is currently under review. Taxation has played an important part in encouraging energy efficiency and in reducing carbon dioxide emissions. The policy has undergone restructuring on several occasions and the resulting tax system is complex.

For historic reasons, the energy tax is levied on volume or weight rather than energy content. The general energy tax, including the tax on electricity and petrol, has had a greater impact on the sector in revenue terms; its design suggests it is intended to be a general revenue tax rather than a tax to achieve specific energy-environment goals. Taxes intended to change behaviour, such as to reduce consumption or to switch fuels, are not neutral between different actors in the economy and, if effective, result in a declining revenue stream. They should be distinguished from revenue taxes, which should be neutral in the impact on economic activity.

Concerns about international competitiveness have been addressed by granting exemptions to the industries faced with the greatest international competition. Fossil fuel use in electricity has not been taxed to avoid damaging competitiveness in the Nordic market. So far as energy-environment policy is concerned, however, Sweden's taxation policies, like those of other IEA countries, exhibit inconsistencies in the implicit value placed on carbon that are unlikely to be addressed in the absence of international agreement.

Four particular aspects might be considered during the review of energy taxation:

- The carbon tax has the effect of encouraging imports of otherwise high-cost fuels, such as waste timber. Arguably, this is an unintended result of the structure of the tax that is of little benefit for the development of biofuels in Sweden.

- The tax on nuclear power is inconsistent with the aim of the carbon dioxide tax and the principles set out in legislation for phasing out nuclear power. It appears to be an arbitrary tax that impedes Sweden's competitiveness in the electricity market and penalises a carbon-free fuel, but has no effect in encouraging the development of capacity to replace nuclear. The immediate beneficiary of the tax is nuclear power in Finland, which would otherwise compete with Swedish nuclear power on an equal footing.

- Harmonisation of taxation is needed in the electricity and heat markets, including a clear choice between production or consumption taxes.

- Harmonisation of taxes is needed in the international electricity market to ensure fair competition between producers in the different participating countries.

Ideally, the tax structure should be simple to ensure its impact is predictable and consistent, and stable to provide a known framework for investors in the sector. The review of the tax policy should take into account all these factors and seek to develop a tax system that balances economic and environmental goals, while establishing a simplified tax regime that is stable over the longer term.

Independent regulation will continue to be necessary and could be strengthened. The Ministry of Industry, Employment and Communications is responsible for developing policy and the National Energy Administration is responsible for implementation. The administration is constitutionally independent from political direction, including from the ministry. Energy regulation is a function of the

National Energy Administration, and is expected to function independently. Consideration might be given to providing further assurances of independence by removing the regulatory role to an organisation entirely separate from the ministry and the National Energy Administration.

Government ownership raises issues to be addressed. Through Vattenfall, the Swedish Government has a significant shareholding in the electricity and gas industries. The Swedish National Grid is also a form of government-owned enterprise. Both organisations function independently of government, so there is little rationale for maintaining a government presence other than as a contingency for government intervention. As the electricity market develops, consideration might be given to withdrawing from energy businesses to ensure that competition is fully effective and transparent. Because of the dominance of a few businesses, and in relation to gas in particular (discussed further in Chapter 8), consideration might be given to restructuring government energy businesses, even if privatisation is not considered.

RECOMMENDATIONS

The Government of Sweden should:

- ☐ Take the opportunity of the debate on the Climate Commission report to review energy policy goals, in consultation with industry and other stakeholders. The aim should be to formulate a set of consistent, achievable and cost-effective priorities based on market principles, and to establish a stable policy environment.
- ☐ Improve the structure of the energy tax regime to reflect more clearly the balance between energy policy, environmental and general revenue goals.
- ☐ Simplify and maintain stability in the energy tax regime to ensure investors are able to plan for the long term in a certain tax environment.
- ☐ Negotiate harmonised energy taxation in the Nordic region to remove distortionary effects on energy trade.
- ☐ Evaluate the cost of unintentional effects of the taxation system.
- ☐ Review the effects of the nuclear production tax, and consider the possibility of abolishing the tax as part of a tax reform.
- ☐ Consider strengthening the independence of energy sector regulators.
- ☐ Review the influence of ownership on the development of competition in the energy sector.

4

ENERGY AND THE ENVIRONMENT

GREENHOUSE GAS EMISSIONS

Emissions Target

Under the Kyoto Protocol[3], the European Union (EU) has made a commitment to reduce, individually or jointly, the emissions of a basket of six greenhouse gases[4] to 8% below their 1990 level by 2008-2012. The EU and Member states together will achieve this target, using the provisions for joint attainment in Article 4 of the Kyoto Protocol. At the meeting of the EU Council of Environment Ministers in June 1998, Sweden agreed to a national target to limit the net increase of emissions of greenhouse gases to 4% *above* 1990 levels in the target period 2008-2012. The Parliament has set a more ambitious target of stabilising carbon dioxide emissions between 1990 and 2000 and thereafter decreasing emissions. Emissions of methane from waste disposal are also to be reduced by 30% between 1990 and 2000.

Sweden considers that its EU-agreed target is a more ambitious target than the targets for the other EU countries, although they in many cases have to reduce their emissions more substantially, since Sweden has virtually no coal-fired electricity production, has a policy to phase out nuclear power, and has already implemented many renewables and energy efficiency measures. The government considers that, compared with other countries, the marginal costs for additional carbon dioxide reducing measures are high in Sweden.

Electricity production is currently responsible for about 5% of the total carbon dioxide emissions in Sweden[5]. The largest proportion (42%) of the carbon dioxide emissions originates from the transport sector. If the projected deficit in domestic electricity production by the year 2000 is compensated by imported electricity, carbon dioxide emissions are estimated to increase by 3.6% from 1990 to 2000, due to the fact that carbon dioxide originating from imported electricity is not included in Sweden's emissions. If domestic oil-fuelled condensing power is used, emissions will increase by 6.7% if the deficit is produced domestically.

3. The full text of the Kyoto Protocol can be found on the UNFCC web site, www.unfcc.de.
4. Gases which contribute to the warming of the earth's surface. The Kyoto Protocol (December 1997) defines commitments to reduce emissions of the following six greenhouse gases: CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), and SF_6 (sulphur hexafluoride). On a global level, CO_2 is the single most important anthropogenic greenhouse gas. Fossil fuel production and use represent about three-quarters of CO_2 emissions from human activity. Other energy-related greenhouse gases include CH_4 from the production, transportation and use of natural gas and coal, and N_2O primarily from fuel wood use. The three other greenhouse gases covered by the Kyoto Protocol are not energy-related: HFCs (used as alternatives to ozone-depleting substances, such as coolants), PFCs (from aluminium smelters), and SF_6 (used in insulators for electrical transmission and distribution systems).
5. Swedish National Energy Administration.

Climate Policies

Sweden has applied policies and measures for climate change since 1988, when the issue was discussed in the Parliament for the first time. A more comprehensive programme was adopted by the Parliament in May 1993 when the Bill regarding Strategies against Climate Change was adopted. Sweden issued its national communication entitled Sweden's National Report under the UN Framework Convention on Climate Change, adopted by the Swedish Government on 15 September 1994. The second national communication entitled Sweden's Second National Report under the UN Framework Convention on Climate Change was adopted by the Swedish Government on 17 April 1997. This report was drawn up before the final adoption of the Bill on A Sustainable Energy Supply.

The Parliamentary decision on energy policy in June 1997 includes a strategy for reducing impact of the energy sector on the climate. The strategy is outlined in Chapter 3. It is based on the view that successful international co-operation presupposes an equitable distribution of commitments and costs. The differing points of departure and conditions in the individual countries should be taken into account when determining the commitments within the convention. The cost-effective distribution of measures advocated by the Climate Convention should also be a guiding principle. In addition, measures already taken and per capita emissions of gases affecting the climate should also be considered.

The main strategy to achieve the carbon dioxide goal is to limit the need for fossil fuels and replace them with renewable energy sources, along with better management and more efficient use of energy. Measures to improve efficiency include technology procurement and development of electricity-efficient products, processes and systems in homes, industry and other premises. Measures to increase the use of renewable energy are being focused primarily on increasing the use of biofuel. In contrast with other countries, Sweden has very few options for reducing greenhouse gases through changes in the electricity sector as only about 5% of electricity generation is based on fossil fuels.

Economic instruments were introduced in Swedish environmental policy in the mid-1970s. Their use has expanded and been refined progressively. General energy and carbon dioxide taxes are summarised in Table 1, and energy taxes on manufacturing industry in Table 2. Carbon dioxide tax is levied at a rate of SKr 0.37 per kilogram of carbon dioxide released.

International co-operation has also been an important element in the strategy to date. Sweden funds programmes in the Baltic states and in Eastern Europe on renewable energy, energy saving and support measures. The potential of the flexible mechanisms under the Kyoto Protocol[6] is of considerable importance to Sweden.

6. Articles 3.10, 3.11 and 3.12 of the Kyoto Protocol allow Parties to acquire and transfer any part of emissions commitments through international emissions trading (Article 17 of the Protocol), Joint Implementation (Article 6) and the Clean Development Mechanism (Article 12). The Kyoto Mechanisms implicitly recognise that countries have different circumstances. They offer a certain flexibility in the location of emissions reductions, where they are least costly.

The Swedish Government has allocated SKr 350 million for international climate-related energy co-operation and investment projects for the period 1998-2004. In 1998, SKr 40 million of this sum were allocated directly to the Swedish Programme for an Environmentally Adapted Energy System in the Baltic Region and Eastern Europe (EAES). In 1999, the allocation was SKr 35 million. In addition, for the period 1998-2004, SKr 70 million have been allocated for co-operative activities in bilateral, regional and international climate policy research.

Table 1

Energy and Carbon Dioxide Taxes

(SKr, 1 January 2000)

Product	*Energy Tax*	*Carbon Dioxide Tax*	*Total Tax*
Petrol *per litre*			
Environmental Class 1	3.61	0.86	4.47
Environmental Class 2	3.64	0.86	4.50
Other	4.27	0.86	0.59
Gas oil, kerosene, heavy fuel oil* *per m³*	743	1 058	1 801
Liquefied petroleum gas (LPG) *per tonne*	145	912	1 257
Natural gas and methane *per 1 000 m³*	241	792	1 033
Coal and petroleum coke *per tonne*	316	920	1 236
Crude tallolja** *per m³*	1 801	-	1 801
Electricity*** *per kWh*			
Manufacturing industry and commercial greenhouse cultivation	0	0	0
Other consumption in certain areas, mainly in northern Sweden	0.106	0.0121	0.0121
Electricity, gas, heating or water supplies in areas other than above	0.139	0.0159	0.0159
Other consumption	0.162	0.0185	0.0185

Note: Value Added Tax and sulphur tax may also apply.

* Marked oil. Marked oil is used in stationary motors and ships for heating purposes. Higher rates are paid on consumption of "unmarked" oil used for the propulsion of motor-driven vehicles and boats.

** Tallolja ("pine oil") is a byproduct from the pulp and paper industry that can be used as a fuel.

*** Electricity consumed in big electrically heated boilers (> 2MW) is taxed at higher rates during November-March. Relief from energy tax is granted if the electricity is produced in a certain manner or used for certain specific purposes, viz. produced in a wind power station; produced and consumed on board a craft or other means of transportation; used in connection with the production of electricity; produced in a reserve power station; if electricity is produced with other fuels than taxed fuels and the electricity is used by the producer himself for the supplies of electricity, gas, heat or fresh water. Energy and carbon taxes on fuels are exempted when the fuels are used for the production of electricity.

Source: Ministry of Finance.

Table 2

Energy Taxes on Fuels Consumed by Manufacturing Industry

(SKr, 1 January 2000)

Fuel	*Energy Tax*
Heating gas oil, heavy fuel oil, kerosene, crude tallolja* *per m^3*	529
Liquefied petroleum gas (LPG) *per tonne*	556
Natural gas and methane *per 1 000 m^3*	396
Coal and petroleum coke *per tonne*	460

Note: Value Added Tax and sulphur tax may also apply.

* Tallolja ("pine oil") is a byproduct from the pulp and paper industry that can be used as a fuel.

Source: Ministry of Finance.

Typical EAES projects include conversion of plants to renewable fuels, renovation of district heating distribution, energy efficiency in buildings, use of land-fill gas, and projects combining each of these elements. Future activities are expected to involve new technologies, such as combined heat and power production, utilisation of waste heat from industrial processes and applications of wind and solar energy. The geographical area and range of the programme is expected to be expanded and to include emissions trading, Joint Implementation, and Clean Development Mechanism projects. Table 3 shows the number of projects in the target countries, the level of investment involved, and the emissions reductions achieved.

Table 3

Emissions Reductions Attributed to the Swedish Programme for an Environmentally Adapted Energy System in the Baltic Sea Region and Eastern Europe

	Estonia	*Latvia*	*Lithuania*	*Russia*	*Poland*	*Total*
Emissions reduction (tonnes/year)						
Sulphur dioxide	1 320	930	900	370	0	3 520
Carbon dioxide	100 260	85 875	62 750	34 915	2 200	286 000
Nitrogen oxides	47	54	49	40	0	190
Number of projects	21	22	9	13	1	66
Investment (US$ million)	10.94	9.27	6.21	6.66	0.33	33.41

Source: Swedish National Energy Administration, October 1999.

A Parliamentary Climate Change Committee was set up in 1998 to suggest measures that could contribute to meeting Sweden's commitment under the Kyoto Protocol. The findings will serve as a basis for an enlarged programme of greenhouse gas response measures and for the decision on the ratification of the protocol.

Trends in Emissions of Carbon Dioxide

Using Swedish data[7], aggregated emissions from the energy sector fell by 30% between 1980 and 1997, mainly as a result of greater efficiency in energy use and the switch from oil to nuclear power for electricity production. Between 1990 and 1997, carbon dioxide emissions from the energy sector have increased by about 3%. Emissions from industry and the transport sectors have increased by 3% and 4% respectively, while those from electricity and district heating production have increased by 8% over the same period. Emissions from the residential and service sectors have decreased by 7% over the same period.

Carbon dioxide emissions by sector and by fuel, using IEA data, are illustrated in Figure 7. In 1998, 77% of carbon dioxide emissions in Sweden originated from the use of fossil fuels. Of these emissions, 79% are from the combustion of oil, 18% from the combustion of coal, and 3% from the combustion of natural gas. By sector, transport contributed 43% of total energy sector emissions, manufacturing industries and construction contributed 20%, electricity and heat production 15%, and the residential sector 9%.

REGIONAL ENERGY-ENVIRONMENT ISSUES

The principal regional environmental problem has been acidification of the ground and water. The granite soils in Scandinavia are less able to neutralise acidity than the limestone soils that are common in most other parts of Europe. Sweden is badly affected, with about 20% of its lakes and much of its forests in the southern part of the country suffering serious acidification damage.

Measures to reduce emissions have included maximum permissible sulphur contents in light fuel oils, requirements or guidelines on maximum emissions of sulphur and nitrogen from fossil-fuelled combustion plants, the sulphur tax and the levy on oxides of nitrogen. Figures 8 and 9 illustrate the effectiveness of domestic and European measures in reducing emissions from the energy sector. They also illustrate the continuing problem of emissions from the transport sector.

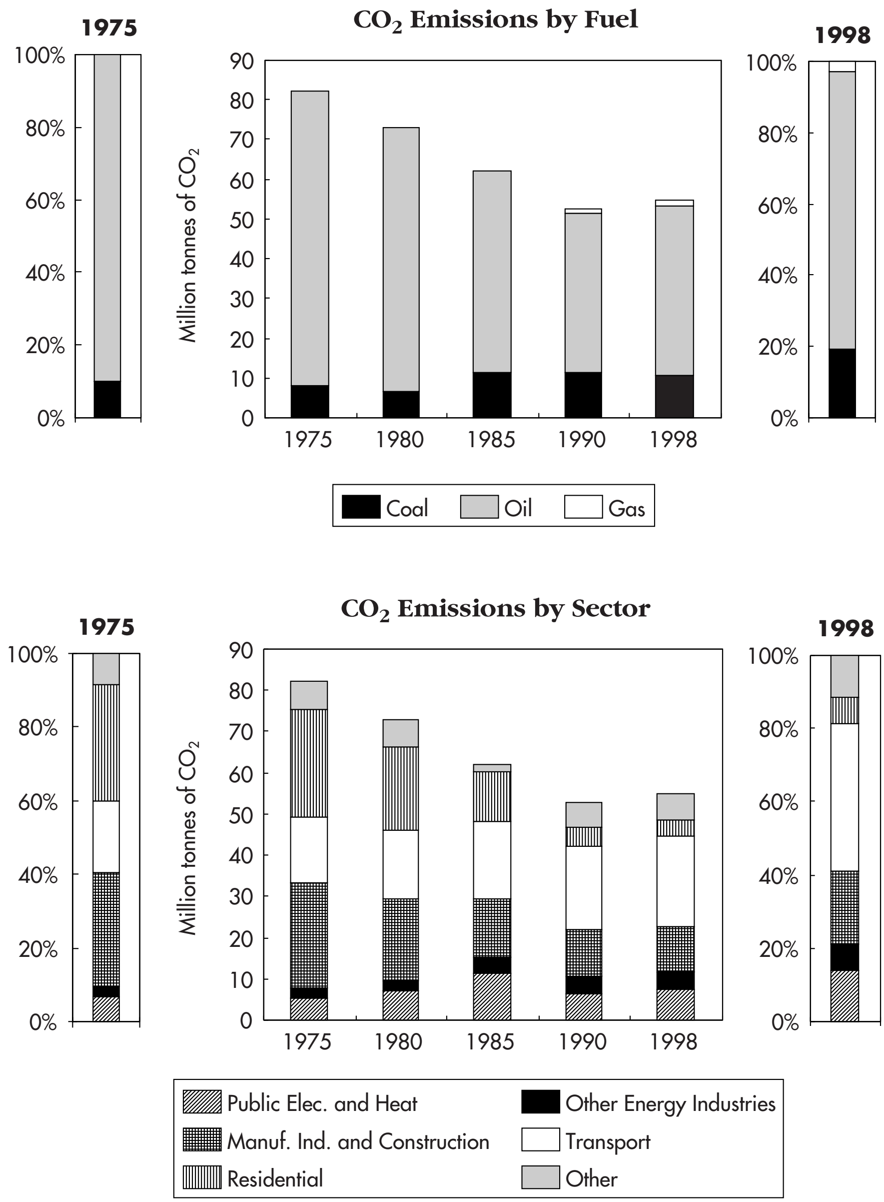
The main source of acidification in Sweden is sulphur dioxide from the combustion of fossil fuels in power generation, industrial processes, and the combustion of oil and gas in transport. Other contributory factors in acidification are emissions of oxides of nitrogen, almost 80% of which are from motor vehicles, and ammonia from agriculture. Forestry practices also contribute to the problem through clear felling and the removal of biomass, resulting in a deterioration of the soil.

For 2000, the Swedish Parliament set an objective for the reduction of sulphur emissions by 80% relative to 1980 emission levels. This objective has already been more than achieved. Sweden's objective had been to reduce emissions of oxides of nitrogen to 30% of their 1980 level by 1995. But emssions were reduced by only 21% over this period.

7. *Energy in Sweden 1999*, Swedish National Energy Administration, 1999.

Figure 7

Carbon Dioxide Emissions by Fuel and by Sector, 1975-1998

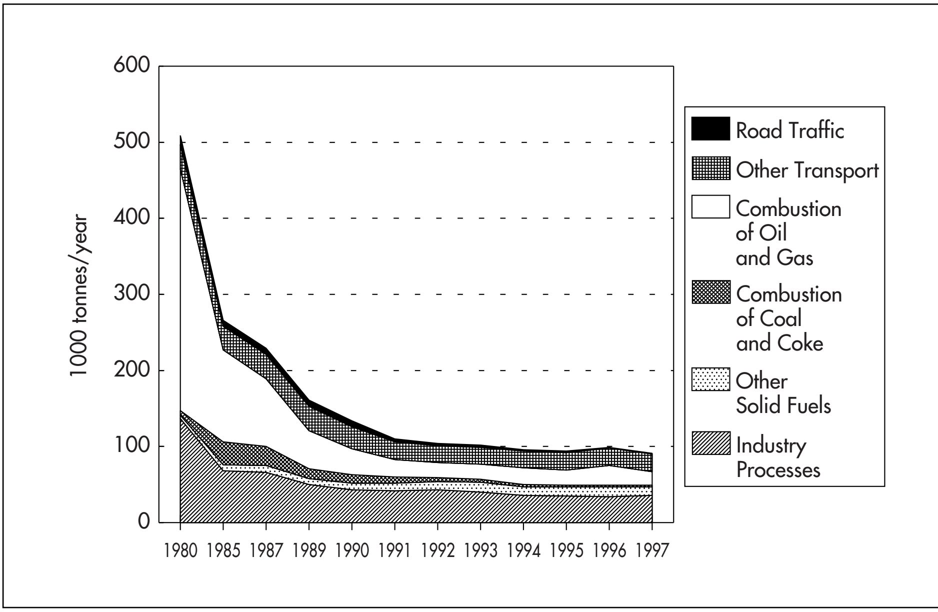


For presentational purposes, the statistical difference and the differences due to losses and/or transformation have been allocated between the sectors.

Source: *CO_2 Emissions from Fuel Combustion*, IEA/OECD Paris, 1999.

Figure 8

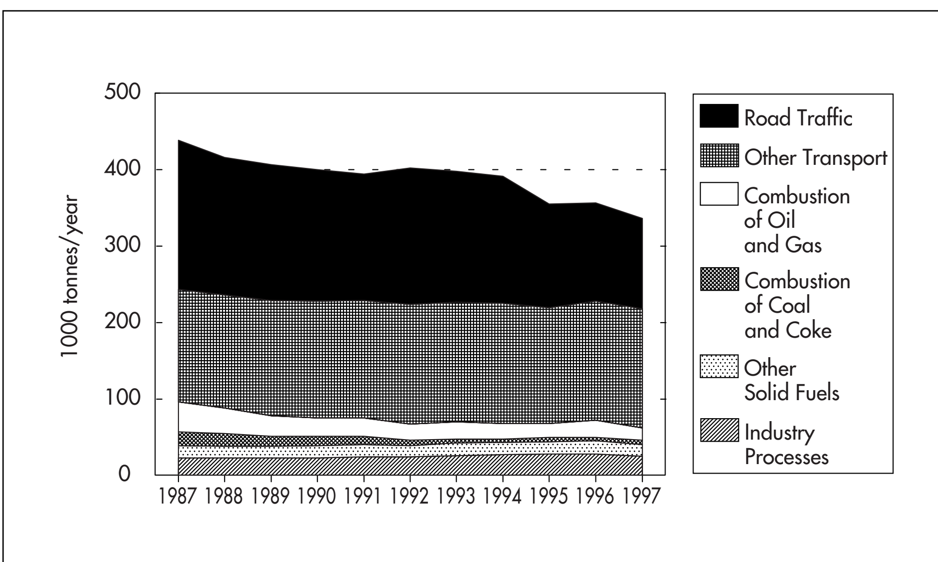
Emissions of Sulphur Dioxide in Sweden, 1980-1997



Source: *Energy in Sweden 1999*, Swedish National Energy Administration, 1999.

Figure 9

Emissions of Oxides of Nitrogen (expressed as NO_2) in Sweden, 1987-1997



Source: *Energy in Sweden 1999*, Swedish National Energy Administration, 1999.

In 1997, only 10% of sulphur dioxide and 17% of oxides of nitrogen precipitated in Sweden originated from domestic sources. The remainder came principally from Germany, the United Kingdom and Denmark. Much of the emissions from these countries, particularly of sulphur dioxide, is from combustion of coal. The 1994 sulphur protocol of the UN Economic Commission for Europe came into force in August 1998 and has resulted in significant reductions in sulphur emissions. A draft acidification programme was released by the commission in 1997 to, among other things, set national limits on emissions of sulphur dioxide, nitrogen dioxide and ammonia.

CRITIQUE

Most of Sweden's greenhouse gas emissions are from burning fossil fuels; phasing out nuclear will increase the challenge of achieving Sweden's emissions target. More than three-quarters of carbon dioxide emissions in Sweden originate from the production and use of fossil fuels, but a very significant share of total emissions is offset by forestry activities. Sweden's per capita carbon dioxide emissions are among the lowest of all OECD countries, largely because of reliance on nuclear and hydro-electric power, but also due to use of co-generation and the quite extensive use of biomass fuels. In this environment, and with increasing pressure to phase out some of Sweden's nuclear reactors, the challenge for Sweden's policy-makers is clear.

In the EU burden-sharing agreement, Sweden negotiated a 4% increase in emissions, reflecting the commitment to phase out some of the existing nuclear reactors. This is not to say that the target will be easy to achieve, but difficulty in meeting this goal may be reduced since it is now more than likely that only one reactor, or possibly two, will be closed before 2010. The future of nuclear is discussed in Chapter 7.

Any increase in Swedish electricity imports arising from phasing-out nuclear or from seasonal variations in the availability of hydro is likely to lead to an increase in global emissions since imported electricity will most probably be generated by coal-fired plants in Denmark and other countries in the region. Danish coal-fired plants used for generating electricity for export do not always have flue gas desulphurisation equipment and therefore also contribute to increased emissions of sulphur. In principle, greenhouse gas emissions attributable to exports are accounted for in the emissions inventory of the exporting country. Denmark considers this is inappropriate and discounts its reported emissions for electricity exchange[8].

Taxes have played an important role to date. Sweden was one of the first countries to introduce taxes on carbon dioxide to limit the growth in emissions. A similar approach taken for sulphur dioxide delivered an 80% reduction over the last

8. This issue is discussed in *Energy Policies of IEA Countries, Denmark 1998 Review*, IEA/OECD Paris, 1998.

two decades. In taking such unilateral action, Sweden had to tackle concerns about international competitiveness. This was achieved largely through granting tax exemptions to the industries faced with the strongest international competition. For instance, fossil fuel use in electricity generation has not been taxed, as Sweden was opening its market and had to compete with its Scandinavian neighbours.

Leadership has been shown in the use of international measures. Sweden provides an example of how domestic and international action can be harmonised. Sweden has been a long-standing partner in electricity co-operation with its neighbours. Such activity contributes both to the reliability of regional electricity supply and to the economic efficiency of the Nordic electricity system. To continue playing this role, Sweden needs to minimise the cost of its electricity, but without backtracking on its commitment to act on climate change. The electricity market is discussed in Chapter 6.

Through its project on an Environmentally Adapted Energy System, Sweden has been a leader in Activities Implemented Jointly (AIJ) undertaken in the Baltic states. Sweden currently has 66 projects under this initiative, a majority of all AIJ projects worldwide. The experience resulting from these projects will be invaluable in planning future Swedish initiatives in the Baltic states and in Eastern Europe, and for Clean Development Mechanism projects in developing countries. It also makes an important contribution to further developing these instruments in the international arena.

International agreement on emissions trading would be of major benefit to Sweden. By allowing the power sector to buy carbon dioxide emission permits from the international market, Sweden would ensure that its power sector competes as nearly as possible on equal terms with other suppliers, while also encouraging the sector to develop and implement least-cost technologies to reduce its emissions domestically. Such a system would create the appropriate price signal to guide future investment decisions in the power sector.

Renewables are a focus of policy, but natural gas and sinks are two areas deserving closer consideration. On the domestic front, Sweden, like most other IEA Member countries, is still developing a strategy for fulfilling its Kyoto commitments. Reductions from new measures will have to be significant, to offset increases from any reduction in nuclear power. The question arises whether renewable energy can be sufficiently developed in time to have a significant impact. In 1997, solar, wind and other renewables (excluding hydro and biomass) represented less than 1% of Sweden's energy supply. This issue is taken up further in Chapter 7.

Natural gas is not regarded as an option for environmental policy in Sweden, unlike in other European countries. While natural gas necessarily involves higher emissions than nuclear power, its contribution to balancing economic and environmental objectives in the Swedish context should not be dismissed. This issue is discussed further in Chapter 8.

Nearly 90% of the land area of Sweden is under forest or other woodland, bogs, fens and lakes. The Swedish forest is an important sink[9] for carbon since about 25% of a tree is carbon. The annual growth of the forest exceeds removals, which means that carbon dioxide is sequestered (accumulated) in the biomass. The net accumulation of carbon dioxide in Sweden is estimated at 30 million tonnes per year, corresponding to about one-half of the annual emissions of carbon dioxide from fossil sources in Sweden. Most of the forest increment is anthropogenic, due to forest management practices that increase the stock of standing timber at a rate greater than would be the case in a natural forest.

Sweden plans on increasing the use of biofuels, largely forest wastes. The use of biofuels will reduce the value of the forests as carbon sinks. Consideration may need to be given to the value of the forests as sinks, compared with the value to be derived from their greater exploitation for biofuels. Biomass can only be considered neutral in emissions terms, and renewable, if annual growth is equal to or exceeds removals. It will be important to monitor the balance of growth and removals as demand for biofuels rises.

RECOMMENDATIONS

The Government of Sweden should:

- ☐ Move quickly to settle a package of cost-effective policies and measures to meet Sweden's greenhouse gas target.
- ☐ Integrate environmental concerns (local, regional and global) into energy policies, while also maintaining the objectives of security of supply and competitiveness.
- ☐ Continue the pilot development of the Kyoto flexible mechanisms in the Baltic Sea region in anticipation of international agreement on the implementation of the mechanisms.
- ☐ Take into account the role of sinks as a potentially important measure for use by Sweden.

9. A "sink" is any process, activity or mechanism that removes a greenhouse gas, an aerosol or precursor of a greenhouse gas from the atmosphere.

5

ENERGY EFFICIENCY

TRENDS IN ENERGY END USE

Energy Consumption

Final energy consumption has been relatively stable between 1985 and 1997. Final energy consumption of electricity has increased on average at about 3% per year since 1973 amounting to about 11 Mtoe or about 30% of total final energy consumption in 1998, but during the recent years there has been a considerable easing-off in the rate of growth. The greatest increase is to be found in the residential and service sectors because of a change from oil to electricity for heating, coupled with a greater use of electricity for building services systems. District heating accounts for about 11% of total final energy consumption.

Energy Intensity

Two general indicators illustrate the overall energy efficiency trends in Sweden: primary energy intensity (i.e., the ratio of primary energy consumption to GDP), and final energy intensity (i.e., the ratio of final energy consumption to GDP). These indicators illustrate the energy productivity of the economy as a whole, and of final consumers. Final energy intensity gives an indication of the overall energy efficiency trends of final consumers.

Table 4

Variations in Primary and Final Energy Intensities in Sweden

(% per year)

	1973-1982	*1982-1990*	*1990-1997*
Primary intensity	–1.1	–0.3	–0.3
Final intensity	–2.5	–1.6	+0.1

Source: Swedish National Energy Administration.

Variations in final energy intensity are caused by many factors: climate fluctuations from one year to the other, changes in the structure of GDP, changes in lifestyles (more cars, bigger cars, larger dwellings) or in the economy not reflected in the structure of GDP, as well as changes in energy efficiency. The role of climatic variations is very important in a country with a varying climate such as Sweden's, when the focus is on short-term variations, but is negligible over long periods.

Final energy intensities adjusted to allow for climate variations and structural changes in the composition of GDP are summarised in Table 5. The observed declining rate in energy intensity during recent years is affected by the recession in the Swedish economy during the early 1990s. If the figures were corrected for lower economic growth in the period 1990-1994, the decline in energy intensity would probably be in line with results in the 1980s.

Table 5

Variations in Adjusted Final Energy Intensities

(% per year)

	1982-1990	*1990-1994*
Final intensity with climate corrections	–1.2	0.1
Final intensity at constant structure with climate corrections	–0.8	1.6
Role of structural changes	–0.4	+1.7
% of structural changes in the final intensity decrease	33	

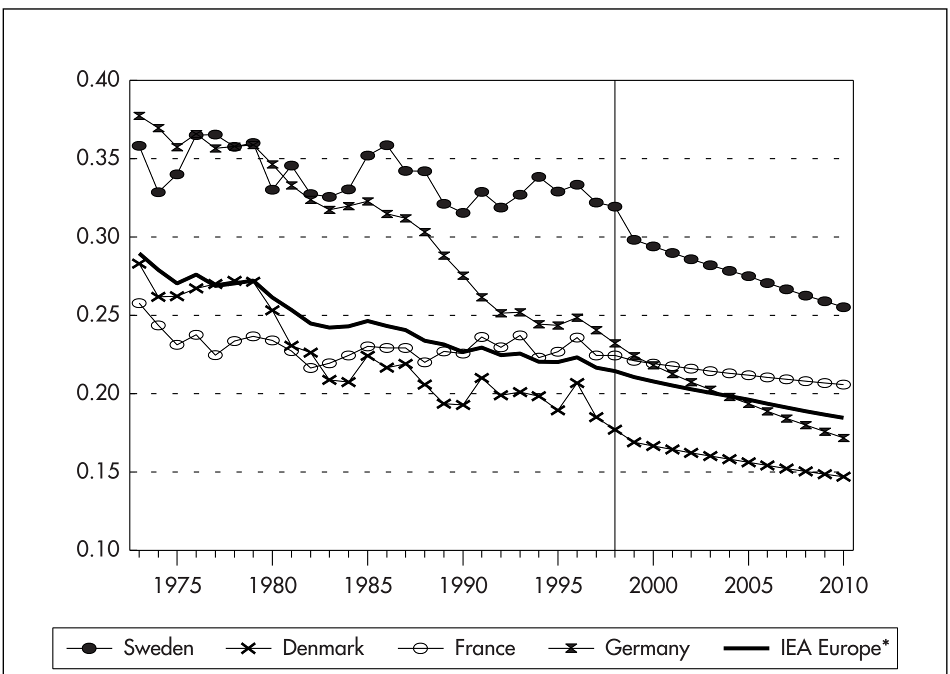
Source: Swedish National Energy Administration.

Figures 10 and 11 compare energy intensity in Sweden with other selected IEA countries.

Figure 10

Energy Intensity in Sweden and in Other Selected IEA Countries, 1973-2010

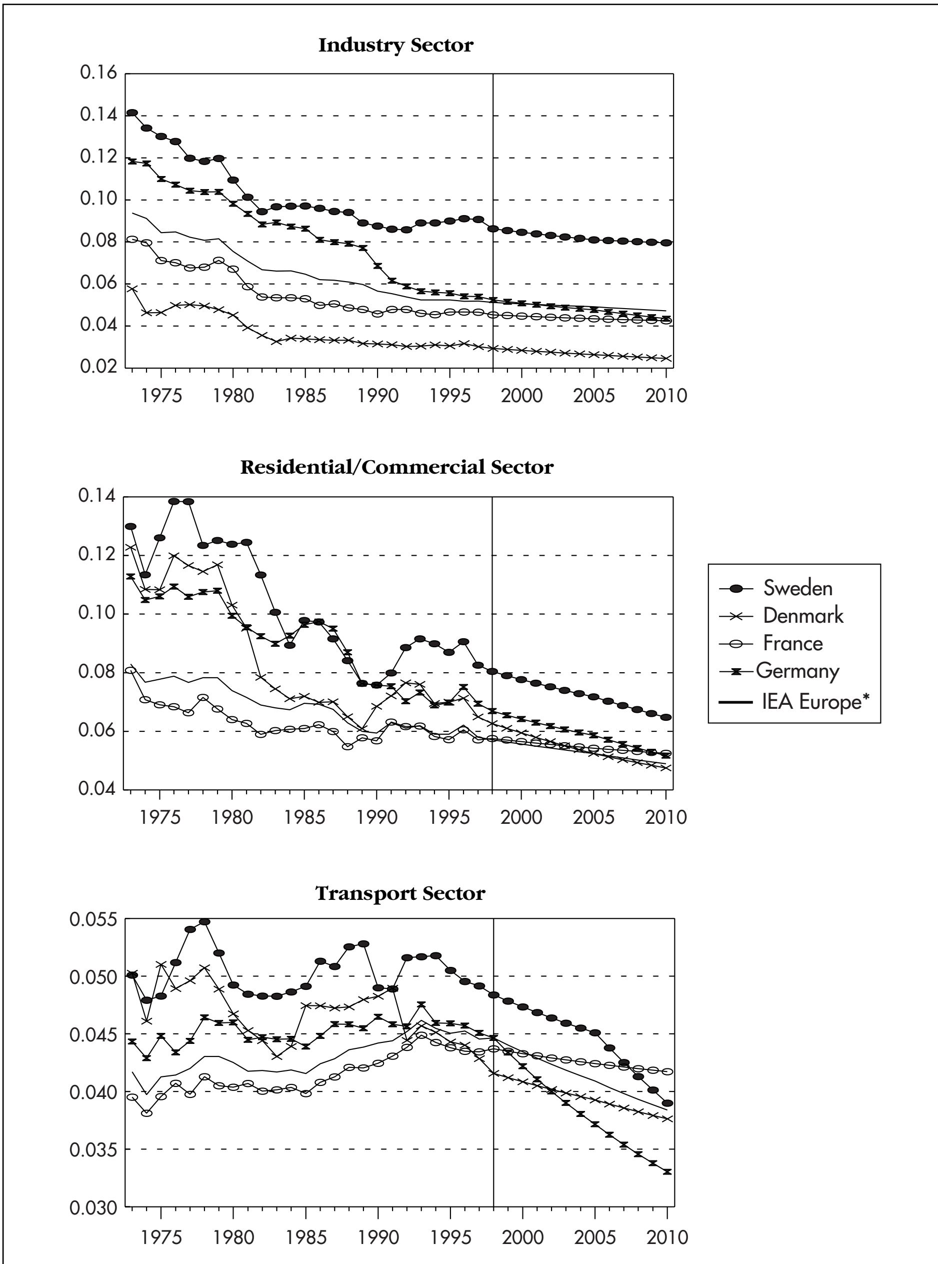
(Toe per thousand US$ at 1990 prices and purchasing power parities)



* Excluding Norway from 2000 onwards.

Sources: *Energy Balances of OECD Countries,* IEA/OECD Paris, 1999; *National Accounts of OECD Countries*, OECD Paris, 1999, and country submissions.

Figure 11
Energy Intensity by Sector in Sweden and in Other Selected IEA Countries, 1973-2010
(Toe per thousand US$ at 1990 prices and purchasing power parities)



* Excluding Norway from 1999 onwards.

Sources: *Energy Balances of OECD Countries,* IEA/OECD Paris, 1999; *National Accounts of OECD Countries*, OECD Paris, 1999, and country submissions..

SECTORAL TRENDS

Residential/Commercial/Service Sector

In 1998, the residential/commercial/service sector accounted for about 14 Mtoe or over 40% of Sweden's total final energy use[10]. Total energy use in the sector has remained relatively stable since 1970 on a temperature-corrected basis, but the composition of energy use has changed over the period. Electricity and, to a lesser extent, district heating, have grown, replacing the use of oil products. The use of biofuels and peat has remained stable over the period. Total use of fossil fuels has fallen by nearly 70% in the period 1970 to 1998. Much of this reduction is due to a move from the use of oil for heating to electricity and district heating.

Over 60% of the energy use in this sector is accounted for by space heating and domestic hot water production and about 26% by the powering of domestic appliances. Energy used in land use applications accounts for a further 5%, holiday homes for 2%, and other service applications the remainder.

Final energy consumption used in providing services increased by 1.1% per year from 1983 to 1996 and amounted to 4.2 Mtoe in 1996. For electricity, the intensity increased by 2% on average per year between 1983 and 1996, after a rapid growth of 6% per year in the 1970s. The increasing numbers of electrical appliances, such as computers and air-conditioners, may explain the increase. The relatively slow growth rate during the latter period is probably explained by greater efficiency of electricity use. Lighting and ventilation in the service sector have become more efficient as a result of more operational control and correct sizing of systems at the time of installation.

Energy use for space heating and hot-water production is affected by external temperature conditions, and can vary randomly from year to year. 1998 was 5% warmer than an average year, so energy use for space heating was lower than normal. Allowing for such variations, energy use in the sector as a whole rose by 0.7% in 1997-1998. Nevertheless, there has been a regular decrease in energy consumption per dwelling between 1983 and 1996 of 0.7% per year on average for total household energy use, and of 1.5% per year for space heating.

Factors affecting energy use in the residential/commercial/service sector include:

- Increase in the number of dwellings (single-family houses and apartment buildings) by 30% in the period 1970 to 1998, but very low rate of construction in the 1990s, amounting on average to 14 300 dwellings per year.

- The application of building standards and a decrease in the size of new dwellings. New single-family houses and new multi-family houses built according to the

10. Swedish National Energy Administration; 35.3% when using IEA definitions. This section uses Swedish national data to allow consistent description of components of sectoral energy use.

latest standards consume about 24% and 27% respectively less energy than similar dwellings built between 1977 and 1980. Compared with new buildings from 1981 to 1989, the decrease amounted to 20% for dwellings in multi-family houses and 5% for single-family houses.

- Increased use of electricity and hybrid electricity/wood or oil heating in detached houses, and district heating in apartment buildings, replacing oil for space heating. Almost 30% (1997) of detached houses now use hybrid systems as their main heat source.

- Considerable increase in the number of small heat pumps for space heating and hot-water production.

- Increasing use of various types of energy conservation measures, such as retrofitting additional thermal insulation and upgrading windows in older buildings, and use of more energy-efficient equipment.

- Greater ownership and use of domestic appliances, computers and air-conditioning.

- Substantial increase in the total floor area of office premises. There is considerable potential for further improvements in the efficiency of electricity use in commercial buildings.

Industry Sector

In 1998, the industry sector accounted for 38% of Sweden's total final energy use. Of the sector's total energy consumption in 1998, electricity accounted for 36%, and biomass, peat and wastes 34%. Nearly 80% of the biomass, peat and wastes (about 27% of total industry sector energy) is used in the pulp industry, mainly in the form of black liquors[11] and manufacturing wastes. Natural gas accounted for only 2.5%. Final energy use in the industry sector was composed of 27% fossil energy.

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

Energy consumption in industry grew at an average annual rate of 1% between 1983 and 1990, and a little faster (1.2%) from 1990 to 1996. Energy use follows variations in industrial output, but is affected in the longer term by changes in the types of

11. Black liquors are a by-product of chemical pulp manufacture and are burned to recover process chemicals and to release energy.

goods produced, technical developments, taxes and energy prices. Between 1990 and 1992, industrial output fell by 6%, energy use by 5% overall and electricity by 6% as the recession hit the electricity-intensive sectors harder. Industrial output and energy consumption recovered after 1993. But while output in 1998 was 43% higher than in 1992, energy use rose by only 12% and electricity use by about 8%.

Major improvements in energy intensity have been made in Sweden's traditional industries. In 1996, energy consumption per unit of steel production was 58% less than in 1980. For pulp and paper, the unit consumption was 24% lower in 1996 compared to 1980. Allowing for structural changes, energy efficiency in manufacturing industry improved until 1990, but the rate of improvement declined after 1982 (1.1% per year against 1.6% per year). During the 1990-1992 recession there was no improvement in energy efficiency, but it resumed after 1992. A major increase in mechanical engineering industry output has been achieved with almost unchanged electricity use, resulting in a substantial fall in electricity use in the industry sector overall.

Transport

In 1998, domestic transport accounted for over 22% of total final domestic energy use. Energy use in transport is almost entirely in the form of oil products, primarily petrol and diesel which made up 70% of total energy use in the domestic transport sector.

Transport sector energy use increased substantially at the end of the 1980s, but fell by 4% in 1990. After a period of wide variations, demand increased in 1994 as economic activity picked up, resulting in an increase of nearly 3%. Annual growth in demand has been steady at 1% to 2%, except in 1996.

In general, improvements in fuel economy have been offset by a switch to bigger cars and longer distances travelled. The specific consumption (i.e. consumption per kilometre under test conditions) of new passenger cars was 9% lower in 1988 than 10 years earlier. From 1988 to 1996, the specific consumption of new cars has increased slightly, which can be partly explained by the switch to bigger cars.

The unit consumption per car (i.e. actual consumption) decreased slightly by 0.5% per year between 1986 and 1997. The average unit consumption of cars is currently about 1.1 toe per car. The average unit consumption depends on the average specific consumption of cars (litres consumed per 100 kilometres) and the average distance driven by cars (kilometres per year). As the specific consumption is decreasing, the smaller reduction of the unit consumption stems from an increase in the average distance travelled by cars. Cars are more efficient, but the larger share of big cars has influenced the specific consumption (Table 6).

Table 6
Unit Consumption and Specific Consumption of Cars in Sweden
(% change per year)

	Unit Consumption	*Specific Consumption*	*Influence of Distance Travelled by Car*
1986-90	−1.7	−2.3	+0.6
1990-97	+0.2	0	+0.2

Source: Swedish National Energy Administration.

Since 1990, trucks have shown greater improvement in efficiency than cars, with a decrease in specific consumption of 2.2% per year, and a steady decrease in unit consumption per tonne-kilometre of 2.4%.

Table 7
Energy Efficiency Indicators for Road Transport of Goods
(% change per year)

	Unit Consumption (toe/tonne-km)	*Specific Consumption (litres/100 km)*	*Traffic Management (tonne-km/veh-km)*
1986-90	−3.6	−0.2	+3.4
1990-96	−2.4	−2.2	+0.2
1986-96	−2.4	−1.4	+1.0

Source: Swedish National Energy Administration.

ENERGY EFFICIENCY PROGRAMMES

Government policy is intended to increase knowledge about, and stimulate interest in, economically and environmentally sound energy efficiency. A total of SKr 450 million have been allocated over a five-year period for the procurement of energy-efficient technology, as well as for information, training, municipal energy advisory services and the testing, marking and certifying of energy-requiring equipment. Subsidy schemes for measures to reduce electricity consumption in households have also been in place since mid-1997.

Residential/Commercial Sector

Building Code

Thermal insulation requirements in building codes were introduced in 1960 and revised in 1975, 1980, 1988 and 1998. In some of these revisions the changes were related to energy requirements. The revised building regulations of 1988 introduced a building performance standard instead of requiring insulation for certain building components. The building performance standard only includes requirements concerning function. The code only states what, in principle, should be achieved, and not how it should be done. The aim is to promote cost-effective solutions. This means that the building code does not include specific requirements for thermal insulation or windows.

Testing and Labelling

SKr 40 million have been assigned to information on, and trials, testing and marking of energy-using products and systems over a five-year period from July 1997. The National Consumer Board is responsible for the programme.

A national labelling programme for household appliances has been in effect since 1993. Approximately 25% of Sweden's appliance stores use the programme in their marketing activities. It corresponds well to the 1995 EU labelling directive for refrigerators/freezers. Voluntary energy efficiency labelling has been implemented for computer screens.

Sales statistics on white goods show a large increase in sales of efficient refrigerators/freezers. EU label categories A and B achieved a 70% market share by 1998. Probable causes are a combination of the impact of the EU label, national information campaigns and price changes.

District Heating

District heating was first introduced by local authorities in the 1940s. Its use spread during the 1950s and 1960s as a result of opportunities presented by extensive investments in new housing and other buildings. The biggest growth in district heating occurred during the period 1975 to 1985. Until the beginning of the 1980s, most district heating systems were operated as local authority services. However, during the 1980s and 1990s, most have been restructured as limited companies owned by local authorities. There were about 220 companies supplying heat in Sweden in 1997. About 68% of the companies are owned by local authorities, 13% are privately-owned, 10% are owned directly or indirectly by the state and 9% are operated as local authority services.

The nominal connected load in 1997 was about 22 GW, supplied through about 9 600 km of mains. During the year, 42.2 TWh of heat were supplied, equivalent to 43.1 TWh after correction for statistically averaged climatic conditions. Fifty-six per cent of the heat was supplied to residential users, almost 36% to the service sector and over 8% to industry.

The Swedish National Energy Administration is responsible for the administration of financial support for conversions from electric heating to district heating that was approved by Parliament in the 1997 energy policy decision. In 1998 and 1999, a total support of about SKr 300 million was granted, leading to the connection of 9 504 houses, 12 436 apartments in apartment blocks, and 174 other premises to district heating grids. This is estimated to amount to a reduction in electricity use of 175 GWh. Technical developments have improved the economic viability of connecting smaller residential areas to district heating supplies.

Financial Support

The 1991 Energy Policy Bill included a programme aimed at promotion of efficient use of energy. About SKr 950 million was allocated for a seven-year period. The main purpose of the programme was to promote market introduction of new energy-efficient technology and the main tools to achieve the goals of the programme were technology procurement, dissemination activities and support for demonstration of new technology.

Information, Education and Motivation

In 1993, the Parliament allocated SKr 5 million to the Swedish Environmental Protection Agency for education and raising public awareness. The funding has been used for seminars, brochures, newsletters, fairs, exhibitions, etc. A campaign was held to promote energy-efficient household appliances.

Parliament has allocated funds amounting to SKr 250 million for local authority energy advisory services. The National Energy Administration is responsible for disseminating information concerning opportunities for using energy-efficient technology, coupled with training and the provision of advisory services.

Industry

Energy Advisers

Funding was included in the 1991 Energy Policy Bill for technical assistance projects and employing advisers for industry. The projects have been relatively small-scale. Studies of savings potentials in enterprises and industries have also been conducted.

Standards and Regulatory Instruments

Voluntary standards have been established for lighting, fans, pumps, ventilation systems and other products used in production. Production standards have been established in the engineering, plastics, metals, saw-mill, rubber, and pulp and paper industries.

EKO Energy Voluntary Agreements

EKO Energy is a voluntary agreement programme of the National Energy Administration for improving energy efficiency in non-energy-intensive industrial companies. EKO was part of the earlier programme for promotion of energy efficiency, and began in 1994. Voluntary agreements typically include the following elements:

- The National Energy Administration undertakes a comprehensive inventory and analysis of energy use in the company's production processes and premises, including a list of suggested measures to be taken. The suggested measures usually concern the building (ventilation, heating, lighting) and surrounding equipment (compressed air).
  - The company sets energy and environmental targets and establishes an action plan based on reasonably economically viable measures that the inventory and analysis suggest. The action plan has to be revised every year and submitted to the National Energy Administration.

- The National Energy Administration provides a comprehensive material flow analysis as well as an introductory comparison of the company environmental awareness and environmental management with guidelines based on EMAS or ISO 14001 standards.
  - The company establishes long-term energy and environmental policy in accordance with EMAS or ISO 14001.

- The Swedish National Energy Administration provides an educational package on the process of energy-efficient industrial purchasing, ENEU 94. ENEU 94 introduces investment calculations using life-cycle analysis and not pay-off analysis. This is regarded as a very important part of EKO Energy and also the most difficult part for the company to fulfil.

- The company establishes ENEU 94 as a company standard method for purchasing energy-efficient machines and tools.

- The National Energy Administration arranges goodwill activities such as spreading success stories through the press and/or appointing the most successful EKO energy company of the year in a ceremony covered by the media.

- Should no action be taken by the company, no sanctions are applied against the company other than the loss of goodwill.

More than thirty Swedish companies are involved in EKO energy activities. No company has yet found that it could afford not to follow the expert advice on energy efficiency measures. Energy efficiency has mainly been obtained in areas such as ventilation (27%), motors and drives (22%), lighting (2%), compressed air (7%), heating (8%) and process measurement areas (32%).

In 1998, ten companies reported energy savings of 0.098 TWh (12% of their total consumption), of which 0.036 TWh was electricity. The savings per energy efficiency measure range from 4% to 28%.

Development of Long-Term Agreements

The EKO Energy programme is currently being phased out, and long-term agreements are being considered as a way to promote energy efficiency. A feasibility study will investigate the introduction of environmental agreements between the government and certain energy-intensive industry sectors in Sweden with the aim of promoting energy efficiency. The intention is to continue to develop the conditions for long-term agreements in Sweden.

Technology Procurement

Technology procurement of energy-efficient products was developed originally by the National Board for Industrial and Technical Development as a means of encouraging the development and marketing of such products. The programme is now the responsibility of the National Energy Administration.

Technology procurement activities aim to encourage competition to make more energy-efficient products. Consumer representatives are invited to submit proposals for products such as a better refrigerator. These potential purchasers indicate that they are prepared to place an order if specified conditions are fulfilled. Suppliers then compete on the basis of design and price. The National Energy Administration organises the competition and assists the purchasers of the first series of products.

About 30 technology procurement projects have been organised and over 1 500 other related projects initiated. About 100 incentive agreements have been signed. The Technology Procurement Programme has resulted in the introduction of 15 new technologies in the residential and commercial sectors. The technologies include refrigerators/freezers, two types of washing machines, tumble dryers, heat pumps, efficient windows, new detached houses, radiator control systems, water heaters, systems for converting electrically heated houses to district heating, refrigerated display cases, ventilation units, video display units, ballast and lighting fixtures. The procurement procedures include disseminating information. After market introduction, sales statistics and market surveys of the major target groups are used to monitor progress.

The technology procurement projects have resulted in a clear technology leap for refrigerators/freezers and have accelerated the mass production of low-energy appliances. The market for improved high-frequency fluorescent lighting systems has grown rapidly. The success of technology procurements for visual display units and heat pumps has also achieved savings and stimulated the market. However, the technology procurement for high-performance windows was a failure: the market introduction of high-performance windows coincided with a recession in the building industry and the proposed windows were not competitive with ordinary, cheaper windows.

For expenditure over a seven-year period, Parliament has allocated SKr 100 million for the development and introduction of energy-efficient technology through technology procurement.

Corporate Commitment and Recognition

Corporate commitments have been made by large chain stores with their own manufacturing facilities. The companies have agreed with their suppliers, customers and the National Energy Administration that energy-efficient products are to be used or produced in virtually all stages of production and distribution. Under voluntary agreements signed by several large enterprises, energy-efficient methods are required for all semi-manufactured goods bought by the companies, as well as for all production processes. Products used in the distribution and marketing of goods, such as lighting and ventilation, must also be energy-efficient. For products sold by the companies, an adequate and representative selection of energy-efficient technology must be offered. Participating companies receive a small subsidy to defray some of the cost of adjusting their inventories and production methods to include energy-efficient products and processes.

Information

The Electricity Conservation Programme provides technical information on energy use in small and medium-sized industries. Industry organisations co-operate by sharing experiences of energy efficiency efforts. About SKr 10 million are budgeted for these activities.

Transport

1998 Transport Policy

In 1998, the Parliament adopted a new transport policy based on the government bill Transport Policy for Sustainable Development. The legislation requires that transport policy shall contribute to social, cultural, economic and ecologically sustainable development.

The same year, the government adopted a ten-year investment plan for railway infrastructure amounting to SKr 36 billion. This will enable completion of work to adapt the rail network for high-speed trains. Since freight traffic is currently struggling with capacity problems on several lines, SKr 10 billion are targeted on freight traffic. In addition, there are other projects involving improvements for both passenger and freight traffic.

For the road network, there has been a reorientation from big investments in the national trunk roads to increased efforts to improve the accessibility, environmental impact and safety of existing roads. A plan for the period 1998-2007 has been prepared by regional and central authorities.

Environmental Targets

For the transport sector, the government has set a target for carbon dioxide emissions equal to emissions in 1990. Support is given to local authorities for actions to reduce emissions, including improved public transport, modal shifts and multi-modal transports, and local awareness campaigns. The *Final Report by the Government Commission on Transport and Communications*, 1997, proposed the following targets for the transport sector (Table 8).

Table 8
Environmental Targets for the Transport Sector

Substance	*Base Year*	*Intermediate Objective*	*Long-term Objective*	*Achieved to 1995*
Carbon dioxide	1990	–15% by 2020	–60% by 2050	+10%
Nitrogen oxides	1980	–50% by 2005	–80% by 2020	–11%
Sulphur	1980	–45% by 2005	–90%	–37%
Volatile organic compounds	1988	–70% by 2005	–85%	–26%

Source: *Heading for a New Transport Policy: Final Report by the Government Commission on Transport and Communications*, The Swedish Government Official Report SOU 1997:35, 1997.

A new authority, Rikstrafiken, has been created to promote the long-distance public transport system. The authority will encourage use of public transport and support unprofitable public transport that is judged to be socially desirable.

Changes have been made to taxation of company cars so that drivers pay for petrol either directly or indirectly. Further changes have been proposed by the government in a white paper. Among other things, vehicles using non-conventional fuels would not be disadvantaged by taxation. The white paper is now subject to a consultation procedure. New electric cars and electric hybrid vehicles are exempt from motor vehicle tax for five years as from 1 July 1999.

Information

The Consumer Agency and the Swedish National Road Administration provide consumers with information concerning the energy consumption of vehicles. The Swedish National Road Administration and the Swedish National Energy Administration co-operate with associations of driving teachers to improve knowledge of energy-efficient driving behaviour. Information campaigns also encourage companies to improve efficiency in their logistics and transport planning.

Car buyers must be given information consistent with the Consumer Agency's *Guidelines for Information about Fuel Consumption, Carbon Dioxide Emissions and Environmental Class for New Cars*. Since 1977, the Consumer Agency has published annually a brochure on fuel consumption of new cars. The latest issue of *Which car do you choose? Hard facts about fuel consumption, carbon dioxide emissions and environmental class*, must be available in every outlet selling new cars in Sweden. Car suppliers also have to provide information about fuel consumption in all advertisements for specific models of new cars. Information is also available on the Internet.

Taxation

Taxation of road traffic is an important element of transport policy, providing an instrument to influence the composition and turnover of the motor vehicle fleet, thus improving its average fuel efficiency. Since 1991, the tax on petrol includes a carbon dioxide tax that is estimated to have generated about 11% of the state's revenues from road traffic-related taxes in 1996. VAT of 23.46% was imposed on petrol in 1990, and has since been raised to 25%. Up until October 1993, a tax was paid on diesel-powered trucks, cars and buses, based on distance driven (kilometre tax). This tax required border controls and was replaced by a diesel oil tax after Sweden joined the EU. Sweden also levies sales tax, annual vehicle tax, and user charges. Sales taxes are levied on light vehicles only. The annual vehicle tax is differentiated according to vehicle weight and fuel. Only heavy goods vehicles are charged so-called user charges (Eurovignette).

Rail transport is excluded from energy taxes, but there is a user fee system. Parliament reduced this fee in 1998 in order to increase the relative competitiveness of rail transports.

Energy tax does not apply to maritime and air transport. Shipping pays environmentally differentiated seaway charges, and aviation pays route charges according to the Eurocontrol procedure.

MONITORING AND ASSESSMENT

The various energy efficiency programmes are systematically evaluated each year and the results are submitted to the government. One of the main tasks assigned to the National Energy Administration is to monitor the implementation of the various measures. As it is often difficult to quantify the gains in energy efficiency from the programmes, new methods for their evaluation and assessment are considered necessary.

In 1998 an *ad hoc* group was formed, composed of representatives from the various ministries with responsibilities for the energy policy programme, led by the Ministry of Industry, Employment and Communications. The National Energy Administration was represented on the group, as well as representatives of government agencies with expertise in economic evaluation and administrative development. The task of the group was to design a plan for monitoring and evaluating the energy policy programme. As part of its work within the group, the National Energy Administration has developed performance indicators for the various activities within the programme. For example, the indicators for the technology procurement activities are:

- Number of projects.
- Cost of projects and subsidies.
- Number of units sold in the first series of the new technology.
- Market share for the procured products and systems.
- Increased efficiency per unit with the new technology.

The work of the group resulted in a plan for monitoring and evaluating the programme, which was presented to Parliament in the Budget Bill for 2000.

External evaluations of elements of the energy programme have also been undertaken.

CRITIQUE

Energy efficiency has not made significant progress since 1988. A review of energy efficiency in Sweden prepared by Statistics Sweden and published by the National Energy Administration in March 1999[12], concludes that energy efficiency improvements have slowed down to an almost negligible rate since 1988. By sector the report concludes that:

- Energy intensities by industry sector are on average stable, with some energy-intensive branches such as steel and chemicals continuing to improve their energy efficiency.
- On average, less energy is used per dwelling for space heating, largely as a result of the switch to electricity and a greater number of more energy-efficient dwellings, and, to a lesser extent, as a result of the decreased average area of new dwellings.
- No energy efficiency improvements have occurred in cars since 1986. An increased share of larger cars in the fleet has offset any improvement in energy-efficient car design.
- Energy efficiency in trucks per tonne-kilometre continues to improve steadily as a result of truck design and use of larger trucks.
- Energy intensity in the service sector has been stable since 1990, but consumption of electricity per unit of value added has steadily decreased, mainly as a result of improvements in lighting and ventilation.

Energy efficiency is an important means of achieving two policy goals: sustainable growth and phasing out nuclear power. The results of the 1999 review of energy efficiency are not surprising, and are similar to general trends seen in other IEA countries. The significance for Sweden might be considered from two general policy viewpoints: the need to improve energy efficiency as a means of securing economic growth while achieving a reduction in greenhouse gas emissions, and to reduce electricity consumption to permit phasing out nuclear power.

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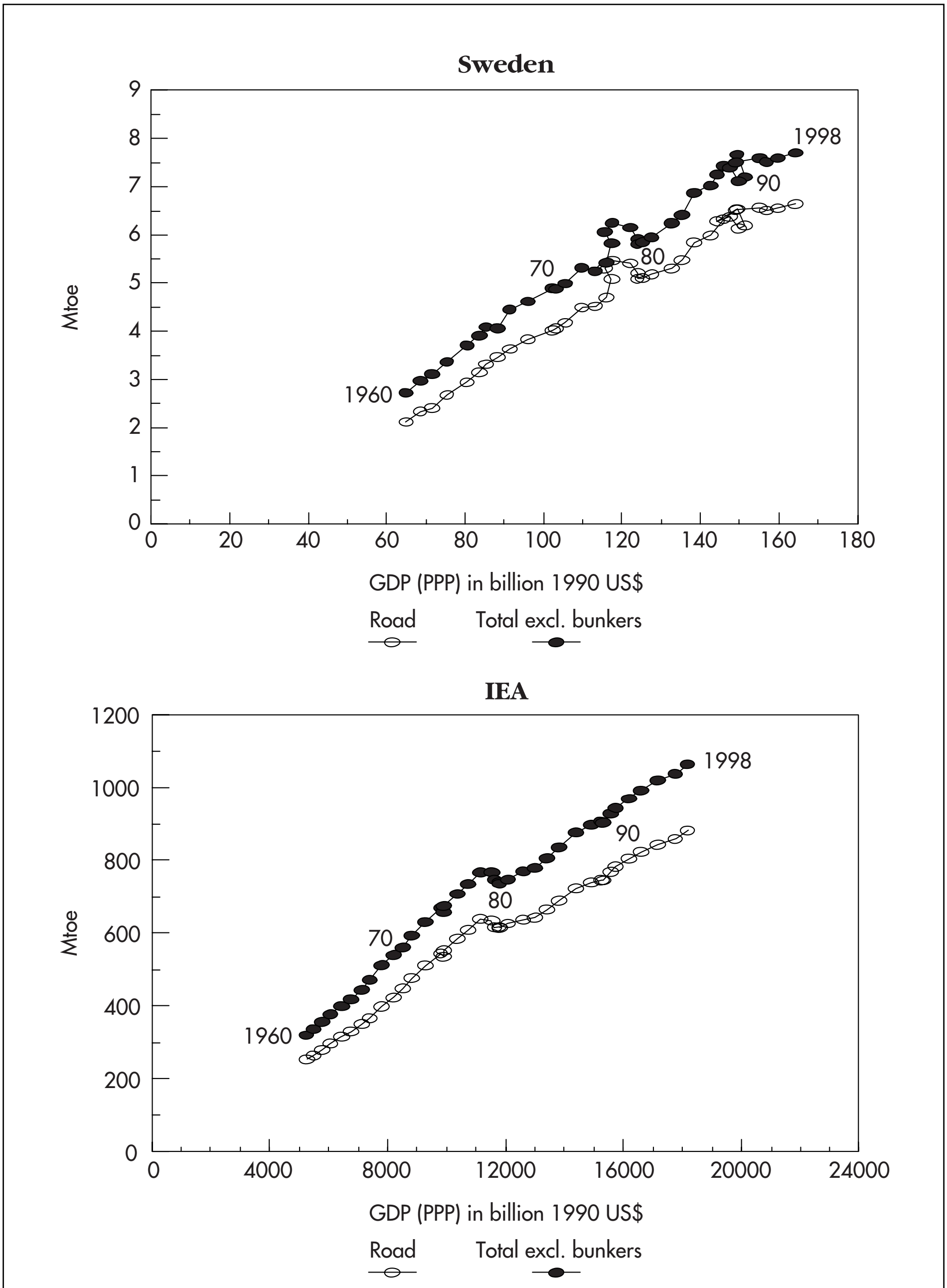
12. *Energy Efficiency in Sweden - Analyses based on the ODYSSEE Data Base from the SAVE Project "Cross-country comparison on energy efficiency indicators"*, Statistics Sweden and the Swedish National Energy Administration, March 1999.

Figure 12
Total Final Consumption vs GDP in the Transport Sector in Purchasing Power Parities, 1960-1998



Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and *National Accounts of OECD Countries*, OECD Paris, 1999.

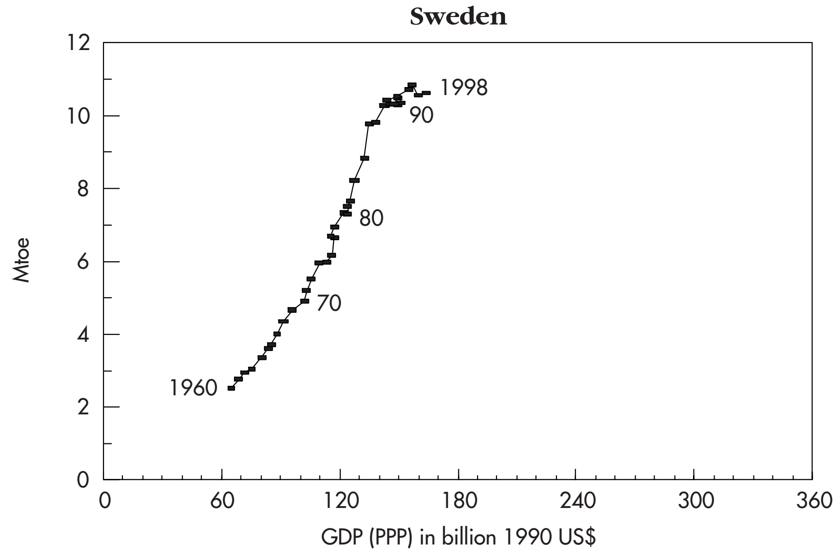
In addition to strong measures in other sectors, major steps have been taken to improve performance in the transport sector. A combination of economic measures, regulations, voluntary measures and information programmes have been effective in bringing about considerable improvement in energy efficiency in the industry and residential/commercial sectors. As in other IEA countries, making progress in transport has been more difficult. An ambitious target has been set to stablilise carbon dioxide emissions from the transport sector at the 1990 level by 2010. Achieving the goal has strong support, and it has triggered a number of measures such as considerable investment in the rail network and freight transport. Taxation of fuel and vehicles is already high and related to both emissions and vehicle weight, and offers little room for major change. Despite the goal and the strong supporting measures, it will be difficult to change the historical relationship between transport energy consumption and economic growth illustrated in Figure 12.

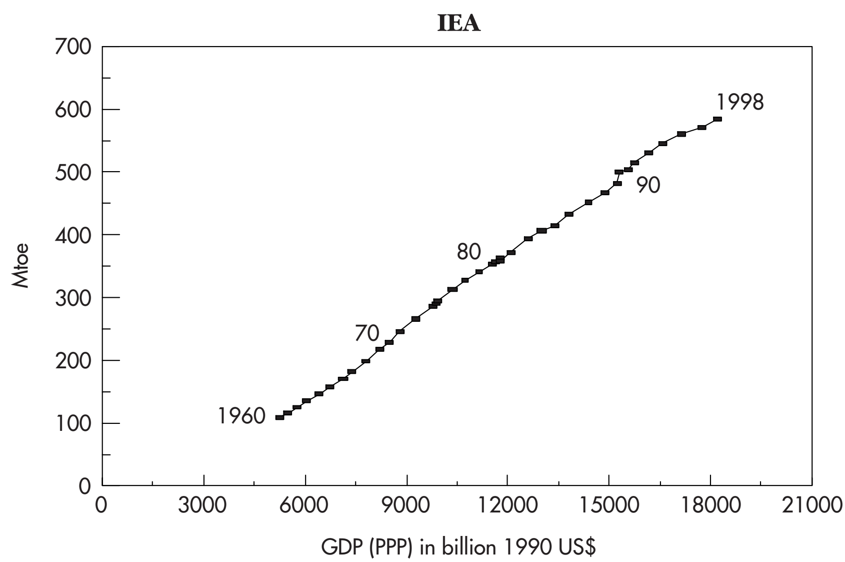
Reducing electricity consumption is a precondition for phasing out nuclear power. Improving efficiency of electricity use is a particular goal for Sweden because of the policy to phase out nuclear power. Conversion to district heating is seen as the best means to reduce electricity consumption. The Swedish National Energy Administration also considers there is potential for further improvement in the efficiency of electricity use in commercial premises. Measures designed to achieve this sort of structural change in the delivery of energy services are necessary if electricity consumption is to be reduced since, as with transport, electricity consumption and economic growth are historically closely linked (see Figure 13) and policies would have to be extremely strong to have any significant impact and may not be achievable.

District heating using biofuels is seen as an alternative to electrical heating. Replacing electrical space heating with district heating is a key policy measure to reduce growth in electricity consumption in Sweden. District heating is generally a large-scale investment with a long lifetime. A decision to use district heating is generally taken collectively, typically by a local government. Once the decision is taken, flexibility to change is limited collectively because of the expense in investing in the network, and probably non-existent for individual consumers. Local heat markets are typically regarded as monopolies since the network cannot be used for any other purpose and competition is not feasible. Consequently, district heating will put in place a natural monopoly to replace a potentially competitive space heating market, where electricity suppliers could compete with each other, and with suppliers of alternatives to electricity, for the benefit of consumers and the nation as a whole.

Moreover, since the decision to use district heating is encouraged by government, there is likely to be an expectation on the part of consumers and local authorities that heat prices will remain as low, or lower, than current prices for electrical space heating. Although district heating is a deregulated market, prices are set in relation to electrical space heating rather than according to the actual cost of heat. Since the pricing mechanism on the district heating market is different from other more competitive markets, the government has given the National Energy Administration the task to make an overview of the district heating market. This overview will be reported to the government by 1 October 2000.

Figure 13
Electricity Consumption vs GDP in Purchasing Power Parities, 1960-1998





Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and *National Accounts of OECD Countries*, OECD Paris, 1999.

A possibly more efficient and effective approach to moderating growth in electricity consumption would be to use taxes to adjust prices to different groups of consumers. It should be noted at the outset that such an approach would further complicate the tax system, and is proposed here as an alternative means of addressing the policy goal, rather than endorsement of the goal itself.

A market approach to moderating growth in electricity consumption would be to use final consumer electricity prices to encourage efficient use of electricity. Taxing household electricity consumption, for example, would encourage consumers to use less electricity, or to look for cheaper suppliers of electricity, or to look for alternatives to electrical heating such as other forms of heating or insulation. Final consumers are likely to choose the lowest-cost alternative to electrical heating and decisions by consumers should influence investment decisions by competing energy suppliers.

Taxing household electricity consumption should not directly impact on competitiveness. Using taxation as a means of moderating electricity consumption need not be limited to the household and commercial sector. International competitiveness need not be affected by higher electricity prices in instances where economic alternatives, such as gas, exist. Clearly, the use of prices would have to be approached cautiously in the industry sector.

Electricity pricing to improve the efficient use of electricity could be a means of supplementing market-based measures to achieve broader nuclear policy goals. Possible market-based nuclear policy measures are discussed in Chapter 7.

The policy to reduce electricity consumption works symetrically with the policy to promote the use of biofuels since district heating is increasingly based on biofuels. While the policy is internally consistent, some caution might be exercised to ensure that it is cost-effective and that competition between fuels is free and undistorted by tax measures designed, in part, to encourage the use of biofuels. This issue is discussed in Chapter 8 where it is noted that the effect of production taxes combined with the carbon dioxide tax for heat and consumption taxes for electricity have distortionary impacts on fuel use in district heating and combined heat and power.

Objective evaluation of progress is essential in view of the policy on nuclear power. Energy efficiency improvements will have to be large and sustained to justify closure of any nuclear capacity. Evidence of the effect of efficiency programmes on electricity consumption would need to be demonstrated over a span of years to ensure that the necessary structural changes had taken hold. The historical trend to date suggests that efficiency improvements could not justify closure of economically viable generating capacity.

At present, energy efficiency programmes are evaluated principally on qualitative grounds since undue use of quantification criteria, such as targets, is considered by Sweden to be potentially interventionist and costly. Nevertheless, the importance of any decisions to close nuclear power plants, which may be taken by the Parliament on the basis of reported improvements in energy efficiency, is such that an agreed, objective basis for measuring improvement is essential.

RECOMMENDATIONS

The Government of Sweden should:

- ☐ Clarify existing qualitative goals for efficiency improvement programmes to ensure an objective assessment can be made of their cost-effectiveness and, in particular, the contribution energy efficiency programmes may make to offsetting any further reductions in nuclear capacity.
- ☐ Consider increasing taxes on household electricity consumption as an alternative to promoting the expansion of district heating as a means of reducing electricity consumption.
- ☐ Harmonise taxation of heat and electricity production from combined heat and power plants.

6

ELECTRICITY

DEMAND, SUPPLY AND TRADE

Demand

Sweden is an electricity-intensive country. Consumption of electricity amounted to almost 144 TWh in 1998, including transport losses of about 10.7 TWh and pumped storage power. Per capita use of electricity in 1997, at nearly 16 000 kWh, was the fourth highest in the OECD (after Norway, Iceland and Canada) and nearly double that of other industrialised European countries such as France, Germany and the United Kingdom. Industrial use, accounting for 45% of the total in 1998, is concentrated in a small number of energy-intensive sectors including the pulp and paper industry, the iron and steel industry, and the chemical industry. Household electricity use is also large due, among other factors, to the use of electricity for heating, and fluctuates depending on outside temperature.

Electricity demand growth has been modest since the mid-1980s. Annual growth from 1990 until 1998 averaged around 1% and in 1998 it was only 0.4%, partly reflecting unusually warm weather conditions. Recent electricity demand growth reflects a stabilisation of demand in the residential and services sectors and adverse economic conditions in the period from 1990 to 1992. Since then, industrial electricity demand has risen again at about 1.1% per year.

Table 9
Consumption of Electricity, 1998

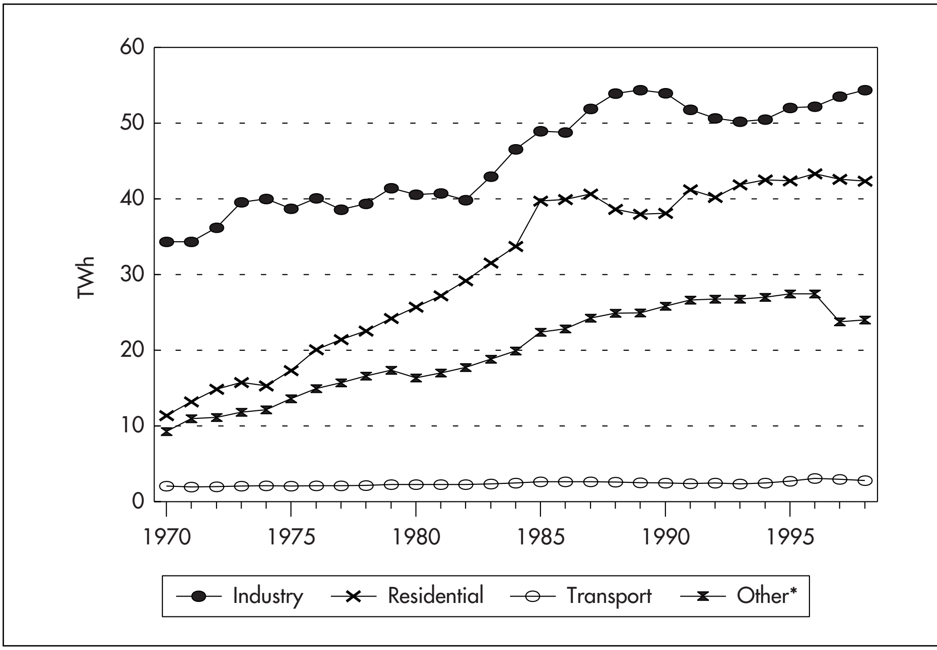
Housing	31%
Industry	45%
Trade and services (including transport)	21%
Other (including agriculture)	3%
Total (TWh)	**143.5**

Source: Nordel.

Supply

Sweden is located on the so-called hydro-thermal border. Sweden has access to relatively cheap hydropower supplies, particularly from the northern part of the country and from Norway. More costly nuclear power is available domestically, and thermal (coal or gas) based electricity is imported from Denmark and, to a lesser extent, Germany. Since hydro reserves fluctuate seasonally and from year to year, there is a complementarity between hydro and other sources in the region that is reflected in Sweden's fuel mix.

Figure 14
Electricity Consumption by Consumer Group, 1970-1998



* Includes commercial, public service and agricultural sectors.
Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999.

Electricity generated in Sweden is produced mainly from hydro and nuclear power plants (93% of total production in 1998) with a roughly similar contribution from each source in a typical year. The remainder is produced by Combined Heat and Power (CHP) plants (6% of total production in 1998) and, to a lesser degree, from oil condensing power, gas turbines and wind power. Industrial CHP production is based mainly on biofuels while electricity produced in district heating plants is 40% coal-fired. Around 1.3 TWh were produced from biofuels in 1998. Table 10 illustrates the fuel mix for power generation in 1998, a relatively humid year. The fuel mix varies from year to year as discussed further below.

The use of available production capacity reflects the cost merit-order of generation units. Base load power is provided primarily by hydro and nuclear power stations while oil and gas are primarily used as reserve capacity. The ranking of production capacity according to variable cost yields a similar order: hydropower is the cheapest option, followed by nuclear, CHP in industry, CHP associated with district heating, coal, oil and gas turbines.

Production capacity has remained stable over the last decade. In the 1970s and early 1980s, new nuclear generating capacity met electricity demand growth and replaced oil used both in power generation and heating. No additional nuclear capacity has been put on line since 1985. Hydropower and CHP capacity have remained more or

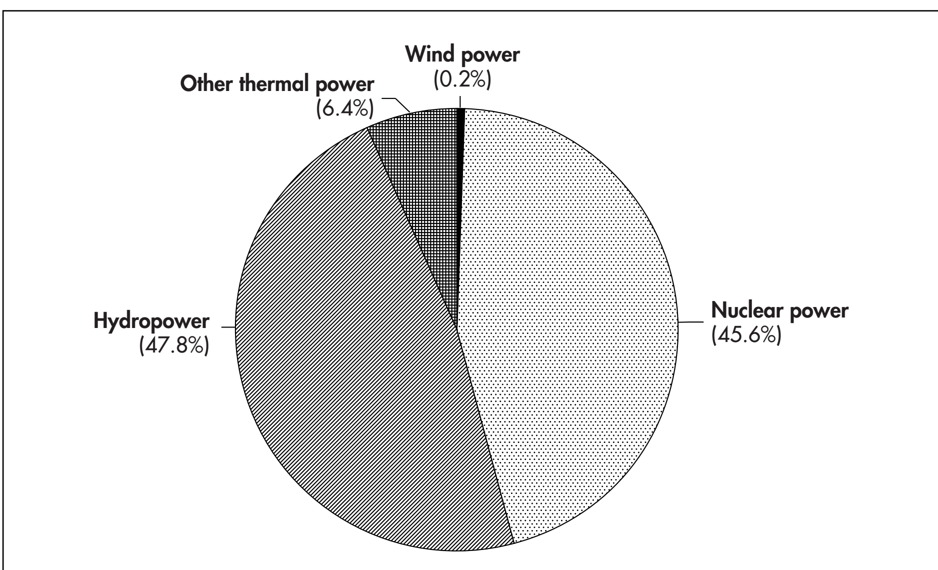
Table 10
Electricity Consumption and Generation, 1998 (GWh)

	Sweden	*Finland*	*Norway*	*Total*
Gross consumption	141 630	76 352	115 715	333 697
Total generation	154 340	67 183	116 953	338 476
of which (%):				
Hydropower	47.77	21.73	99.42	60.45
Nuclear power	45.66	31.24	-	27.02
Other thermal power	6.38	46.99	0.57	12.43
condensing power	0.18	9.63	0.09	2.02
CHP, district heating	3.29	19.46	-	5.36
CHP, industry	2.91	17.88	0.29	4.98
gas turbines, etc.	0.00	0.02	0.18	0.07
Other renewable power	0.19	0.04	0.01	0.10

Note: Consumption excludes pumped storage power.
Source: Nordel.

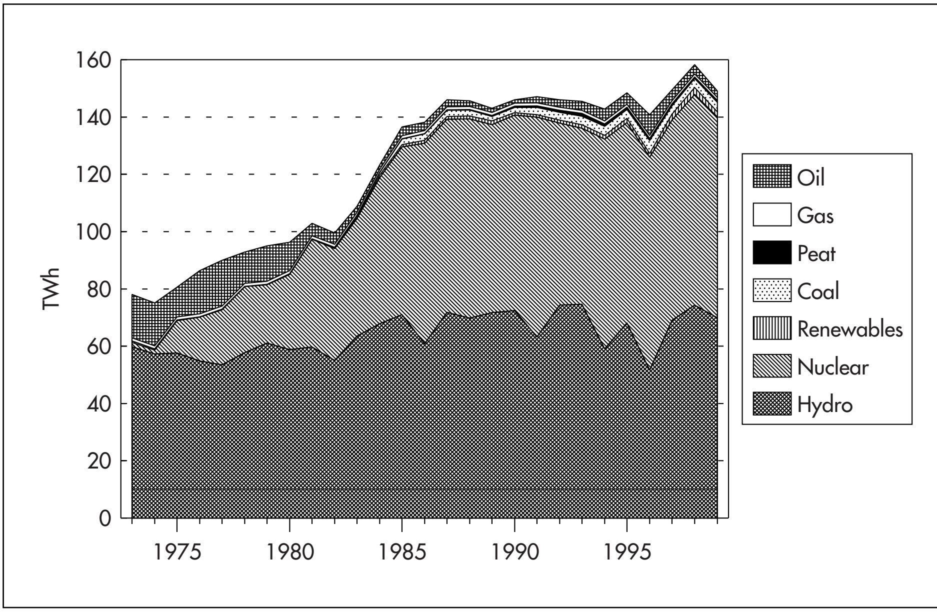
less stable over the period. In the 1990s, there has been an increase in wind power and gas-fired generating capacity but their contribution to total electricity production remains very small. Oil-fired generating capacity has continued to be decommissioned, including an additional 1 930 MW decommissioned in 1998.

Figure 15
Generation and Consumption of Electricity (%)



Source: Swedish Power Association, Annual Report 1998.

Figure 16
Electricity Generation by Type of Power, 1973-1999



Source: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999.

Reserve generation capacity is at levels comparable to those of other countries in the region and is reinforced by strong international transmission ties. Installed production capacity in Sweden was around 32 GW in 1998. Maximum system load was 24.6 GW in the same year, thus yielding a reserve margin of 23% (i.e. 7.4 GW of reserve over 32 GW of installed capacity). This figure compares to a reserve margin of 22% in Norway, 26% in Finland, and 40% in Denmark in the same year. In addition, the capacity of Swedish international connections was about 8 GW.

Table 11 summarises installed power generation capacity in the Nordic region as of 31 December 1998.

Trade

There is extensive electricity trade between Sweden and Denmark, Finland and Norway. Trade depends on economic conditions affecting the demand for electricity in the region, but principally on the availability of water reserves for hydro generation in Norway and Sweden. In years with high precipitation, Sweden is typically a net exporter of electricity, mainly to Denmark, while in dry years the pattern of trade reverses. In 1997 and 1998, Sweden was a net exporter. Sweden's electricity trade in 1998 (an extremely wet year) is summarised in Table 12. Import and export activity also fluctuates within the year, with net imports typically being lower during the summer and higher during the winter months.

Table 11
Installed Capacity on 31 December 1998 (MW)

	Sweden	*Finland*	*Norway*	*Total*
Installed capacity, total*	31 994	16 458	27 690	76 142
Hydropower	16 204	2 937	27 388	46 529
Nuclear power	10 052	2 640		12 692
Other thermal power	5 564	10 864	293	16 721
condensing power	846	3 903	73	4 822
CHP, district heating	2 246	3 606		5 852
CHP, industry	841	2 477	185	3 503
gas turbines, etc.	1 631	878	35	2 544
Wind power	174	17	9	200

* Refers to the sum of the rated net capacities of the individual power plant units in the power system, and should not be considered to represent the total capacity available at any single time.

Source: Nordel.

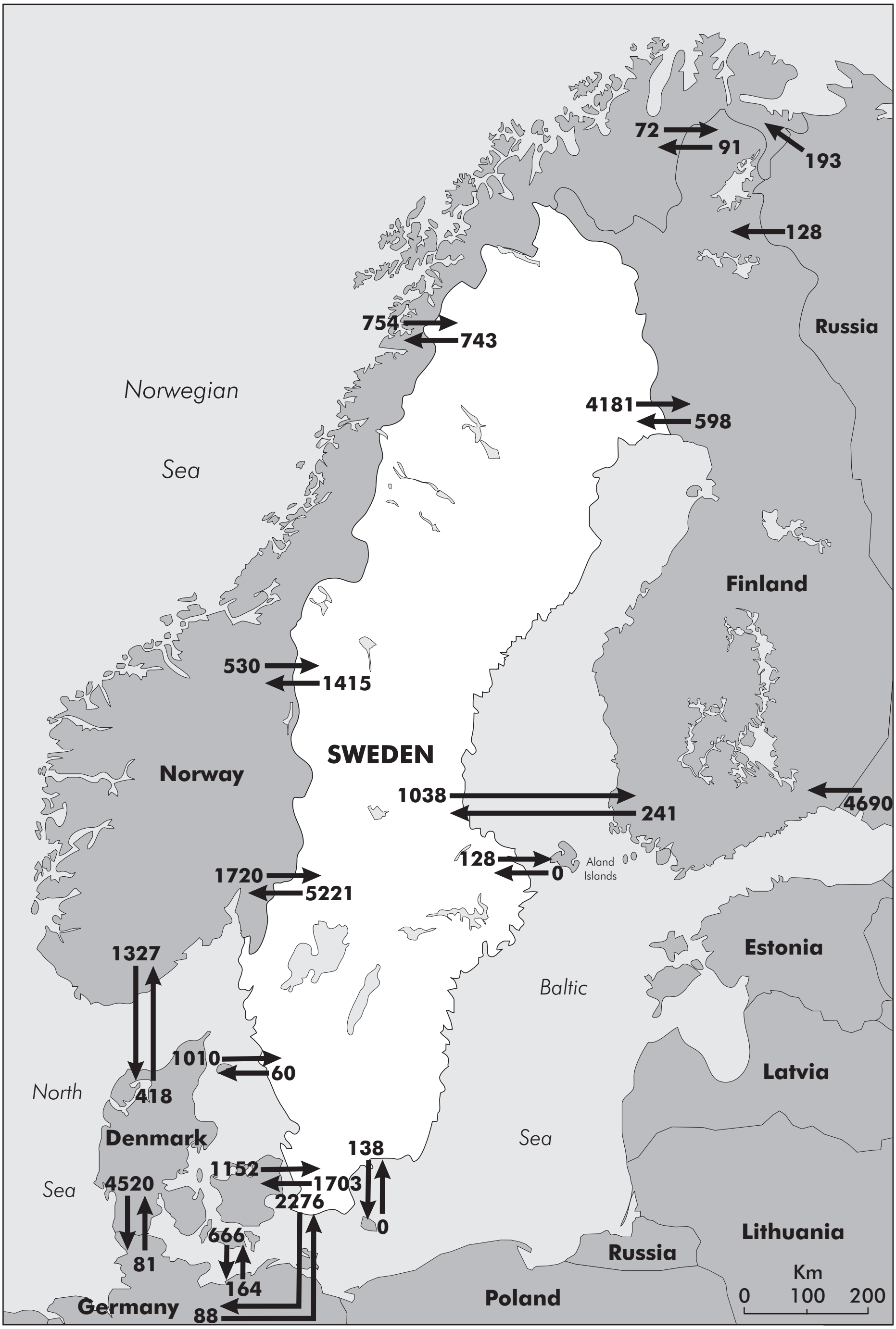
International trade is supported by strong interconnections to neighbouring countries. Import capacity from Norway, Finland and Denmark at 220 kV and above amounts to 3.9 GW, 1.3 GW and 2.2 GW, respectively. There is also a line to Germany (0.6 GW) and construction of an interconnector to Poland began in 1998.

Table 12
Imports and Exports, 1998 (GWh)

	Importing countries				*Other countries*
	Denmark	*Finland*	*Norway*	*Sweden*	
Exporting countries:					
Denmark	–	–	418	2 162	5 186
Finland	–	–	91	839	–
Norway	1 327	72	–	3 004	–
Sweden	1 901	5 347	7 379	–	2 276
Other countries	245	4 818	193	88	–
Total imports	**3 473**	**10 237**	**8 081**	**6 093**	**7 462**
Total imports	3 473	10 237	8 081	6 093	
Total exports	7 766	930	4 403	16 903	
Net imports	**–4 293**	**9 307**	**3 678**	**–10 810**	

Source: Nordel.

Figure 17
Exchanges of Electricity (GWh)



Source: Nordel.

A strong national transmission grid and eight regional networks support electricity trade within Sweden. Electricity flows are typically southbound reflecting the heavier concentration of demand in the southern part of the country, while a relatively larger share of generation, particularly hydropower, is located in the north. Transport losses in 1998 amounted to 10.7 TWh, or around 7% of total electricity demand.

Forecasts

Forecasts of supply and demand are available from a number of sources. In 1997, the Swedish National Board for Industrial and Technical Development (NUTEK) forecast consumption of electricity of 145.5 TWh in 2000, 147.5 TWh in 2005 and 152.3 TWh in 2010. According to IEA statistics (1999), electricity generation may reach 151 TWh in 2000, 150 TWh in 2005 and 154 in 2010. Installed capacity is forecast by Nordel to be 31 000 MW in 2000, and 31 100 MW in 2005. Based on NUTEK's Climate Report, Nordel also forecasts a maximum system load of 27 450 MW in 2000 and 27 890 MW in 2005.

INDUSTRY STRUCTURE

The Swedish electricity supply industry is integrated physically and commercially with the Finnish and Norwegian industries. Consequently, some key industry issues such as market concentration, the fuel mix and security of supply have to be analysed with reference to Finland, Norway and Sweden together.

There are also close links with Denmark. Following the incorporation of West Denmark into the Nord Pool in 1999 and the implementation of electricity market reforms in Denmark during 2000, the integration of the Danish industry with the Nordic market is now accelerating.

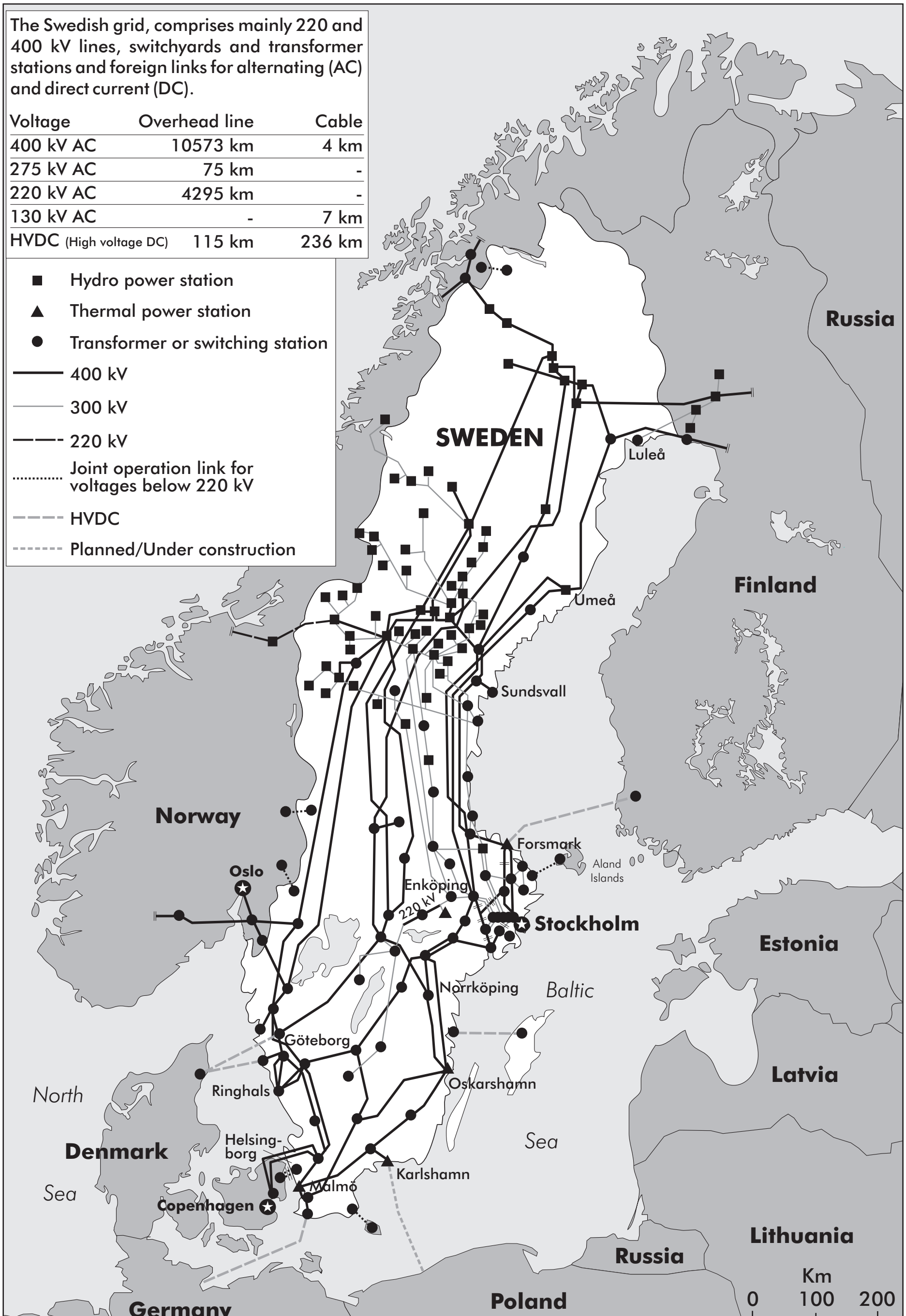
The vertical structure of the industry in Sweden, Finland and Norway is similar. Transmission and system operation are unbundled from all other supply functions and are managed by an independent and publicly-owned transmission company. In addition, the Swedish industry comprises six major power producers vertically integrated into distribution and trading activities, around 224 distribution companies that typically own some power generation assets, and around 215 electricity trading companies. There are also some new non-traditional players in the Swedish electricity market, including brokers and traders, groups of retailers and portfolio managers.

Generation

Electricity generation within Sweden is highly concentrated. The two largest generators produce about three-quarters of total output. This has resulted from a wave of mergers and acquisitions during the last fifteen years. This process continues: in 1999 the third

Figure 18

Swedish National Electricity Grid



Source: Ministry of Industry, Employment and Communications.

and fourth largest Swedish generators, Gullspang and Stockholm Energi, merged into Birka Energy which is partly owned by the Finnish group Fortum. The concentration of generation in the Nord Pool area is lower. The four largest producers accounted for around 50% of Nordic electricity generation as of July 1999 (see Table 13).

Table 13

Main Generation Companies in the Nordic Region, including Denmark (July 1999)

Company		*Production TWh*
Vattenfall	Sweden	83
Fortum-Birka	Finland/Sweden	40
Statkraft	Norway	32
Sydkraft	Sweden	30
Elsam	Denmark	25
PVO	Finland	17
Elkraft	Denmark	14
Hydro Energi	Norway	9
Graninge	Sweden	3

Sources: Vattenfall and IEA.

The geographical scope of the electricity market changes depending on demand conditions. Often, wholesale prices in Sweden, Finland and Norway are close or identical in the Nord Pool, suggesting that the price is formed through unrestricted international competition. However, significant price differences emerge during particular time periods. Price differences are a clear indication that international transmission capacity constraints limit the geographical scope of competition in generation and that the price is formed by competition in Sweden alone. When this occurs, the high concentration of ownership of generation within Sweden raises concerns that firms may be using their market power to raise prices.

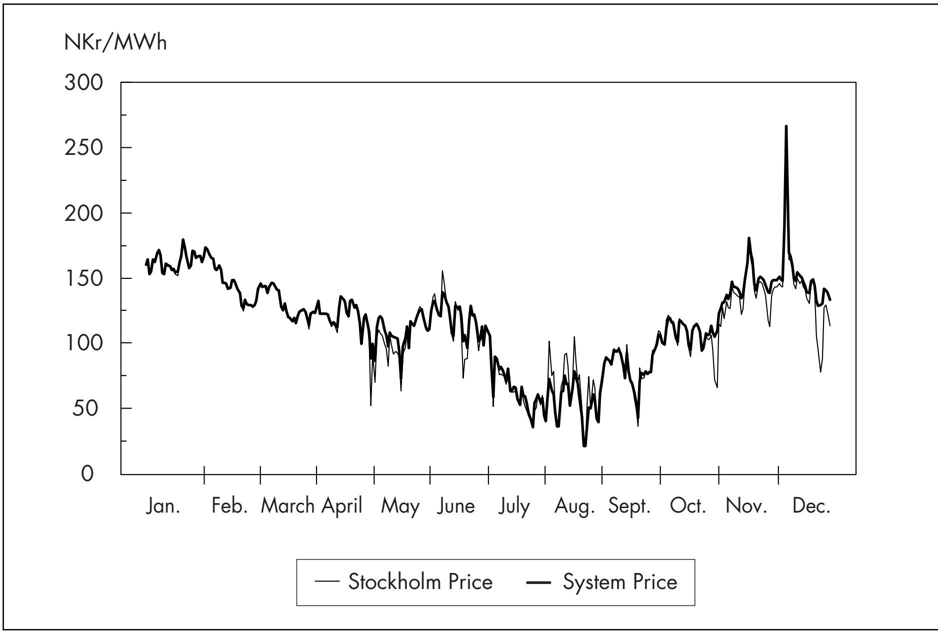
Ownership of generation is mixed. The government owns 49% of the generation assets through Vattenfall, which is the largest generating company in the region. The municipalities own around 23% of Swedish generation capacity. A substantial share (17%) is owned by foreign utilities and the remainder is owned by independent Swedish investors. The second largest company, Sydkraft, is owned by municipalities and various power companies, including the German company VEAG and the Norwegian company Statkraft. There is also Swedish ownership of foreign electricity companies, mainly through Vattenfall's acquisitions in the Nordic region and Germany.

Grid and Supply Activities

The national transmission grid and the international transmission links are operated by Svenska Kraftnät (SK), a state-owned company that was spun off from Vattenfall in 1992. SK is also responsible for system operation, including

Figure 19

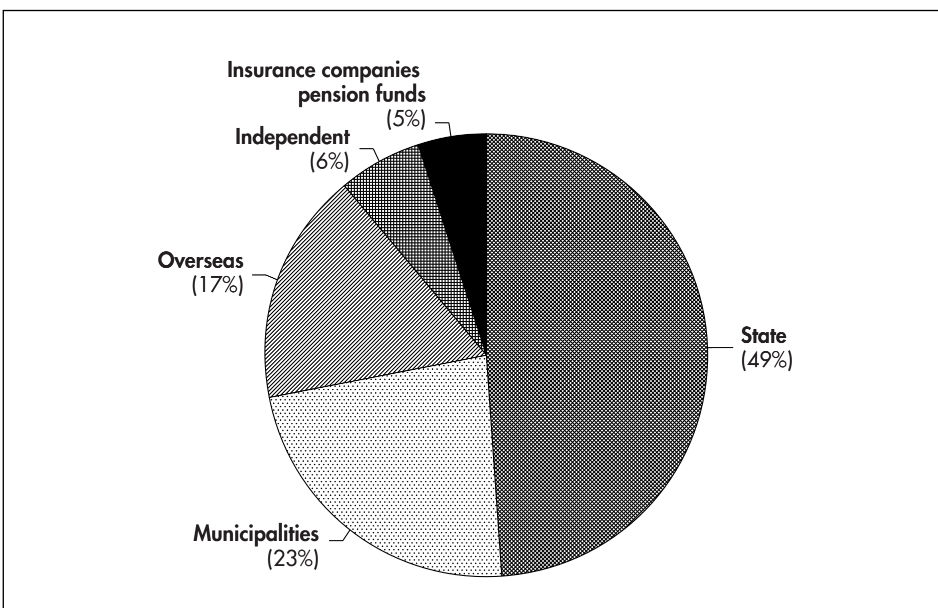
Spot Prices in the Nord Pool, 1998: Sweden and System Price (Daily)



Source: Nord Pool.

Figure 20

Breakdown of Ownership of Electricity Generating Capacity



Source: Swedish Power Association, Annual Report 1998.

the balance service. The balance service is provided through a regulation market run by SK, discussed below.

Distribution activities are required by law to be managed by separate legal entities that are not allowed to engage in other electricity supply industry activities. The largest distribution companies are listed in Table 14. Most distribution companies are also retail suppliers of electricity.

Table 14
Main Distribution and Retail Supply Companies in Sweden, Norway and Finland (July 1999)

Company		*Distribution Customers (thousands)*	*Retail Supply Customers (thousands)*
Fortum-Birka	Finland/Sweden	1 175	1 600
Vattenfall	Sweden	1 100	1 525
Sydkraft	Sweden	600	700
NESA	Norway	495	490

Source: Vattenfall.

Distribution remains fragmented despite significant consolidation during the last decade, mainly resulting from the purchase of distribution by generation companies. Table 15 shows the size of distribution companies by the number of customers. As of 1997, there were more than 200 companies with less than 50 000 subscribers. Many of the smaller distribution companies are municipally-owned.

Table 15
Size of Distribution Companies

Number of Subscriptions	*1991*	*1997*
50 to 999	26	7
1 000 to 4 999	77	62
5 000 to 19 999	125	94
20 000 to 49 999	44	39
50 000	17	21
Total	**289**	**223**

Source: Swedish National Energy Administration.

Links between Natural Gas and Electricity

Natural gas is an input to power generation and also competes with electricity for many energy end uses. Natural gas is supplied to Sweden from Denmark through only one transmission pipeline. The transmission pipeline has an annual capacity equivalent to 22 TWh that could be increased to around 30 TWh by installing compressors. As of 1998, this capacity was underutilised, with imports amounting to an equivalent of 8.3 TWh or around 42% of available capacity.

The two largest Swedish electricity supply companies are vertically integrated into the gas industry where they have a dominant position. Vattenfall Naturgas, a subsidiary of Vattenfall AB, owns and operates the transmission pipeline and is the only importer of gas to Sweden. Imports are made on the basis of take-or-pay contracts between Vattenfall Naturgas and the Danish supplier, DONG Naturgas. The contracts expire in 2003, 2006 and 2010.

Sydgas, a subsidiary of Sydkraft, is the biggest distributor of gas in Sweden, controlling around 75% of the natural gas market. Pending the implementation of the EU gas directive in August 2000, the distributors have a *de facto* monopoly in their local markets.

Prices

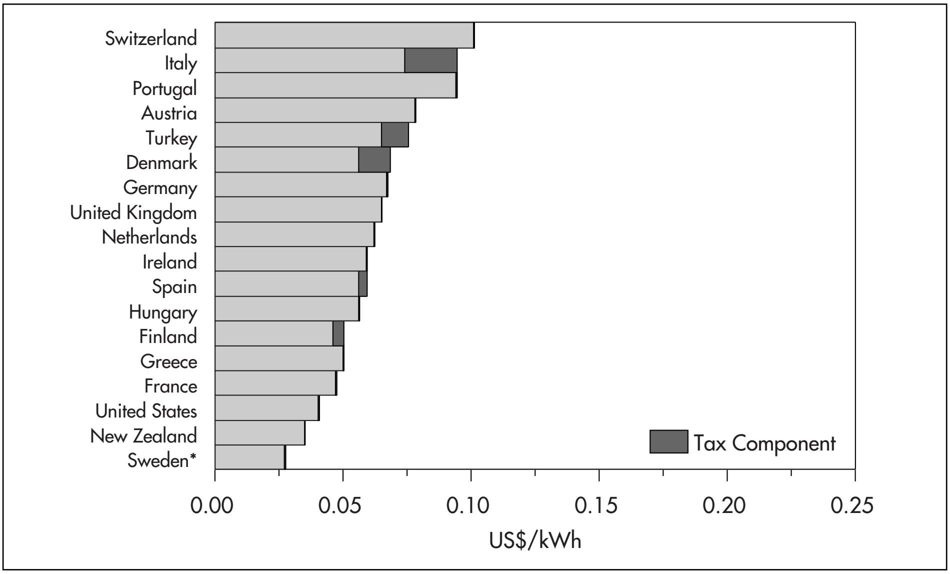
End-user electricity prices are among the lowest in the OECD, both for industrial and domestic consumers. Pre-tax domestic prices rose by around 3.5% in 1996, the year when the market was opened. At the end of 1999, they were roughly at the level of 1996 and are expected to decrease in 2000. However, after-tax prices have increased significantly over the period. Electricity prices measured by the consumer price index rose by 13% from 1995 to the third quarter of 1999. Industrial prices have remained more or less stable over the period 1996 to 1998.

The main components of end-user prices are the cost of energy and network charges. An indication of the cost of energy is provided by Nord Pool prices for the Sweden price area. These figures must be interpreted cautiously since they represent only 20% of all electricity trade. The average Nord Pool spot price in 1999 was SKr 119.42/MWh, down from 120.49 in 1998, 143.77 in 1997 and 260.01 in 1996. This steep downward trend is not reflected in end-user prices. The current price level in Nord Pool is relatively low compared to total electricity generation costs in new plants which are estimated to be in the order of SKr 300 to 350/MWh for oil, gas and coal-fired plants.

Network charges include transmission, regional network, and distribution fees. Transmission fees are low by European standards, averaging 1.4 ore/kWh in 1998. Regional network and distribution fees vary depending on the company that provides the service and have been criticised for being too high, as discussed below. Differences in distribution prices among companies can be explained partly by the impact on distribution costs of customer density. However, unequal prices also seem to reflect other factors such as differences in scale and efficiency among distribution companies and distortions in their tariff structure.

Figure 21

Industrial Electricity Prices in IEA Countries, 1998



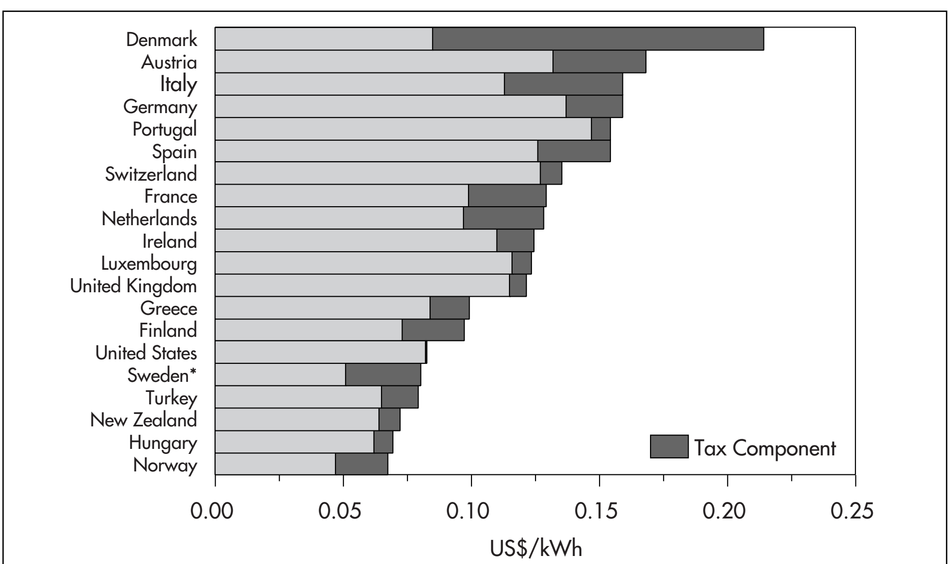
* 1997.

Note: Ex-tax price for the United States. Data not available for Australia, Belgium, Canada, Japan, Luxembourg and Norway.

Source: *Energy Prices and Taxes*, IEA/OECD Paris, 1999.

Figure 22

Domestic Electricity Prices in IEA Countries, 1998

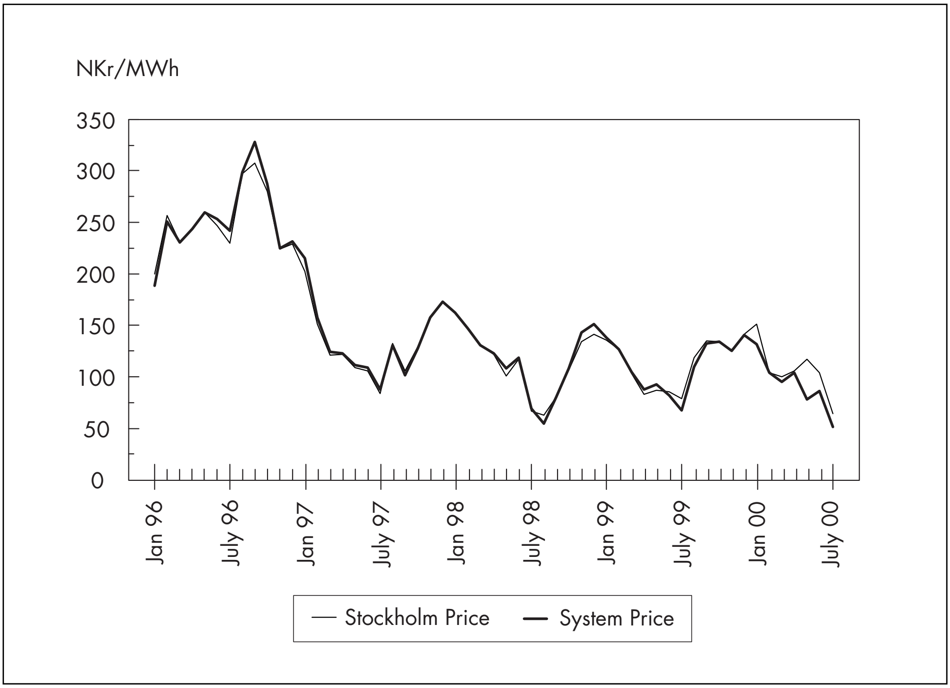


* 1997.

Note: Ex-tax price for the United States. Data not available for Australia, Belgium, Canada and Japan.

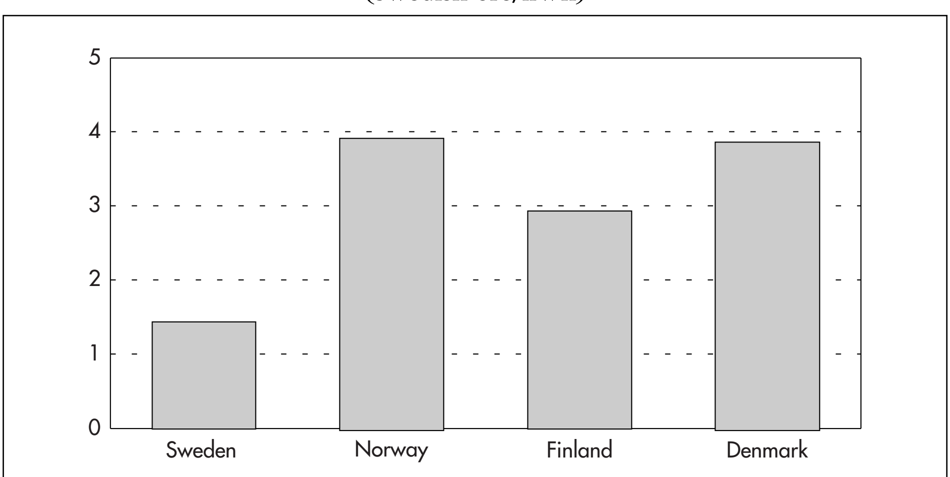
Source: *Energy Prices and Taxes*, IEA/OECD Paris, 1999.

Figure 23
Spot Prices in the Nord Pool, 1996-2000: Sweden and System Price
(Monthly average)



On average in 1999, NKr = US$ 0.129.
Source: Nord Pool.

Figure 24
Average Transmission Fees for the Nordic Grid
(Swedish ore/kWh)



Source: Svenska Kraftnät.

Organisation of the Market

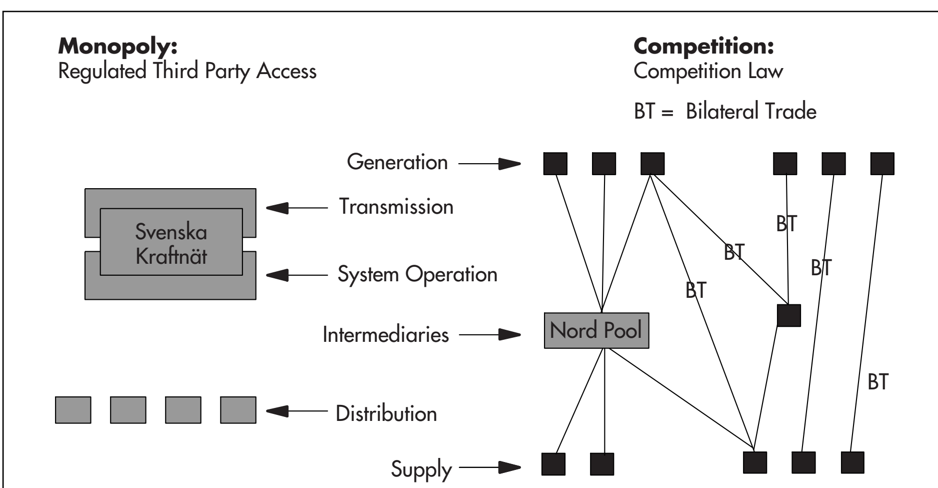
Generation and retail supply are fully open to competition and trade is decentralised. Generators can sell their output directly to end-users and to intermediaries such as supply and trading companies. Bilateral trade is by far the most common form of electricity trade in Sweden and the other Nordic countries. Bilateral contracts accounted for 80% of all electricity trade in the region in 1998.

Generators can also sell electricity through an organised electricity exchange, known as the Nord Pool, that has operated in Norway and Sweden since 1996. Finland became a member of the Nord Pool in 1998 and West Denmark in 1999. The Nord Pool comprises a spot market (Elspot), a futures market (Eltermin), which deals with futures contracts for up to three years ahead, and a clearing service for the settlement of bilateral contracts.

Elspot is a one-day ahead auction market. Bids are made for each of the twenty-four hourly markets and consist of price-quantity pairs specifying how much the bidder is prepared to buy or sell at different prices. Supply and demand schedules are constructed from selling and purchasing bids and, in turn, this determines a market-clearing "System Price". Bids are firm, i.e. entail a commitment to physical delivery or withdrawal of electricity. All scheduled bids are settled at the market clearing price. When the despatch schedule is not feasible because of transmission constraints, the market can be segmented in up to five zones corresponding to Finland, Sweden, West Denmark and two areas within Norway. Individual prices are then calculated for each of the constrained zones. Constraints within a zone are handled by the system operator as described below. Approximately 56.7 TWh were traded in Nord Pool's spot market in 1998, which represents a 30% increase from 1997.

Figure 25

Organisation of the Swedish Electricity Market



Source: IEA.

A balancing or regulation market operates in each Nord Pool member country to manage transmission bottlenecks and imbalances resulting both from trade in the pool and from bilateral trade. Svenska Kraftnät in Sweden and Fingrid in Finland make use of the countertrade principle. This means that Svenska Kraftnät takes bids for "up" and "down" regulation power from generators and other market players, despatches regulation units so as to keep the electrical system in balance and pays for the downwards regulation of the surplus area and for the upwards regulation in the deficit area. The costs connected with the counter purchase are regained through tariffs for power transmission. By contrast, Norway uses a pricing or "split the market" approach to deal with congestion. The price of energy is reduced in the surplus area and increased in the deficit area until the transmission need is reduced to the capacity limit. Under the countertrade system, market players see an "infinitely strong network" while, under the "split the market" approach, market players internalise the cost of congestion.

The Nordic electricity market has provided the blueprint for many other organised electricity markets around the world. Trading arrangements similar to those in the Nord Pool have been adopted in the Netherlands, Spain, the United Kingdom and the United States. The emphasis on opening the market to all end-users regardless of size is now a standard feature in many countries. The establishment of a separately owned transmission company is widely regarded as an effective way to deal with transmission.

Policy and Regulation

Major Policies and Regulations Affecting the Electricity Supply Industry

The main regulatory building blocks, including regulated third party access to the network and the liberalisation of generation and supply, were established in 1996 and are contained in the Swedish Electricity Act (1997) and its amendments. Competition law applies to generation and end-user supply activities.

In addition, a number of policies influence the industry. Two parliamentary decisions, adopted in 1991 and 1997, set guidelines for the future development of energy policy. In particular, they set guidelines for electricity generation capacity and established subsidies and other support measures to promote energy efficiency, and the development of electricity production from renewables. The 1997 Bill on a Sustainable Energy Supply places a strong emphasis on energy efficiency measures. Energy taxes, currently under review, are also important. New legislation to implement the EU Natural Gas Directive will also affect the electricity supply industry.

Fuel Mix

The use of input fuels for power generation is restricted in a number of ways. The single most important potential constraint is the decision to phase out nuclear power and its replacement with renewables, particularly biofuels and wind power, and offsetting reductions in electricity use. The decision to phase out nuclear power may mean that a major change in the fuel mix could take place over the next 20-30 years, starting from 2010. During that period, nuclear capacity may, in any case, be reduced as a result of commercial decisions. In the short to medium term, changes in the fuel mix are expected to be limited and to take place gradually. Apart from the possible closure of Barsebäck 2, no other nuclear plant closures are anticipated for the next ten years or so.

The development of hydropower is also limited by a parliamentary decision banning the further exploitation of "national rivers" and other hydro resources.

Any investments in gas infrastructures must be financed on strictly commercial terms, so the role of gas in the future electricity input fuel mix is to be decided by market forces. Consumption of natural gas is expected to increase through a more intense use of existing infrastructures. Major additions to gas import capacity are not expected to be economic in the immediate future although a number of studies on new natural gas interconnections to Sweden are being conducted.

Transmission and Distribution

A concession from the government is required to erect or operate high-voltage power lines. Holders of network concessions are obliged to connect consumers on reasonable and non-discriminatory terms. Connection to the network can only be denied when there is not enough capacity and, once connected, consumers cannot be denied access.

Network tariffs are set by the network companies and monitored by the Network Authority. If a network company is found to have unreasonable tariffs, the authority will serve it with an injunction to adjust its prices. The authority's decisions can be appealed before the courts. Network tariffs have to be published annually, for example, on the Internet.

Transmission tariffs are based on the postage stamp principle, that is, network fees provide access to the entire network regardless of location. There is, however, a location-dependent correction intended to price losses. The transmission tariff comprises a connection fee, paid only once, an annual capacity fee, and an energy fee. The last two fees provide about one-half each of Svenska Kraftnät's revenue.

Postage stamp tariffs with a two-part structure are also charged for distribution and regional network services. However, many distribution companies obtain a relatively large proportion of their income through the fixed capacity charge.

The level of distribution tariffs are considered too high by the electricity regulator (now part of the Swedish National Energy Administration). In 1997, the then Network Administration advised the local network companies to lower their revenues by 2.4% during 1998. Household charges dropped by 0.4% on average, much less than the value recommended by the Administration. Proposed increases in the distribution tariffs are being reviewed by the Office for the Electricity and Gas Regulator of the National Energy Administration and are subject to a price cap.

End-user Supply

The Swedish electricity market has been open for all customers since 1996. However, competition in supply has been constrained by a number of factors. Until 1 November 1999, switching suppliers was costly for small customers. Customers were required to notify their decision up to six months in advance and needed to install a meter with hourly metering capabilities if they wished to switch from their local supplier. Choice for all customer classes was further constrained by long-term bilateral contracts linking up to 80% of all Swedish electricity consumption and extending typically until 1998 and 1999. Most of these contracts were signed before the opening of the market in 1996.

Measures to facilitate choice by small customers were introduced in November 1999. Since then, small customers – those below 200 amperes – have been charged on the basis of a load profile and are no longer required to install special meters. The notification period has been shortened to a month and switching fees are not permitted. In the first two months following the new legislation coming into force, an estimated 50 000 to 60 000 customers switched suppliers.

Supply concessions carrying an obligation to supply consumers within the supply areas were also abolished in November 1999.

International Trade

Imports and exports of electricity are open to all parties subject only to a notification requirement. International transmission links are regulated to facilitate trade within the Nord Pool area. There are no cross-border transmission tariffs for spot exchanges with Norway and Finland and all interconnection capacity is made available on a non-discriminatory basis, i.e. bilateral capacity reservations are not allowed.

Disparities in the regulatory frameworks still pose challenges to the development of the Nordic market. Differences persist in various key areas including the management of transmission constraints, the level of transmission tariffs and the definition of the networks to which different tariffs apply. These differences inevitably distort trade in the region.

Trade with other countries, particularly Denmark, is subject to cross-border transmission tariffs comprising a capacity and an energy charge. Following the incorporation of Denmark into the Nord Pool, cross-border tariffs charged on Danish trade are being reviewed. According to the Electricity Act, cross-border tariffs could be abolished if the electricity market in a third country "can be deemed to constitute a common market with the Swedish electricity market." In determining whether this requirement is met, key prerequisites are that trade involves several actors and a certain volume of energy, that transmission capacity constraints are handled in a non-discriminatory way and that market conditions, such as tariffs and taxes, are similar in third countries. There is no third party access to the Swedish-German interconnector.

Rules governing international transmission within the EU internal market are currently being debated among EU countries and have yet to be established.

Security of Supply

Security of supply is largely determined by the market. When generation is scarce relative to demand, high prices serve to balance supply and demand, and signal the need for capacity additions and/or reduced consumption in the long term. Experience in using market prices to balance supply and demand has been satisfactory so far. There have been large price spikes in the Nord Pool during peak demand periods, such as some cold days in January 2000, which kept the system in balance.

Svenska Kraftnät is responsible for maintaining system reliability. The company performs capacity assessments and secures disturbance reserves. Current reserves include 400 MW of gas turbines owned by Svenska Kraftnät, 600 MW of gas turbines available on the basis of three- to six-year access contracts, and 85 MW contracted shedding of industry demand. The cost of this physical capacity is met by Svenska Kraftnät, and not passed on to the market participants as a cost of maintaining reliability.

A much debated issue has been whether existing reserves are adequate. In a worst case scenario, it has been estimated that up to 2 400 MW of imports would be needed to maintain the system in balance. This import capacity is normally available. However, since balance services are managed at national level, there may be a need for greater co-ordination among Nordic system operators. Co-operation among Nordic system operators, mostly at a technical level, already occurs through Nordel, the association of system operators in Denmark, Sweden, Finland, Norway and Iceland. There is also extensive co-ordination between the regulatory authorities of Finland, Norway and Sweden. In this context, it would be possible to assess the availability of reserves in the whole region, develop a more precise assessment of future needs, and to further develop short-term co-ordination mechanisms among the system operators.

Taxes and Subsidies

Energy taxes are complex and have been modified frequently over the last decade.

- The main tax on electricity is charged on electricity consumption. Revenue from the electricity tax reached around SKr 11 billion in 1999, up from around SKr 6 billion in 1995.
  - Industry and greenhouse horticulture have been exempt from the electricity tax since 1993.
  - Certain municipalities in northern Sweden and electricity users supplying power, gas, heating and water pay a reduced rate.
  - In all other cases, a tax rate of SKr 0.151/kWh is charged (as of 1999).

- In addition, electricity generated in nuclear power plants is taxed at SKr 0.022/kWh.

- General taxes also apply to electricity, including a tax on industrial property and VAT.

- No tax is levied on fuels used in generating taxable electricity.

This scheme is expected to change in the context of the new principles for energy taxation that are being elaborated by the Swedish Government.

Electricity generation from renewable sources, notably biomass, wind and small hydro, is supported by investment grants, tax credits and a simplified network tariff. The investment grants cover 15% of investment costs for wind energy and hydropower, and up to SKr 3 000/kW for biofuel-fired CHP. Tax credits are only given to wind power for an amount equivalent to the tax on electricity consumption.

Additional support for renewables was introduced for 2000 to replace the purchase obligation on supply concessions, which was abolished in November 1999. A procurement price for electricity produced from renewables has been established in the range of 13-14 ore/kWh.

From January 2001 a new support scheme will be established, replacing both the special support scheme for 2000 and the pre-existing investment grants and tax credits. Its objective is to introduce market-oriented solutions to support the expansion of renewable electricity production, while avoiding disturbances in the electricity market in the transition to the new support mechanism.

Regulatory Institutions

The responsibility for regulating the network resides with the Office for the Electricity and Gas Regulator, which is part of the National Energy Administration. The Office for the Electricity and Gas Regulator handles the regulation of the network independently, within the framework of the Electricity Act, which has been decided by Parliament. The office has the task of monitoring network tariffs and other conditions within the monopoly part of the industry. Complaints regarding tariffs from companies or private households are handled by the regulatory authority. Its decisions can be appealed to the public administrative court.

In order to make changes in the Electricity Act, the goverment can make proposals for new legislation to Parliament. Responsibility for drafting such proposals for changes resides within the Ministry of Industry, Employment and Communications. The government then decides to make a proposal to Parliament. Decisions to make proposals to the Parliament must be taken by the government as a whole, not solely by the responsible minister.

The overall regulatory approach is based on light-handed regulation in the sense that the regulatory system is an ex-post conduct regulation. The grid companies manage tariff setting. The Office for the Electricity and Gas Regulator monitors tariffs and has the power to take decisions on the tariffs and other conditions for the use of the grid if deemed necessary. The office is entitled to request information that is required for the purposes of supervision. Such a request may be combined with a penalty in case of non-compliance. The office may also issue the instructions and orders necessary to ensure that the directions and conditions covered by the supervision are complied with and such instructions may be combined with a penalty, in case of non-compliance.

The Competition Authority applies the Competition Act to the electricity industry and monitors the competitive conditions of production and trading in electricity. It was also given the special task by the government of reviewing the electricity market during the first six months after deregulation in 1996, and has been active in making recommendations on strengthening competition in the electricity supply industry. No major competition cases affecting the industry were reported in 1998.

CRITIQUE

Electricity policy, based on trade, has successfully reduced prices. Sweden has developed a successful electricity policy based on the application of market principles to the potentially competitive segments of the electricity supply industry. A key element of this approach is the opening of the market to international trade. Trade reduces the cost of electricity. In a relatively small country like Sweden, trade is essential for effective competition to emerge. Foreign competition reduces concentration in the domestic market and reinforces competitive pressure. Another key element of the Swedish (and Nordic) approach is the introduction of full end-user choice since the beginning of the reform. Obstacles to effective choice were recognised and removed in the 1999 reforms. More recent reforms in other countries in the EU and in North America have adopted a similar approach based on regional integration and the introduction of end-user choice.

The Swedish policy approach combined with the availability of inexpensive hydro resources for electricity production has resulted in low electricity prices. Low electricity prices are a key source of competitive advantage for Sweden. On the other hand, the intensity of electricity use in Sweden is among the highest in the world, double the IEA European average and slightly higher than in the United States. This means that the price of electricity is disproportionately important for the Swedish economy. For these reasons, it is an explicit and essential priority of Swedish energy policy that electricity prices must remain at competitive levels, even if the fuel mix changes.

The continuing competitiveness of the Swedish electricity supply industry will depend largely on how the input fuel mix evolves. The goal of the Swedish Government is to replace nuclear power with renewable sources. For this goal to be reached without an adverse impact on prices, the cost of renewable generation would have to drop significantly in the next 20 to 30 years. In addition, the replacement of nuclear would have to be gradual and not immediate. Natural gas could play a role in the phase-out, and assist in maintaining competitiveness while incurring some environmental cost. These issues are discussed in greater detail in Chapter 7.

In addition to these long-term issues, the Swedish electricity supply industry faces other challenges posed by the need to adapt the regulatory and institutional framework to an increasingly open electricity market, and to integrate environmental objectives within this framework. These issues are examined below.

Vertical integration of gas and electricity needs to be addressed. The vertical integration of gas and electricity may raise a barrier to the development of gas-fired electricity generation (and gas-fired heat production) in Sweden. Generators willing to use gas for power generation would receive their gas supplies from a competitor in the generation market, thus raising concerns about discrimination. Discriminatory access conditions or prices would hamper competition in the electricity market. The possibility of this occurring may simply discourage investment in gas-fired units.

In order to ensure a level playing field for competition in power and heat production, it is essential that no discrimination against gas-fired energy production can take place. Apart from divestiture, which would eliminate the incentive to discriminate, a number of measures could help to reduce the ability of gas companies to discriminate against their competitors in the electricity market. These measures may include the regulation of the relevant gas tariffs and access conditions, the active monitoring and enforcement of these regulations, and the active enforcement of competition law to prohibit discrimination.

An additional issue is the impact that the monopoly on gas imports and the investment climate may have on investment in new gas import infrastructures and, subsequently, on the development of gas-fired generation. This issue is discussed in Chapter 8.

Competition has been extended to most areas of the market. Developing effective competition in electricity markets often takes time. The experience in electricity markets around the world, including Sweden, is that the full benefits of competition do not immediately reach consumers. This is explained by a number of factors, including excessive market concentration, barriers to the exercise of choice by consumers and long-term contracts that span across regulatory regimes.

End-user prices in Sweden have remained more or less stable since the introduction of competition in 1996 despite the decreasing path of prices observed in the wholesale market. This suggests that competition in supply, particularly in the small consumers segment, was lagging. A major obstacle for the development of competition to supply small consumers was the cost and administrative red tape involved in switching suppliers. This has discouraged consumers from leaving their traditional franchise suppliers. The last package of reforms, implemented in November 1999, is a comprehensive attempt to promote competition by reducing these obstacles. The initial impact, including a marked increase in retail market activity, has been positive. However, a full assessment will have to wait until evidence on the evolution of electricity prices becomes available.

An additional, but possibly temporary, obstacle to the development of effective supply competition has been the existence of long-term supply contracts linking a large share of total electricity demand. Many of these contracts, dating back to the pre-liberalisation period, expired during the last two years and the change should be eventually reflected in electricity prices.

At the wholesale level, vigorous competition has developed. However, the high concentration of generation within Sweden raises concerns about the potential for anti-competitive pricing when the Swedish market is separated from the rest of the Nordic region because of transmission constraints. The issue of domestic market power should be given explicit consideration, both in competition cases, such as authorisation of mergers and acquisitions, and in planning additions to international transmission capacity.

Transmission and system operation require improvement. There is wide agreement that the regulation and management of transmission and system operation have to be improved and adapted to the new market conditions in three areas:

- There is room for further progress in the harmonisation of Nordic regulations, including those on tariffs and system operation. Unequal transmission tariff levels may distort competition in the Nordic market and, therefore, a convergence of transmission tariffs in the region is desirable. Enhanced co-ordination among system operators could contribute to improving the management of reserves and reliability even if responsibility for reliability resides with the national system operators. The integration of national markets implies that security and reliability have a Nordic dimension.

- The advent of the EU internal electricity market requires the development of new rules for international transmission. Sweden is participating, together with the other EU countries, in the debate to establish a new framework for trade within the EU through the so-called Florence process to establish common rules for cross-border transmission within the EU that are consistent with the development of the internal market. The set of rules on international trade developed in the Nordic market provides a leading example of how the EU framework could be developed. Once a decision is taken, Swedish international transmission tariffs and other rules will have to be modified accordingly.

- Transmission pricing and the management of congestion could be improved in line with developments in other electricity markets. Transmission pricing and congestion management have evolved quickly in the last four years. Market approaches such as nodal pricing or "split the market methods" have been developed, making a more efficient management of the system feasible. In parallel, the perceived complexity of these methods has been drastically reduced. A review of transmission pricing methods aimed to incorporate more sophisticated pricing methods seems appropriate.

Some distribution issues need to be addressed. Distribution tariffs are not cost-reflective. The predecessor of the National Energy Administration noted in 1997 that the level of distribution tariffs was too high. In addition, tariffs vary across companies and, in some areas of the country, do not seem to be cost-reflective. Ideally, all tariffs should reflect costs. Distribution tariffs should reflect the cost of building and operating the network with the best available technology. Higher tariffs not only result in customers paying too much, but also erect a barrier to the development of competition in end-user supply. High distribution prices increase the costs of supply companies and, in parallel, distribution companies may use extra revenues from network activities to cross-subsidise their own supply activities.

Distribution activities remain fragmented. Some distribution companies may be too small to be efficient. Network costs could possibly be reduced through further consolidation of distribution activities.

The Network Authority is addressing these issues by essentially imposing a price cap on network tariffs. This provides for a gradual elimination of distortions and puts pressure on inefficient companies to reduce their costs and/or to consolidate. The publication of network tariffs, now mandated by law, also puts pressure on network prices by making distortions easier to detect. This policy needs to be continued. In addition, an assessment of the current situation and its impact on the development of retail competition is needed to determine whether a more comprehensive action plan is required.

Regulatory institutions could be more independent. The establishment of a separate ministerial agency, the Swedish National Energy Administration, is a welcome development that will help to clarify and reinforce energy policy. In this new framework, the Swedish Government continues to play a dual role as both regulator of the industry and owner of the largest company within it. The issue now is to ensure the neutrality of energy policy and regulation.

Many reforming countries have chosen to establish an independent regulatory agency. This is the case, for instance, in Australia, Canada, Finland, France, Italy, Portugal, the United Kingdom and the United States. Independent regulatory agencies help to ensure an arm's length relationship between the regulator and market players. In addition, they reduce the influence of short-term political pressures on regulatory decisions. The case for independent regulation is stronger when there is state ownership because, as in Sweden, governments may find conflicting interests in both owning and regulating companies in the industry.

The Office for the Electricity and Gas Regulator, which is the main regulatory body in the electricity supply industry, handles the regulation of the network independently, within the framework of the Electricity Act. Reviewing the role of the Office for the Electricity and Gas Regulator to identify options to reinforce its powers and independence would improve the quality of regulation.

Taxes and subsidies need to be harmonised. Energy taxes require review in relation to their effects on fuel choice and their impact on trade in electricity. Harmonisation of taxation is needed in the electricity market, including a clear choice between production or consumption taxes. Harmonisation of environmental objectives, ideally in the wider EU context, would be desirable as a starting point for rationalising the taxation system. Pending this development, consideration needs to be given to particular aspects of the Nordic electricity market. The approach to coal-based electricity production, principally from Denmark, but also from other countries, needs to be rationalised to avoid the clear inconsistency of developing carbon-free fuels domestically while importing low-cost coal-fired electricity.

Support measures for renewables are being redesigned to make them compatible with the 1999 reform of the regulatory framework. Market-based approaches, such as those based on green certificates for renewable production and tradable emission permits for carbon dioxide and other gases, are being considered by the Swedish Government as an alternative to the less efficient subsidies provided in the past. Market-based solutions have a number of advantages in addition to their efficiency properties. In particular, they are competitively neutral and are easy to extend to an international context, thus facilitating the harmonisation of environmental policy in the Nordic market.

RECOMMENDATIONS

The Government of Sweden should:

- ☐ Consider the influence of the present major players in the gas and electricity markets on the development of gas-fired electricity generation and ensure that there is no discrimination in the gas market against gas-fired energy production.

- ☐ Review transmission congestion and pricing mechanisms to identify potential improvements such as pricing methods that better reflect costs and enhanced co-ordination between Nordic system operators in the management of reserves.

- ☐ Introduce, as planned, a scheme to support market entry of renewables that does not distort competition.

- ☐ In the context of the EU's "Florence process", consider reforms to the cross-border tariff system to facilitate trade with EU countries outside the Nordic countries.

- ☐ In the context of the ongoing review of distribution tariffs, identify options to provide stronger incentives for efficiency in distribution and to ensure that distribution tariffs are cost-reflective and do not cross-subsidise supply activities.

7

NUCLEAR AND RENEWABLES

NUCLEAR

Nuclear Power Plants

There are currently 11 nuclear power reactors in operation in Sweden: eight boiling water reactors (BWR) installed between 1972 and 1985, and three pressurised water reactors (PWR) installed between 1972 and 1983. The reactors are located at Barsebäck, Ringhals, Forsmark and Oskarshamn. A research reactor installed in 1960 also operates in Studsvik. A power reactor was installed in 1964 in Ågesta, a suburb of Stockholm, and shut down in 1974. Barsebäck 1 reactor was shut down in November 1999.

Table 16
Operating Nuclear Power Reactors in Sweden

Reactor	*Capacity (MWe Net)*	*Type*	*Commercial Start*
Barsebäck 2	600	BWR	1977
Forsmark 1	970	BWR	1980
Forsmark 2	970	BWR	1981
Forsmark 3	1 158	BWR	1985
Oskarshamn 1	442	BWR	1972
Oskarshamn 2	605	BWR	1975
Oskarshamn 3	1 160	BWR	1985
Ringhals 1	795	BWR	1976
Ringhals 2	875	PWR	1975
Ringhals 3	915	PWR	1981
Ringhals 4	915	PWR	1983

Source: IEA.

Availability of Swedish reactors was on average 84% in 1996 and 80% in 1997. Higher availability in 1996 compensated in part for lower hydro-electricity production in an extremely dry year. In 1998, nuclear contributed 47% of the output of electricity in Sweden. The proportion of nuclear has been stable for several years and is about equal to the contribution from hydro.

The uranium used in Swedish reactors is imported mainly from Canada and Australia. Some fuel elements are manufactured by ABB Atom AB in Västerås, but Sweden also imports fuel elements from France, Germany, Spain and the United States.

The four utilities operating nuclear power plants in Sweden are Vattenfall AB, BKAB, OKG AB and Forsmark Kraftgrupp AB. The Ministry of Environment and Natural Resources has overall responsibility for issues concerning safety management and

Figure 26
Nuclear Facilities in Sweden

Note: Barsebäck 1 is now shut down.
Source: SKi.

radiation protection at the plants. The Swedish Nuclear Power Inspectorate (SKi) and the Swedish Radiation Protection Institute (SSI), which report to the Ministry of Environment, are the authorities responsible for evaluating nuclear safety, waste management and radiation protection issues. In addition to these organisations, the Swedish National Council for Nuclear Waste (KASAM) was established in 1985 as an independent expert committee to provide advice on nuclear waste management issues.

Nuclear Policy

In December 1997, Parliament passed legislation, effective from 1 January 1998, on the decommissioning of nuclear reactors to allow the government to decide when a permit to run a nuclear reactor for energy production could be discontinued for energy policy reasons. The legislation provides for compensation to be paid to the reactor owners when a decision is taken to discontinue a permit.

In February 1998, the government decided that the operating licence of the Barsebäck 1 nuclear power reactor should be terminated by the end of June 1998. Sydkraft challenged the legality of this decision and the case was tried by the Supreme Administrative Court of Sweden. The Court ruled in favour of the government, and the reactor was shut down in November 1999. Legislation to formalise an agreement on compensation for the closure was presented to the Parliament in April 2000.

According to the Parliament's 1997 decision on energy policy, the second reactor at Barsebäck is to be shut down before 1 July 2001, provided that new production capacity and a decrease in electricity consumption can compensate for the electricity production loss. Two consulting companies have been commissioned to evaluate the results of the short-term activities in the energy policy programme (see Chapter 3), so that data are available that could be used by the government as a basis for deciding if the conditions to close Barsebäck 2 are met. This is a part of the planned evaluation process of the Energy Policy Programme as a whole. The government will present its assessment of the terms for closure of Barsebäck 2 in the Budget Bill for 2001. The government's assessment will be based on the evaluation by the consulting companies.

Waste Management

The utilities that produce electricity in nuclear power plants are responsible for the management and disposal of the waste. These utilities have jointly formed the organisation Swedish Nuclear Fuel and Waste Management Company (SKB), which is responsible for the management and disposal of spent fuel and radioactive waste from nuclear power plants, including decommissioning wastes.

SKB builds, owns and operates the Swedish waste management facilities and conducts research and development. After an initial cool-down period of approximately one year at reactor sites, spent fuel is shipped to SKB's central interim storage facility (CLAB), near the Oskarshamn nuclear power plant, for further cooling and storage for 30-40 years. The spent fuel is stored in rock caverns 25 metres below the surface in water-filled pools. CLAB was put into operation in 1985 and has a storage capacity of 5 000 tonnes. Site investigations are underway for disposal of spent nuclear fuel, but no facility for this purpose is expected to be in use before 2008 at the earliest. Two communities have voted against further participation in the site investigations, but five other communities are presently participating.

Operational waste from reactors is conditioned and deposited in the SFR final repository for radioactive waste near the Forsmark nuclear power station. SFR is an underground repository in crystalline rock 50 metres below the Baltic Sea. It began operating in 1988 and has a storage capacity of 60 000 cubic metres. There are surface storages for low-level waste at each nuclear site, except for the Barsebäck power plant.

RENEWABLE AND NON-CONVENTIONAL FUELS

Biofuels

Just over 15% of Sweden's total primary energy supply is classified as combustible renewables, usually known as biofuels in Sweden.

During 1997, the use of biofuels (principally wood and forest product wastes such as black liquors, bark and sawdust) and peat amounted to about 8 Mtoe, of which about 5 Mtoe are used internally in the forest industry for heat and some electricity production. Single-family houses use a stable 1 Mtoe of renewable energy, mainly logs from their own forestlands. In the district heating sector, the use of biofuels and peat has almost doubled to about 2.2 Mtoe over the five years to 1997. Biofuels now meet more than 50% of the supply for district heating grids. Wood fuels meet most of the growth in demand. Reducing the costs of using biofuels was established explicitly as an important objective in the 1997 energy policy legislation.

Taxes on fossil fuels promote the use of biofuels for heat production. Biofuels in CHP are promoted by investment aid. Investment subsidies for district heating grids indirectly reinforce the promotion of biofuels.

The preconditions for a co-operative project on the generation, distribution and use of biogas as a motor fuel in cars, taxis and buses have been investigated. Biogas as a motor fuel is generally exempted from tax. Motor biofuels are supported by an exemption from taxes in accordance with rules for pilot projects in the EU Mineral Oil Directive. The introduction of motor biofuels is not expected to have a significant impact in the short term, whereas solid biofuels for heating already have a significant market.

Small-scale Hydro

Small-scale hydro was promoted by an investment subsidy, but this aid is currently frozen and new directives for its use are being considered.

Wind

Wind power is currently a negligible contributor to energy supply. But within a few years it is projected to produce 0.7 TWh per year as a result of investment subsidies included in the programme for a sustainable energy supply. Wind power has been demonstrated offshore and will also be demonstrated in arctic and mountainous locations.

The preconditions for further expansion of wind power have been investigated. Key issues were found to be the need for criteria for permission to establish wind power, both onshore and offshore, as well as the need to reinforce local electricity grids to take into account wind power, and related economic considerations. The 1999 report of the investigation states that areas with excellent preconditions for wind power have a potential to produce 10 TWh, including onshore and offshore locations. Some of these might need to be identified as areas where the deployment of wind power would be in the national interest. Minor modifications in the consent process are proposed as well as government aid, in certain circumstances, for any upgrading of the electricity grid necessary for the deployment of wind power.

Solar Energy

Use of solar energy (photovoltaics and artificial photosynthesis) is supported under Sweden's energy research and development programme, and discussed in Chapter 9.

CRITIQUE

Nuclear policy has been clarified since 1997 but further clarification is necessary. From the 1980 referendum decision to phase out nuclear power to the passage of the 1997 Sustainable Energy Bill, there was considerable uncertainty about the future of nuclear power in Sweden. For practical purposes, nuclear issues no longer dominate general energy policy in Sweden. Considerable progress has been made since the last IEA review towards establishing a clear policy under which no further nuclear plant closures (beyond the Barsebäck reactors) are likely to be considered for some time, and then only if criteria endorsed by Parliament are satisfied.

Nonetheless, the policy could be further clarified. Many criteria are mentioned in the decisions of Parliament, but the 1997 legislation does not enshrine them in any detail. In particular, economic criteria are not set out, although it is considered that the closure of the Barsebäck 1 plant would not "noticeably" affect the "general electricity price". Only in the 1991 Parliamentary statement on energy, confirmed in 1997, is consideration given explicitly to maintaining internationally competitive electricity prices.

It is clear that the pace of the phase-out will be determined by the pace of the development of alternative environmentally acceptable generation capacity, and on successful energy efficiency measures. But the details of how to determine when sufficient progress has been made to allow the closure of a nuclear plant remain to be worked out by Parliament, which will also take any decisions on decommissioning.

The debate is now more about the future of biofuels than of nuclear. Since natural gas and coal are not considered options on environmental grounds, and potential new hydro capacity is very limited, any new capacity replacing nuclear must be based on renewables. Since Sweden has no significant renewable capacity at present other than biofuels, the expectation is that nuclear power will be replaced ultimately by a huge expansion in output from biofuelled plants and imports. At present, biofuels contribute only about 2% to electricity output, compared with 47% from nuclear. Replacing a single power reactor would, on average, require tripling output of biofuelled electricity generation. In a sense, the central policy focus has changed from the future of nuclear power to the outlook for renewables, and specifically for biofuels.

Recognising that "problems could occur with employment, welfare, competitiveness and the environment if the nuclear phase-out were to be completed by 2010", Parliament has shown some degree of acceptance for the option that no further reactors will be closed before 2010, and no date has been set for closing the last reactor. There is a danger that with the general language in the legislation and the number of statements arising from other sources, pressure will arise to force the pace of closures, regardless of the state of development of renewables. A comparison might be made with Denmark, where there are detailed plans[13] to replace coal-fired power with renewables, principally wind and CHP. In Denmark, the proportion of electricity generation from coal is higher than from nuclear in Sweden and natural gas is planned as a transitional fuel. Despite these differences, it is notable that the planning horizon for replacing coal-fired power in Denmark is 2030. If a similar year were considered for phasing out nuclear in Sweden, it is likely that many of the existing nuclear plants would be taken out of service on commercial grounds before then. For example, in April 2000 Vattenfall announced that it was not proceeding with a planned overhaul of one of the older reactors at Ringhals because the prospect of lower electricity prices in the future and a surplus in capacity does not justify further investment in the reactor.

13. See *Energy Policies of IEA Countries – Denmark 1998,* IEA/OECD Paris, 1998.

Natural gas should remain an option on economic grounds. Natural gas could be a competitive alternative to nuclear, without the perceived safety and environmental problems of nuclear, and yet avoiding the high cost of a premature transition to renewables. Because Sweden would be moving from carbon-free nuclear power to a fossil fuel, this would necessarily incur an environmental cost. If electricity prices are to be kept competitive, and if nuclear is to be phased out, the role of natural gas may need to be re-evaluated and consideration given to the balance between economic and environmental objectives underlying the nuclear phase-out policy.

According to Swedish policy, the future use of natural gas in electricity production is to be decided on strictly commercial terms. Natural gas is generally regarded as the least-cost option in many electricity systems and is replacing other fuels in many electricity markets around the world. A flexible policy approach, combining the elements of current policy with the gas option, could reduce the cost of replacing nuclear since it would:

- take advantage of the low cost of electricity generated in existing nuclear plants,
- not exclude the development of other options such as natural gas if they prove to be attractive, and
- allow for a gradual introduction of renewables as their cost diminishes.

For this policy approach to be effective, it is essential that decisions concerning the closure of specific nuclear plants and the development of gas import infrastructures be taken objectively. Two considerations are particularly important:

- It is crucial that decisions on closing nuclear stations be based on an objective assessment of the availability of alternative and competitive generation capacity.
- Structural issues raised by the links between gas and electricity companies must be addressed, as discussed in Chapter 8.

Market realities should be acknowledged and could help bring about a smooth transition. Although the Parliament might reasonably decide which power generation technology they favour, it would not be possible to ensure that capacity replacing nuclear will be built in Sweden. In the competitive electricity market, closing nuclear capacity in Sweden may result in new capacity being built in the country, or new capacity being built in another country participating in the electricity market, or simply in the use of existing under-utilised capacity in any one of a number of countries. Increased imports may well mean encouraging the use of fossil-fuelled plants to replace carbon-free nuclear power.

Greater reliance on markets to decide the pace of the phase-out (and to identify the reactors to be phased out) would help in reducing the cost of replacing nuclear power. A market-oriented approach need not conflict with the political decision to phase out nuclear, but could implement the phase-out in a more cost-effective way and help ensure that Parliament's ultimate goal – the encouragement of renewables –

is achieved. For instance, the existing tax on nuclear, the subsidies given to renewables and enhanced nuclear safety obligations, all discourage the use of nuclear power and accelerate the deployment of renewables, while leaving actual entry and exit decisions to market players. The nuclear tax is at present not directly related to assistance to renewables and acts as an impediment to competition as noted in Chapter 3, but it could be developed as part of a package of market-based mechanisms designed to encourage a transition from nuclear power to renewables.

But care should be exercised in developing policies on deployment of renewable energy technology. Unless internationally harmonised support for renewables[14] is introduced, support schemes in Sweden would raise domestic electricity costs and reduce competitiveness of electricity in the international electricity market and general competitiveness of the electricity-consuming industry. Policies such as "green certificates" help introduce renewables by least-cost means, but still raise the overall cost of electricity. Renewable generation technologies will have to be competitive, free of government support, and available on a very large scale to successfully replace nuclear. In a competitive international electricity market, decisions by the government on the relative competitiveness of nuclear and renewables, and the adequacy of capacity of renewables, will be tested by the market. Incorrect political judgements on the economic maturity of renewables could be very costly.

To summarise, the long-term objective of moving the energy sector to a renewables base has to be implemented taking into account the need for electricity prices to remain competitive. Flexibility, caution and reliance on market-based mechanisms may help to reduce the cost of the nuclear phase-out. Ultimately, the electricity market will determine the success or failure of the outcome.

RECOMMENDATIONS

The Government of Sweden should:

Nuclear

- ☐ Assess the economic advantages of allowing existing nuclear to be phased out on the basis of the economic life of existing reactors.

- ☐ Ensure full transparency and independence of the evaluation to be made to determine when the criteria established by the Parliament for the closure of reactors have been met.

14. It is important to keep separate the encouragement of renewables to achieve the EU target, which is a harmonised policy that should be largely neutral in its trade impacts, and a large-scale replacement of nuclear with renewables. The latter could have major trade impacts if renewables are not genuinely economic.

- ☐ Pending any further government decisions on nuclear reactor closures, ensure the continuing safe and economic operation of existing reactors.
- ☐ Continue progress towards the selection and construction of a final repository for high-level wastes; review the adequacy of the present low- and medium-level waste repositories and facilitate their expansion, if necessary for decommissioning waste.

Renewables

- ☐ Keep government support for renewables under continuous review, with the objective of ensuring that satisfactory progress is being made towards the goal of competitiveness with other fuels.
- ☐ Ensure that policy on the use of biofuels does not give rise to support for indigenous fuels principally for reasons of supply security, or for social, regional or industry policy purposes.
- ☐ Continuously update assessments of the capacity of forest-based industries to supply sufficient biomass at acceptable cost to meet the requirements for biomass in electricity generation.

8

OIL, GAS AND COAL

OIL

Industry Structure

Sweden has no oil reserves and no exploration is being undertaken. All oil and petroleum products are imported without restriction.

The Swedish oil market has undergone considerable structural change during the last two decades, with environmental issues dominating the market trends. Oil met about one-third of total energy supply in 1998. More than 50% of Sweden's crude oil requirement is imported from the North Sea.

Refining

Sweden has a significant capacity in oil refining, and the total output exceeds domestic demand. Exports in 1998 amounted to about 10 million m^3. Low-sulphur crude North Sea oils are well suited to the requirements of the Swedish refinery industry. There are three modern, large-scale units that are to some extent specialised in certain qualities such as low-sulphur, low-aromatics gas oil and gasoline specifications in line with the EU auto oil programme. Encouraged by EU programmes, refiners have also invested heavily in capacity to produce low-sulphur diesel fuel. There is no special regulation for the sector other than strict environmental legislation.

Use of automotive diesel fuel has risen and refiners have invested about SKr 1 billion in developing production capacity for diesel. Diesel production in Sweden competes with jet-fuel production capacity and the latter is now imported. Policy on use of diesel requires a judgement to be made on the balance between better fuel economy on the one hand, and health effects caused by higher emissions (of particulate and nitrogen oxides), on the other. Specifications for diesel in Sweden, as elsewhere in Europe, are now set to minimise emissions. At present, diesel in Sweden is used primarily in heavy vehicles such as trucks and buses, and the Swedish Environmental Class 1 Diesel has been effective in reducing emissions. Diesel-fuelled cars account for about 4.6% of the car fleet. Taxes on fuel and on cars are designed so that the total cost of owning and running a diesel or petrol car is more or less comparable.

The oil companies are now working with agricultural interests on a 5% ethanol fuel to supply Stockholm.

Retail Market

The number of marketing companies in the gasoline retail market has been more than halved from 14 in 1979. Today six companies dominate the gasoline market, of which three, OK-Q8, Statoil and Shell, have some two-thirds share of the market.

In addition to these companies, Preem Petroleum and Norsk Hydro have significant shares in the auto diesel, heating gas oil and fuel oil markets. The number of retail outlets has fallen from 9 000 in 1975 to 3 500 in 1998. Base prices have not risen in real terms, but taxes on gasoline have risen from 50% of the producer price in 1980 to nearly 75% in 1998. Most retail outlets are now large and diversified. Self-service outlets are becoming more common, but there are no supermarket outlets.

The general competition law is applicable to the oil industry. In this context it is notable that the lack of competition in remote areas has not led to higher prices as has been reported in other IEA countries.

Market Trends

The Swedish domestic market used about 15 million cubic metres of oil products in 1998, which represents an overall reduction of 47 % since 1979. Heating gas oil and fuel oils account for most of the reduction, while the use of gasoline and auto diesel have increased by about 10% and 30% respectively during the same period. The use of oil products is expected to increase modestly during the coming years, depending on growth in industrial output. Relative prices and taxes for gasoline and automotive diesel are illustrated in Figures 27 and 28. Demand for oil, primarily for transport, is illustrated in Figure 29.

Emergency Response Measures

Since its oil requirements have to be met entirely by imports, Sweden is especially vulnerable to oil supply disruptions. The government, therefore, gives high priority to maintaining well-prepared emergency response measures and has promoted oil substitution policies and energy conservation programmes. These have contributed to considerable reduction in the proportion of energy requirements provided by oil.

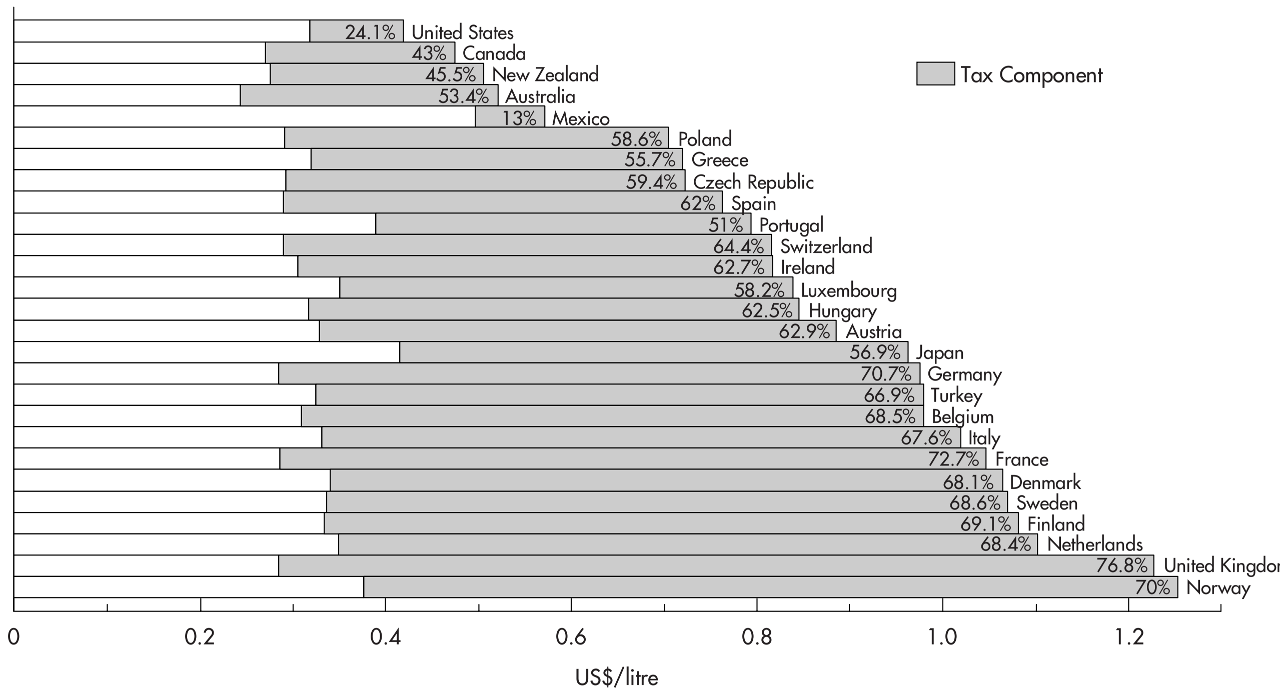
The Swedish National Energy Administration has the main responsibility for emergency response. The Rationing Act is the legal authority for establishing and operating the Swedish National Emergency Sharing Organisation (NESO) for IEA emergency response measures. The Department for Strategic Energy Preparedness of the Swedish National Energy Administration is the core of Sweden's NESO. In an emergency, industry experts would participate in NESO activities.

The legal framework for emergency response measures in Sweden consists of the following instruments:

- The Contingency Storage of Oil and Coal Act, and the Contingency Storage and Oil and Coal Ordinance.
- The Oil Crisis Act.
- The Rationing Act.
- The Total Defence Bill.

Figure 27

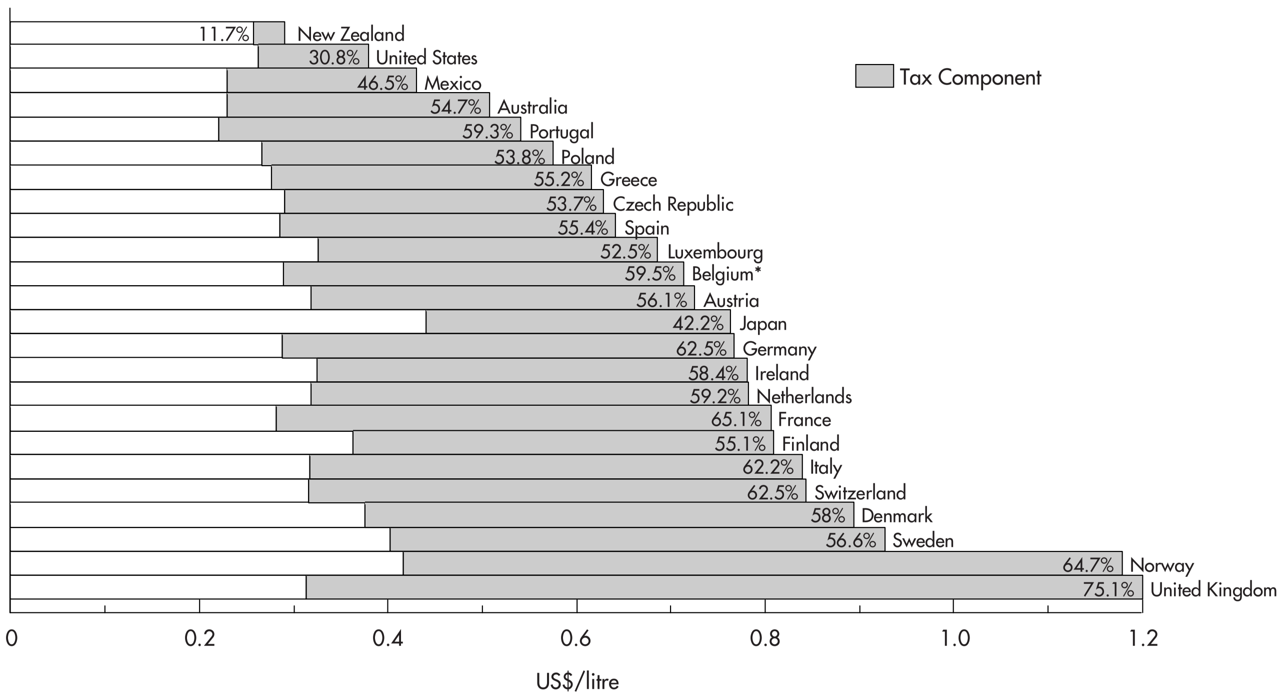
OECD Gasoline Prices and Taxes, 1st Quarter 2000



Source: *Energy Prices and Taxes*, IEA/OECD Paris, 2000.

Figure 28

OECD Automotive Diesel Prices and Taxes, 1st Quarter 2000

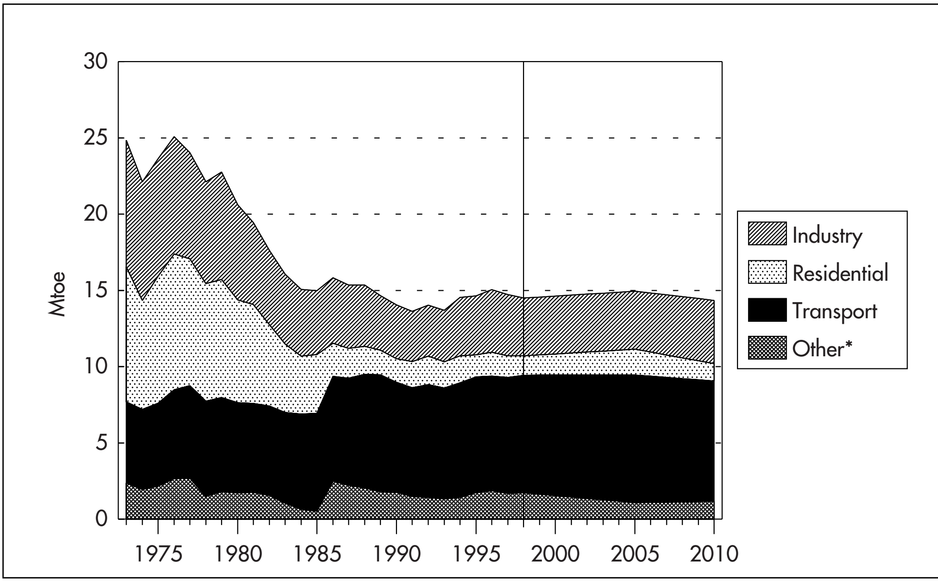


* 4th quarter 1999 for Belgium.

Note: Data not available for Canada, Hungary and Turkey.

Source : *Energy Prices and Taxes*, IEA/OECD Paris, 2000.

Figure 29
Final Consumption of Oil by Sector, 1973-2010



* Includes commercial, public service and agricultural sectors.
Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and country submission.

Emergency Reserve Policy

The Contingency Storage of Oil and Coal Act and the Contingency Storage of Oil and Coal Ordinance enable the government to ensure that it has sufficient oil stocks in non-emergency periods to meet the IEA emergency reserve commitment. Stock holders are oil companies and large consumers such as manufacturing plants and heating stations. The stock-holding obligation is 25% of the previous year's deliveries or consumption in accordance with the Total Defence Bill. Since Sweden has no oil production, consumption and imports are virtually identical.

The Act provides the government with the legal power to draw down stocks under the relevant articles of the International Energy Program. Since there is no threshold in terms of depth or duration of a disruption in the Swedish legislation, use of emergency stocks is at the discretion of the stock-holders.

Sweden has bilateral stock-holding agreements with the governments of Denmark and Finland. Sweden is negotiating similar agreements with the United Kingdom, the Netherlands and Ireland, and hopes to have these in place during 2000.

Demand Restraint Measures

Demand restraint measures are carried out in accordance with the Rationing Act. The Swedish National Energy Administration has the authority to implement a variety of demand restraint measures with government approval and without parliamentary ratification, except for rationing.

Sweden considers that demand restraint is an effective measure on an equal footing with stock draw. Given the importance of stock draw as an effective response in the early stage of a crisis, Sweden is reviewing the combined use of demand restraint and stock draw, especially in situations not requiring the full range of measures defined in the International Energy Program.

NATURAL GAS

Gas Supply

Natural Gas

No reserves of natural gas are known to exist in Sweden and no exploration is being undertaken. All natural gas is imported. The Swedish grid is connected to the Danish grid, which in turn is connected to the German grid. Gas is imported mainly from Denmark under long-term contracts, and on more flexible contract arrangements from Germany.

Natural gas was introduced in 1985. In 1998, total Swedish gas imports amounted to 853 million cubic metres. The capacity of the main pipeline is approximately 2 billion cubic metres, and using compressors, this capacity could be boosted to about 3 billion cubic metres. Certain expansions of the main grid and distribution grid are underway in order to reach new customers and expand the volume of gas sold.

Natural gas accounts for about 2% of Sweden's energy supply. In areas where natural gas has been introduced, it meets around 20%–25% of energy demand. About 42% of the total natural gas consumed is used in district heating and power production, 40% in industry, 17% in households and buildings, principally for residential heating, and 1% is used as a motor fuel. About 10 000 customers use natural gas for individual heating. In addition, there is a large number of households using natural gas for cooking purposes only. In areas where it is available, natural gas has basically replaced oil in industry, in combined heat and power generation and in district heating stations.

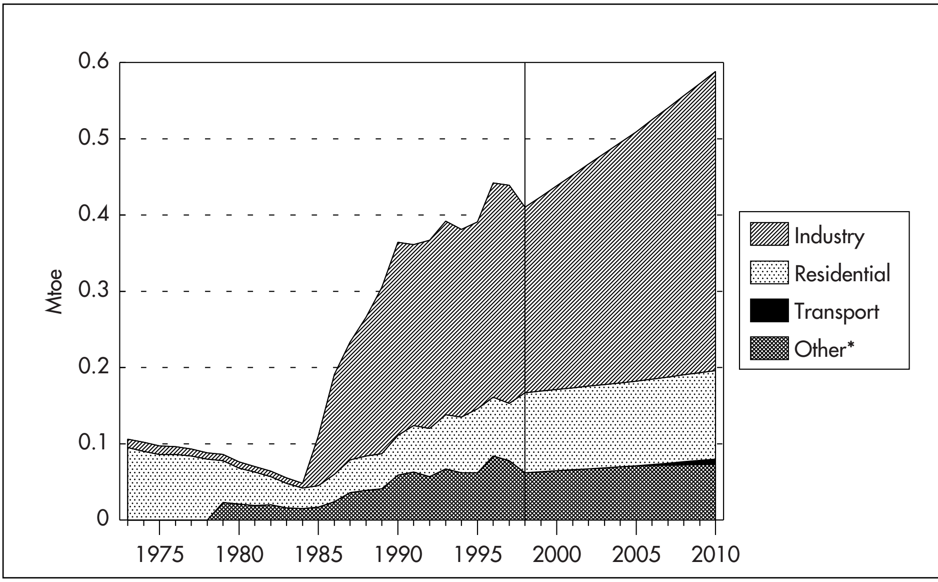
Liquefied Petroleum Gas

Liquefied petroleum gas (LPG) accounts for about 1.6% of energy supply in Sweden. In 1998, imported and locally produced LPG amounted to approximately one million tonnes, of which about half was used for energy purposes and the remainder as a raw material in the petrochemical industry, or was exported. LPG is mainly used in industry, restaurants, and for CHP and heat production.

Biogas

There are about 100 biogas plants in Sweden, mostly associated with sewage treatment works and waste deposits. Biogas is mainly used for local and district

Figure 30
Natural Gas Consumption, 1973-2010



* Includes commercial, public service and agricultural sectors.
Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999, and country submission.

heating (452 GWh in 1997), as well as for electricity production (58 GWh). It is also used as a vehicle fuel.

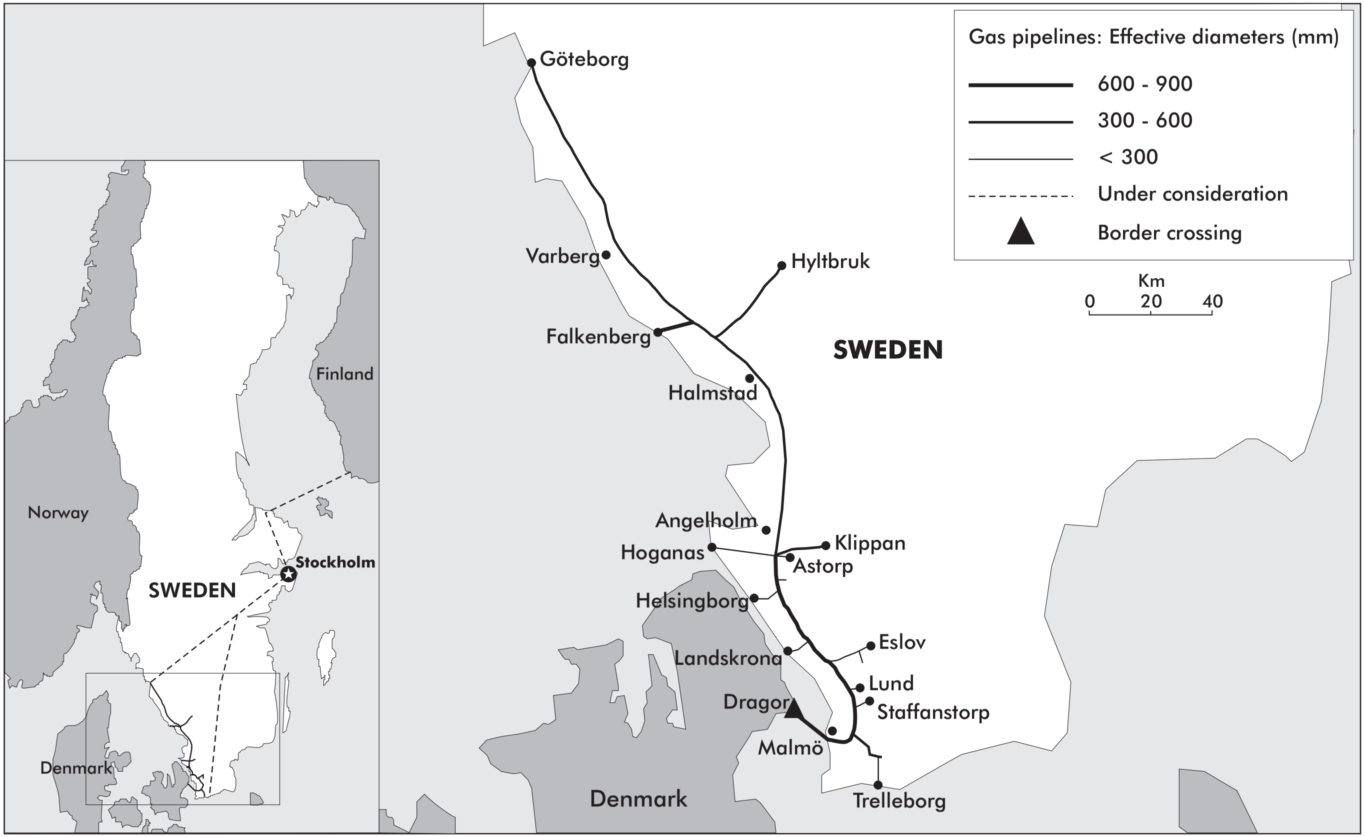
There is one producer of town gas in Sweden, Birka Energi AB, in Stockholm. The gas is produced from light naphtha. In Stockholm, about 120 000 customers are supplied with town gas, of which 100 000 use it for cooking purposes only.

Industry Structure

Following the 1980 referendum decision to phase out nuclear, natural gas was considered to be a possible replacement for nuclear power. The state-owned company Swedegas (now Vattenfall Naturgas AB) negotiated supply agreements with DONG Naturgas A/S, the Danish state-owned company, to supply gas to 2010. Gas supply commenced in 1985. Under supply agreements signed in 1980, 1985, 1986 and 1989, DONG delivers approximately 900 million cubic metres of gas annually to Sweden. The contracts are of a take-or-pay nature and expire progressively in 2003, 2006 and 2010.

Vattenfall Naturgas owns the main pipeline between Malmö and Gothenburg and is currently the only importer of natural gas. Formerly owned by the state electricity utility Vattenfall, its present owners are:

Figure 31
Natural Gas Network



Source: *Natural Gas Information 1998*, IEA/OECD Paris, 1999.

- Vattenfall AB, Sweden (51%).
- Ruhrgas AG, Germany (14.5%).
- Statoil, Norway (14.5%).
- DONG A/S, Denmark (10%).
- Neste OY, Finland (10%).

Swedegas also signed a transportation agreement with DONG in 1985 to run to 2005. The agreement gives Vattenfall Naturgas the right to transport gas through Denmark to Dragör. The quantity of gas which may be transported exceeds the current level of consumption in Sweden.

Vattenfall Naturgas sells almost all of its gas to local and regional distributors, some of which are owned by local communities. Agreements between Vattenfall Naturgas and distributors are similar to the import agreements between Vattenfall Naturgas and DONG Naturgas. The largest distributor, Sydgas AB (a subsidiary of Sydkraft AB), delivers around 75% of all gas consumed in Sweden. In some areas, Sydgas AB sells gas to local sub-distributors, which have built local distribution networks. Distributors have a monopoly in local markets. Only the west and south coast regions of Sweden currently have access to the natural gas grid. The gas network has been built gradually and now covers 26 municipalities with about 55 000 customers. There are at present no storage facilities for natural gas in Sweden, but seasonal capacity is met by supplies from Denmark.

Implementation of the EU Natural Gas Market Directive[15]

The EU Natural Gas Market Directive is much more far-reaching than the present Swedish legislation on natural gas. New legislation in Sweden is expected to govern activities related to concessions, obligations of the pipeline owner, and separate accounting and supervision.

- A concession of 40 years will be required to operate a natural gas pipeline and use a natural gas storage facility. Exemptions will apply to pipelines for individual households and for use exclusively in port and industrial areas.
- Access to natural gas pipelines will be based on a regulated procedure with published tariffs. The obligation to connect natural gas pipes and to transport

15. On 22 June 1998, the European Parliament and the Council of Europe adopted the Natural Gas Market Directive. The directive aims to increase competition on the gas market and to create an internal market for natural gas in Europe. To achieve this, the directive includes provisions for ensuring that owners of transmission and distribution networks will allow other players access to these networks. National legislation to implement the directive is required by 10 August 2000.

natural gas will apply to entitled customers. These will initially be pipeline owners, customers who have gas-fired electric power generation, and certain large end-users, with an annual consumption of more than 25 million cubic metres. This corresponds to a market opening of about 60%. All customers will become entitled from 1 January 2006, i.e., the market will be entirely open. To encourage investment in gas infrastructure that might otherwise not be profitable in a competitive market, an exemption will apply in geographically limited areas not previously supplied with natural gas.

- Separate accounts for natural gas transmission, distribution and storage operations will be required annually by the supervising authority appointed by the government.

To implement the directive, modifications to legislation on trade, transport and distribution of natural gas, and other energy commodities transported in pipelines, are being prepared.

Taxes

The carbon dioxide tax rates on natural gas and LPG are proportional to their carbon content. The energy tax rates on natural gas and LPG are lower than on oil and coal. In the 1997 energy decision, Parliament supported the principle that the environmental benefits of natural gas should be reflected in the taxes.

Regulation

Under the existing Pipeline Act (1978), a government concession is required to construct and use pipelines, including for natural gas. Consideration is given to the benefits of the pipeline and to the suitability of the applicant. The benefits of the project shall be compared to its negative "societal consequences". These are assessed on a case-by-case basis and could take into account energy policy conditions and guidelines. Conformity with other legislation is also judged.

The trade and transport of natural gas is not regulated. The present Pipeline Act states that the concession holder is bound to transport natural gas for another party as long as this does not cause considerable damage.

Policy on the Future Development of Natural Gas

Sweden's formal policy, established in 1988, is that any investments in gas infrastructure must be financed on strictly commercial terms. According to a statement by the Minister for Trade and Commerce in February 1999, any proposal for a natural gas project should be examined broadly by all interests in Sweden, and this should be part of the process for considering an application for a concession to develop a pipeline.

Following the minister's statement, Parliament rejected two motions to immediately stop any on-going work within the Government Offices, the Nordic Council of Ministers and elsewhere promoting a new pipeline across Sweden. According to the motions, a pipeline for natural gas would threaten the use of biofuels in district heating plants in southern and central Sweden, and counteract the intentions of the Kyoto Protocol. However, the Parliamentary Committee of Industry and Trade stated that even if natural gas is the least environmentally damaging fossil fuel, neither a large-scale introduction of natural gas nor a new pipeline for natural gas is currently "on the agenda". This statement could mean that private development of natural gas is not currently in prospect for economic and financial reasons, so that a firm policy position need not be taken. The committee noted that the existing natural gas grid could be utilised more effectively. It also stated that when implementing the EU Natural Gas Market Directive, Sweden should take note of the detrimental effects that a new natural gas pipeline could have on Sweden's carbon dioxide emissions.

Potential Developments

Pipelines

The prospect of integrating the natural gas networks and storage facilities in the Nordic countries with secure diversified supplies from Denmark, Norway and Russia has been investigated. The EU-supported study of the "Nordic Gas Grid" project was undertaken by seven Danish, Finnish and Swedish gas companies. The pre-feasibility study concluded that such a pipeline might be economically feasible. The main conclusions of the study were:

- The energy markets in the Nordic countries will be under-supplied with gas after 2000.

- A co-ordinated natural gas grid is the optimal approach to bringing more gas to the Nordic countries.

- Transit volumes bring economies of scale and lower tariffs, improved flexibility and better security of supply for all.

Another study, the North Transgas Oy, is a commercial study by a Finnish/Russian consortium in which Fortum and Gazprom are the main actors. The consortium studied the prospects for a transit pipeline from Russia to northwest Europe via Finland. Three alternative routes were considered, two of which pass Gotland (in the Baltic Sea), one to the west and the other to the east. The third route is from the Russian/Finnish border crossing Finland and the Swedish mainland to Germany. Gazprom announced in late 1999 its intention to build a pipeline via the Baltic Sea from Russia to Europe.

Sydkraft AB with Verbundnetz Gas, Sjaellandske Kraftvaerker and Norsk Hydro are undertaking an investigation of the feasibility of a Baltic Sea interconnector to connect the gas network in the southern parts of Scandinavia with the central European network. It is believed by the proponents that an interconnector might stimulate the market for natural gas and be an important means of increasing security of supply in the region. Preliminary studies will continue until the summer of 2000 and an application for a concession may be made soon after. Half the funding (about SKr 15 million) is from the EU TEN programme.

A newly established Norwegian company, Stamgass AS, is investigating the possibility of building a transmission pipeline from Trondheim in Norway via Sundsvall in Sweden to Kristinestad in Finland. The cost of the pipeline is estimated to be SKr 8 billion. Part owners in Stamgass AS are the Swedish power distributor Graninge, the Finnish power distributor PVO, and the Norwegian subsidiary of the US oil company Conoco.

Network Expansions

In June 1999, it was decided to enlarge the national gas network to include municipalities of Partille, Jonsered and Lerum north-east of Gothenburg. The enlargement will be undertaken during 2000 and 2001 in a co-operative venture by Göteborg Energi AB and Vattenfall Naturgas AB. The gas is expected to replace oil and will also supply a new gas station for natural gas vehicles.

During 1999, Sydgas AB made an application to connect Gislaved and Gnosjö, two municipalities in southern Sweden, to the network.

Scandinavia's first installation of biogas into the natural gas network was opened in December 1999. The installation, located outside the city of Laholm on the Swedish west coast, was built by Sydgas AB. The installation upgrades biogas into a quality equivalent to natural gas. The project was financed by Sydgas AB and the Swedish National Energy Administration at a cost of approximately SKr 5.5 million.

COAL AND PEAT

Coal Supply

Coal meets about 4.5% (1998) of the total energy supply, divided equally between steam coal for industrial use and electricity generation, and coking coal for steel-making. All coal is imported.

Coal Consumption

The structure of the tax system is such that steam coal is competitive with other fuels in industrial use and for electricity production. Coal is subject to VAT, energy, sulphur and carbon dioxide taxes, and has the highest level of taxes per energy unit of all fuels. The tax rate is reduced for steam coal used in industry (the carbon dioxide tax is reduced by 50% and the energy tax by 100%), and there is an exemption from the energy and the carbon dioxide taxes for coal used in electricity production as well as for non-energy purposes (for example, for coking coal).

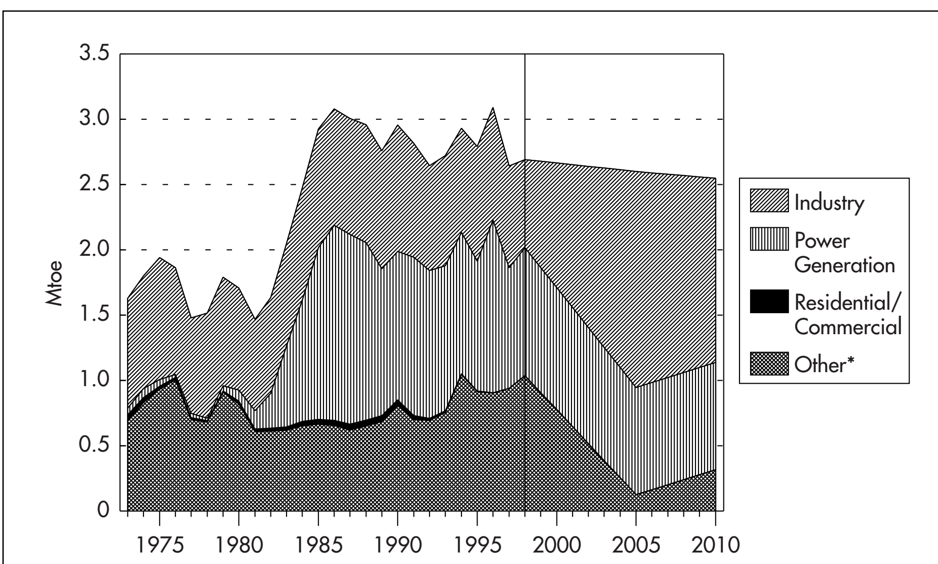
Table 17
Hard Coal Imports (thousand tonnes), 1978-1998

	1978	*1980*	*1985*	*1990*	*1994*	*1995*	*1996*	*1997*	*1998*
Coking coal	**1 239**	**1 790**	**1 834**	**1 315**	**1 606**	**1 674**	**1 592**	**1 790**	**1 835**
Australia			140	449	524	535	500	788	840
Canada	78	159	278	102	220	179	51	71	112
United States	338	1 105	1 074	764	860	950	900	802	753
Russia	417	402	2				129	110	113
Other	406	124	340		2	10	12	19	17
Steam coal	**306**	**392**	**3 034**	**2 228**	**1 445**	**1 825**	**1 654**	**1 488**	**1 204**
Australia		6	614	187	105	44	13	10	11
Poland	174	171	1 292	732	772	1 000	1 261	1 062	787
United Kingdom	30	31	71	103			8	8	10
United States		58	343	117	45	55	30	93	48
Russia					255	455	142	120	65
Venezuela				375	200	198	123	164	277
Other	102	126	714	714	68	73	77	31	6
TOTAL	**1 545**	**2 182**	**4 868**	**3 543**	**3 051**	**3 499**	**3 246**	**3 278**	**3 039**

Note: Separation of coking coal and steam coal imports has been estimated by the IEA for 1990-1998 inclusive.

Source: *Coal Information 1998*, OECD/IEA Paris, 2000.

Figure 32
Coal Consumption by Sector, 1973-2010



* Includes agricultural and non-specified sectors.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 1999 and country submission.

The use of steam coal for district heating and electricity production is declining. It amounted to 685 000 tonnes in 1998 compared with 730 000 tonnes in 1997. Coal was used in eight co-generation plants and two hot-water plants. These are in many cases owned, or were formerly owned, by the local community. Several of the plants have plans to replace coal with forest fuels, waste fuels or natural gas because the tax on coal has made these fuels cheaper than coal. However, there is often some flexibility so that coal can be used should the current tax rates be modified.

The use of steam coal in industry is stable at a level of 700 000 tonnes. Coke consumption in industry was 1.4 million tonnes in 1998.

A considerable proportion of the electric power imported from Denmark and Germany originates from coal-fired cold condensing power plants.

Peat

Peat[16] accounts for 0.6% of Sweden's total primary energy supply. Production virtually ceased in 1950 but started again in the 1980s as an indigenous fuel to replace oil and nuclear. Although peat is thousands of years old, it is classified with renewable biomass for tax purposes in Sweden and consequently is not subject to the energy carbon dioxide taxes, unlike oil, gas and coal. Its sulphur content is low (typically 0.25%–0.5%) so the sulphur tax is also low.

Sweden has some 5.4 Mha of peatland of which about 0.35 Mha are suitable for fuel peat production. Sweden is the fourth largest producer of fuel peat after Russia, Ireland and Finland. Peat harvesting is undertaken by some 30 companies. Production varies greatly from year to year, depending on weather conditions being suitable for harvesting. Peat is stockpiled in good harvesting years to maintain supply. Peat is used for district heating and for providing steam for industrial use. Sweden has the world's largest peat-fired boiler at Uppsala, a repowered oil-fired boiler producing 120 MWe (equivalent to the plant under construction at Clonbulloge, Ireland) and 190 MWt for district heating.

CRITIQUE

Oil

Policies have been very effective in reducing the use of oil. Sweden has sought to reduce the country's use of oil since the oil crises of the 1970s. Unlike other IEA countries, the principal means has been electrification through the

16. Peat is a soft organic material consisting of partly decayed plant matter together with deposited minerals. Peat occurs mainly in wetlands where micro-organisms promoting the decomposition of dead vegetation are unable to decompose all the material, often because of lack of oxygen in waterlogged areas. Peat is generally a few thousand years old, and is often classified for this reason as a fossil fuel although substantially younger than coal which varies from 15 million to some 400 million years old. It is also sometimes classified as a biofuel. Its combustion and handling properties are similar to those of some brown coals.

expansion of nuclear power production, although expansion of the natural gas network has also played a part. Since 1970, use of oil has nearly halved in Sweden. Moreover, in 1998 about 60% of Sweden's crude oil imports came from the North Sea, and a further 10% from other non-OPEC countries. About 8% is imported from Saudi Arabia and 12% from other OPEC countries.

Sweden has been a net exporter of refinery products since 1989, principally to Denmark, Germany and Poland. The use of oil products has declined rapidly, particularly since 1979. The main reduction has been in fuel oils for heating that have been largely replaced by electricity and district heating.

The policy framework for ethanol blends and diesel may need to be reviewed. Government policies, including policies on agriculture, have encouraged refiners to invest in ethanol-blended fuel. Refiners consider ethanol to be an expensive option, but are co-operating with the pilot programme presently underway as all costs, other than the cost of injecting ethanol at depots, are being met by agricultural interests. A major research programme focused on lowering the cost of producing ethanol is being supported by government funding. If the research programme is successful, a financial commitment by refiners is likely to be necessary to fully commercialise the use of ethanol blends. Views of refiners should be considered during the pilot phase of the ethanol programme to ensure that it is directed at achievable goals.

Natural Gas

Investments in infrastructure for natural gas are to be made on commercial terms. There are no domestic resources of natural gas and any substantial growth in imports and consumption may require a new pipeline and investment in the transmission and distribution network. Government policy would prohibit direct government investment in natural gas, but would nevertheless allow investment by private interests. The question arises whether the government has a role in providing a more encouraging investment climate for natural gas, without being involved directly in supporting specific projects.

Natural gas has considerable potential in Sweden and could bring regional benefits. In areas presently supplied, natural gas is meeting 20% to 25% of energy demand. This is higher than in many European countries, and suggests that extending the network to remaining areas of potential demand could substantially increase the share of gas from its present level of 2% of total primary energy supply[17].

Expansion of the Swedish network, together with new pipelines to and through Swedish territory, could bring energy security, environmental and economic benefits to the region, notwithstanding possible increases in greenhouse gas emissions. Increased greenhouse gas emissions resulting from use of natural gas

17. According to statistics from the Swedish National Energy Administration. According to IEA statistics (see Annex A), natural gas accounts for 1.4% of total primary energy supply (1998).

would need to be addressed, but the problem should not be over-stated. If renewables fail to become economic in an acceptable time period, and if pressure continues to phase out nuclear, then natural gas may well be the only economically acceptable domestic alternative to nuclear. In these circumstances, consideration would need to be given to the appropriate balance between economic and environmental objectives in Swedish energy policy.

Natural gas could, however, have positive environmental benefits for Sweden. If domestic use of gas in power generation substitutes for imports of fossil-fuelled electricity, this would at best be environmentally neutral by replacing imported gas-fired power, and possibly preferable on environmental grounds by replacing imported coal-fired power. Since natural gas is at present replacing oil and coal in some uses, it already brings environmental benefits where nuclear is not an alternative and renewables are uneconomic.

Very few players dominate the gas market. The gas market in Sweden is currently dominated by two key players – Vattenfall Naturgas, which owns the pipeline and the main grid, and Sydgas, which owns most of the regional distribution grids. Both companies are subsidiaries of nuclear power generators, and are effectively competing with their parent companies in the energy market. There is at present over-capacity in the market and new gas-generating capacity will only gain entry if it proves to be more economic than existing capacity. Companies with an interest in both gas and nuclear may well prefer not to invest in new gas capacity if new capacity can only be viable by replacing other capacity owned by the same company. Expansion of the gas market may provide opportunities for new capacity without replacing existing capacity, in which case a problem may not arise. However, a conflict of commercial interests could arise and may be anti-competitive.

The transportation agreement between Vattenfall Naturgas and DONG Naturgas may also impede the development of competition. The agreement covers more than the requirements of the present natural gas market in Sweden, giving Vattenfall Naturgas a *de facto* monopoly in the Swedish market. The agreement has been challenged by other gas companies, since the agreement occupies space in the Danish gas grid and makes it difficult for other companies to import. The Swedish Competition Authority decided in January 1999 that the agreement does not infringe upon competition rules. Nonetheless, it is clear that since the transportation agreement provides for more gas than is currently required, it is unlikely that new importers would attempt to compete. It is hoped by the Ministry of Industry, Employment and Communications that implementation of the EU Natural Gas Market Directive will help solve the problem.

The investment climate for gas could be discouraging despite government "neutrality". Official policy is to leave the future development of gas in Sweden to the market. However, political opposition to gas development, both because it may increase national greenhouse gas emissions and would compete with nuclear and renewables, and the ambiguous view of Parliament that gas is "not on the agenda", gives rise to an uncertain political environment in which private interests could be understandably hesitant to invest. Natural gas will inevitably give rise to greenhouse emissions but economic considerations need also to be taken into account. Existing nuclear capacity has been in place for many years and its capital costs must be largely written off. New gas-fired capacity could be expected to face strong competition from existing nuclear capacity.

In the context of implementing the EU Natural Gas Market Directive, government policy will need to actively address some issues concerning the present structure of the market. This will be important if the government wants to ensure that a truly neutral investment climate exists. Ensuring that the energy and environmental tax regimes are stable is also a general energy policy requirement, as discussed in Chapter 3.

Coal and Peat

Coal use has declined, but remains an economic and environmentally acceptable fuel for electricity production. As in many other IEA Member countries, coal played an important part in Sweden's energy supply until the 1950s when it lost ground to oil. Coal contributed again during the 1970s, but its use in electricity and heat production has since declined by over 60% from a peak in 1987. Coal remains more than twice as important in Sweden as natural gas, accounting for 4.5% of total primary energy supply in 1998.

Steam coal imports (for power generation) have been declining steadily since 1995. Sources are diverse, but Poland, the United States and Australia each supply over 25% of total coal imports. Coking coal imports (for steel-making) from the principal sources are stable compared with energy coal imports, which reflects quality and supply security requirements. Sourcing of energy coal fluctuates widely, reflecting prices on the market. Sweden is a marginal market for Australian and US suppliers because of transport costs.

The tax structure affects coal use in heat production and in industry, but not for use in electricity. Since international coal prices have fallen steadily and are currently very low, the tax structure is the main influence on coal use in Sweden. The tax structure leaves coal competitive with other fossil fuels for use in electricity production, but affects its use in heat production and in industry. About 50% of energy coal is used in the district heating sector, either in combined heat and power (CHP) plants or in heating plants.

Taxes in the electricity sector are levied on consumers so that different categories of consumers can be differentiated to maintain competitiveness in industry and competitiveness for Swedish electricity traded in the international market. Since steady advances in combustion technology have matched Sweden's increasingly stringent environmental requirements, coal has maintained its position for electricity production. Coal used in CHP has declined steadily, but in relation to the fluctuating availability of hydro rather than because of taxation. Hence, in dry years such as in 1996, the use of coal for electricity more than doubles.

In the heat sector, taxes are levied on production rather than on consumers. Plants that produce heat only have responded by reducing their use of coal dramatically. Heat plants used about 118 000 tonnes of coal in 1994, 20 000 tonnes in 1997, and 5 000 tonnes in 1998.

Industry uses steam coal, coking coal, coke and smaller quantities of other coal products, such as graphite and pitch. Industrial use of steam coal increased slightly in 1998 compared with 1997, but total coal use has decreased steadily as a result of switching to other fuels, mainly oil and biofuels, partly because of the carbon dioxide tax introduced in 1993. The use of coking coal fluctuates with steel output, moderated by technological change in steel-making which allows a reduced use of coke.

The tax issue should be addressed as a matter for energy efficiency policy affecting development of CHP. The effect of the structure of energy taxation on coal use is best seen as an issue for energy efficiency policy, rather than for coal specifically, although there is scope for reducing coal use as a greenhouse gas emissions measure, for example by encouraging the use of gas. CHP is a more energy-efficient means of generating electricity, but it is not necessarily economic unless a value is placed on heat production through the tax system. If addressed as an energy efficiency issue, all fuels usable in CHP, such as gas, coal and biofuels, would be potentially affected.

There is insufficient evidence for excluding peat from the carbon dioxide tax. The full cycle of peat production and use has a variety of environmental impacts. So far as greenhouse gas emissions are concerned, there are offsetting effects that make it difficult to determine the net impact. Ditching, draining, harvesting and drying peat reduces methane emissions, while transport and combustion emits carbon dioxide. After exploitation, the peatland may be used for forestry, which would absorb carbon dioxide, or for wetlands, possibly giving rise to methane. So far as the combustion phase of the cycle is concerned, peat combustion is estimated to give rise to 20% more carbon dioxide per unit of electricity produced than coal, and some 45% more than diesel or fuel oil[18]. The effect for other greenhouse gases, and the net effect over the full fuel cycle is not known[19].

18. *Fuel Peat – World Resources and Utilisation*, IEA Coal Research, London, 1993. The comparison with coal is with Russian and Polish coal of unspecified quality.
19. See *Fuel Peat – World Resources and Utilisation*, IEA Coal Research, London, 1993, where work on this subject to 1993 is summarised.

RECOMMENDATIONS

The Government of Sweden should:

- ☐ Further develop the policy framework for the use of natural gas, including the following elements:
- ☐ Implementing, as planned, the EU Gas Directive with a view to opening the market as soon as possible.
- ☐ Addressing the influence of the present major players in the gas and electricity markets on the development of the gas market.
- ☐ Establishing a stable tax regime.
- ☐ Adopting measures to facilitate access to the system network and the development of gas infrastructure by interested parties.
- ☐ Take into account the supply security implications for Sweden if any proposal for a second gas pipeline is submitted for approval.

9

ENERGY RESEARCH AND DEVELOPMENT

OVERALL POLICY OBJECTIVES

An energy research, development and demonstration programme to promote an ecologically sustainable energy system was initiated on 1 January 1998 with an allocation of SKr 5 070 million over a seven-year period. The Swedish National Energy Administration is responsible for the implementation of the main part of the programme.

The total funding for energy research, development and demonstration in Sweden is in the order of SKr 2 500 million per year (1997). The sources of the funding are about one-third each from government, electricity companies and other industry.

TARGETED AREAS

Table 17 shows a number of targeted areas given priority in the programme. Within a specific targeted area there are often parallel activities on research, development, demonstration and market deployment. In many cases, a university programme and a corresponding industry programme run in parallel and in co-operation. In some cases, the research activities are jointly or privately financed.

MAJOR RESEARCH PROGRAMMES AND PRIORITIES IN THE TARGET AREAS

CHP and Biomass

Efforts are concentrated on the development of clean and efficient thermodynamic cycles for power or CHP production. The research field covers the whole range from basic research to market deployment, including natural gas applications and biomass applications. The Swedish gas turbine industry is deeply involved in the programmes for strengthening the technological and industrial development and the competitiveness of biomass-derived power. Government supported activities include:

- Thermal processes for electricity production: total funding of SKr 60 million for a four-year period, financed by the National Energy Administration.

- Fluid bed combustion and gasification: total funding of SKr 37.8 million over a period of three years. The programme is largely financed by the Swedish National Energy Administration.

Two different concepts of biomass-based combined cycle technologies have reached the demonstration phase. Sydkraft AB has carried out a technically successful

Table 18
Target Areas for the Energy Research, Development and Demonstration Programme

Targeted Area and Development Stage	*Basic Research*	*Applied Research*	*Technological or System Development*	*Demonstration*	*Market Introduction*
CHP and power from biomass	*	*	*	*	*
Biomass supply including utilisation of ashes		*	*	*	0-10 years
Processes for cellulose-based ethanol production		*	*		5-10 years
Alternative motor fuels: RME and other fatty acid esters			*	*	0-5 years
Alternative motor fuels: production of methanol			*	*	
Alternative motor fuels: production of DME		*			
Large-scale and offshore wind power			*		
Photovoltaics		*	*	5 years	10 years
Energy efficiency in buildings	*	*	*	*	*
Energy efficiency in transport	*	*	*	*	*
Energy efficiency in industry	*	*	*	*	*
Artificial photosynthesis	*	10 years	15 years	20 years	25 years

DME: dimethyl ether; RME: rapeseed methyl ester.
* Indicates the stage of development for the various targeted areas; time periods are an estimation of how long it will take for these technologies to reach a certain development stage.
Source: Country submission.

demonstration of the pressurised concept developed by Foster-Wheeler in a CHP plant in Värnamo. Parts of this programme are co-financed by the National Energy Administration and the French utility EDF. An atmospheric gasification concept has been developed by the Swedish engineering company Termiska Processer AB in co-operation with universities. The work has been partly financed by the National Energy Administration. The atmospheric gasification concept is being demonstrated in the United Kingdom. Biomass gasification technologies are, however, not currently competitive on the liberalised electricity market in Sweden.

A research programme, covering all necessary topics related to the use of salix in short-rotation forestry has been running since the 1970s. As a result, Sweden is today a leader in this field, and knowledge and technology have been transferred to, for example, the United Kingdom, Denmark and the United States. The economy of growing short-rotation forestry is dependent on the EU Common Agricultural Policy. Current EU policy makes short-rotation forestry commercially profitable in many Swedish regions. The Swedish research programme has a budget of SKr 48 million over a period of four years and is funded by the National Energy Administration.

Alternative Motor Fuels

During the last 25 years the Swedish Government has supported research on the production of alternative motor fuels from nationally available, essentially renewable resources as a response to the first oil crisis in 1973. In the early 1980s, research was started in the field of ethanol production from cellulose-containing raw materials, such as wood. The efforts were initially directed towards basic research. In 1990, the financial support amounted to around SKr 4 million per year.

An ethanol programme in the period 1993 to 1997 had a total budget of SKr 45 million. The programme included research on the various process steps in the ethanol production such as pretreatment, hydrolysis and fermentation, process modelling and economic aspects. Two main approaches were taken in the studies of the hydrolysis step: enzymatic and dilute acid hydrolysis. Bench scale equipment was established at the University of Lund, which allowed raw material to go through all individual process steps. The programme also resulted in an increase in the number of research institutions being engaged in this research.

In 1998 a new programme started. The total budget is SKr 210 million from 1998 to 2004, corresponding to an annual budget of SKr 30 million. The aim of the programme is to demonstrate technology for the production of ethanol from forest residues on a commercial scale by the end of 2004. Financial support is given to basic research, development and activities related to pilot plant scale. Compared to the previous period, this programme has shifted its focus towards development activities. One step in this direction is a project to expand the bench scale equipment in Lund to a versatile process development unit, to allow different process steps and process concepts to be studied.

The production of ethanol from lignocellulosic raw materials results in the formation of a solid lignin-rich residue after hydrolysis, which can be used as a solid bio-energy source. Within the programme, research on how to utilise this material is also supported.

The use of wood, being a complex raw material, may result in formation of inhibiting substances that negatively affect the process, especially the fermentation step. Studies on inhibitors are therefore one important field of research to alleviate this problem. Recycling of process streams to find out how this affects the ethanol yield and production rate is one important aspect of this problem.

Five municipal energy companies in northern Sweden have started a company, Energicentrum Norr AB, with the ultimate aim to build an ethanol production plant. The process is based on dilute acid hydrolysis, using wood as raw material. The company has received governmental and other support for the design work of a pilot plant and an application has recently been presented asking for support to construct and operate this research unit.

Apart from research on ethanol, work has been mainly focused on three areas:

- Production of biogas (biomass-based methane).

- Production of vehicle fuels from gasified biomass (mainly production of methanol and dimethyl ether – DME).

- Production of biomass-derived additives for gasoline (e.g. ETBE, MTBE) and diesel oil (e.g. fatty acids as RME from rapeseed, as well as emulgators and ignition improvers, facilitating mixing of diesel oil and alcohols).

Each of these programmes is expected to take about three years with a total budget of SKr 10 million per programme.

The potential for support to research on hydrogen will also be investigated.

Wind

The long-term objective is to decrease the costs of wind power and to improve its competitiveness with other power production options. By concentrating on the development of certain Swedish design concepts for large-scale wind power, it is hoped Sweden will gain a competitive advantage through lower costs and higher efficiency. Despite many years of research, the Swedish wind power plant industry has not yet succeeded in establishing commercial products on the market.

Over a period of three years, the National Energy Administration is financing a programme to improve knowledge of meteorology, aerodynamics, structural dynamics, electricity and automatic control, acoustics, and socio-technical aspects. The programme will be extended to include offshore and mountainous applications for wind power. The programme started on 1 July 1999 with a budget of SKr 46.8 million.

An industry wind power programme is being carried out, focusing on user-related issues such as the follow-up of operational results, standardised communication, optimisation of groups of wind power units, offshore wind power plants, and wind power in a cold climate. The programme is co-financed by Elforsk and the National Energy Administration.

Photovoltaics

The main research programmes for solar power are in the Ångström Solar Centre and SOLEL 97-99. Research is focused on thin-layer cells. This technology is projected to be demonstrated in about five years and to be ready for the market in 10 years.

The Ångström Solar Centre programme is researching thin film layer and nano-crystalline technologies for photovoltaics. The objective is to develop processes for industrial manufacturing of low-cost cells, with a maximum manufacturing cost of SKr 700 per m^2, equivalent to SKr 5 per watt, or about one-fifth of the cost for current crystalline technology. The programme is co-financed by the National Energy Administration and the Swedish Foundation for Strategic Environmental Research (MISTRA). The total budget amounts to SKr 70 million over a period of 4.5 years.

Nano-crystalline cells may be useful for other application areas, such as window glazing, light filters and glass covers. The research programme also comprises "smart windows", i.e. windows that can adjust permeability to light by means of an electric voltage.

The activities within SOLEL 97-99 examine the conditions for utilising photovoltaics in the Swedish grid, including the need for further research to increase the opportunities for photovoltaics in Swedish electricity supply. The total budget of the programme is SKr 9.9 million over a period of three years, co-financed by Elforsk. Government funding amounts to 50%. The programme analyses the environmental impact of various photovoltaics technologies in a life-cycle perspective. Cathodic corrosion protection of power poles is being tested, and demonstration projects concerning photovoltaics in buildings are being evaluated.

Artificial Photosynthesis

Researchers from three Swedish universities are working together in the field of artificial photosynthesis. Their long-term goal is to produce adequate amounts of hydrogen from solar energy and water in a process similar to natural photosynthesis. The group has been active since 1994 with the main financial support coming from a private foundation. Recently the National Energy Administration decided to support their work and is now a major co-financier.

Energy Efficiency in Buildings

The Swedish Council for Building Research is a research agency under the Ministry of the Environment. The council is responsible for energy-related building research. Energy research funded by the council complements research funded by the National Energy Administration on the development of technological systems and their integration in buildings and in the urban environment. Funding for energy-related activities amounted to about SKr 20 million in 1998.

Energy-related research is to be found in several of the council's seven sub-programmes, for example:

- Sustainable Energy Systems in the Urban Environment is targeted at increasing end-use energy efficiency in buildings.

- Electricity Use in the Urban Environment is targeted at significantly reducing the electricity use in buildings.

The long-term objective is to improve end-use energy efficiency in buildings by 50 % in 40 to 50 years and to decrease the annual use of electricity for domestic heating by at least 20 to 25 TWh.

Energy Efficiency in Industry

The objectives of the Klimat 21 research programme are to increase the energy efficiency and decrease the environmental impact of cooling machines and heat pumps by improving knowledge and promoting transfer of competence between universities and industry. The budget is SKr 54 million over a period of four years. It is co-financed by the Swedish National Energy Administration and some 30 companies and organisations. The programme covers a range from components to systems, and may also include work on security and standardisation issues.

CENTRES OF COMPETENCE

Five energy-related Centres of Competence have been established in Swedish universities to work on catalysis, electricity, high temperature corrosion, combustion engines and combustion processes. These centres are all co-financed by the National Energy Administration, various industrial alliances and the universities themselves, each one contributing about one-third of the budget.

- *Centre of Competence for Catalysis*. The centre focuses on heterogeneous catalysis and methods for reducing the emissions from vehicles and industrial processes, as well as on environmentally benign energy technology. The budget is SKr 55.5 million over a period of three years. The Swedish National Energy Administration contributes 28 % of the funding.

- *Centre of Competence for High Temperature Corrosion*. The objective is to improve the performance of materials and processes at high temperatures. The budget is SKr 52.3 million over a period of three years. The National Energy Administration contributes 30 % of the funding.

- *Centre of Competence for Engine Technology*. The centre aims to reduce the environmental impact and the fuel consumption of combustion engines. The budget is SKr 69 million over a period of three years. The National Energy Administration contributes 26% of the funding.

- *Centre of Competence for Combustion Processes*. The objective is to improve knowledge of combustion processes, to increase efficiency, lower emissions of hazardous substances, and increase the use of renewables. The budget is SKr 54.7 million over a period of three years. The National Energy Administration contributes 33 % of the funding.

- *Centre of Competence in Electric Power Engineering.* The objective is to contribute to the development of new technology and its introduction in central areas of the electric power systems to assist in creating cost-effective, environment-friendly, reliable and customer-oriented systems for distribution and use of electricity. There are three sub-programmes: new distribution systems, permanent magnet drives and power quality. The National Energy Administration contributes 36% of the funding.

The Consortium for Gas Turbines promotes the development of gas turbines that can meet future demands on environmental friendliness, efficiency and low costs. The consortium will help build up and maintain knowledge in Swedish universities to support industrial development and research programmes with industrial relevance. The programme is co-funded by the National Energy Administration and industry. The consortium is similar to the Centres of Competence, but is not classified as one because more than one university is involved on an equal footing.

INTERNATIONAL COLLABORATION

Besides actively participating in IEA activities, including 27 implementing agreements, Sweden is involved in essentially all EU energy programmes, and is an active member of the European Energy Network.

The Nordic Ministerial Council (Sweden, Finland, Denmark, Norway and Iceland) finances the Nordic Energy Research Programme. A budget of 25 million NKr[20] per year is allocated to the exchange of doctorate students in the region working in strategic research areas. The objective of the programme is to strengthen the knowledge base at universities in energy areas of strategic importance to the Nordic countries and to promote co-operation between Nordic scientists.

ENERGY-RELATED TRANSPORT RESEARCH

Swedish Transport and Communications Research Board

KFB, the Swedish Transport and Communications Research Board, is a central government authority whose task is to plan, initiate, co-ordinate and support

20. On average in 1999, 1 NKr = US$ 0.129. As at 4 January 1999, 1 NKr = € 0.1231.

overall research, development and demonstration projects in the areas of physical transport, traffic systems, postal and telecommunications services and the impact of communications on the environment, on traffic safety and on regional development. KFB is responsible for SKr 10 million per year for energy-related transport research. Since 1999, KFB has additional funding of SKr 20 million per year to continue efforts on systems demonstration of environmentally sound transport, research on the preconditions for better energy efficiency and less resource consumption in transport, and the follow-up of pilot projects earlier co-financed by KFB. KFB also supports demonstration of electricity vehicle fleets.

KFB runs a dedicated programme for research on emissions from road traffic. A government committee, the Emission Research Committee, has recently presented a programme for research and development on vehicle emissions to be conducted over a period of 10 years.

A demonstration programme on electric and hybrid road vehicles in Sweden was initiated by KFB and currently involves 210 vehicles, mostly private cars and light trucks. These vehicles are used in various applications, mainly by companies. The four on-going projects are:

- Electric vehicles in Skåne.
- Electric vehicles in Gothenburg.
- Battery exchange project in Stockholm.
- ZEUS (Zero and low Emission vehicles in Urban Society).

These activities are evaluated in a separate evaluation project.

Co-operative Programme with Industry

The Swedish Government and the vehicle industry have recently initiated a co-operative programme on environment-friendly vehicles. The programme is to run for six years, starting in 2000. The total budget is expected to be about SKr 2 000 million, with a government contribution of SKr 500 million. The programme will focus on environmental issues, including the greenhouse effect. The programme includes work on more efficient internal combustion engines and drive trains, fuel flexibility, hybrid and fuel cell vehicles, flexible and lighter vehicles, and road traffic information systems.

The National Energy Administration has also launched a complementary research programme on energy conversion in road vehicles. The programme is to be a systems-oriented, multidisciplinary programme focused on longer-term options for energy conversion and emissions reduction in vehicles.

NON-GOVERNMENT ENERGY RESEARCH AND DEVELOPMENT PROGRAMMES, EXCLUDING NUCLEAR

Elforsk

Elforsk AB was established in 1992 to provide electricity supply companies with a body that could efficiently carry out important research and development efforts on the production, transmission and utilisation of electricity. The company is owned by Svenska Kraftverksföreningen (the Association of Swedish Power Producers), Sveriges Elleverantörer (the Swedish Electricity Suppliers) and Svenska Kraftnät (the Swedish National Grid).

Total funding for research and development from the electricity companies is SKr 700 to 800 million per year, of which SKr 100 million are spent through Elforsk. The total Elforsk funding, including government contributions and other co-financing, amounts to SKr 220 million per year.

Elforsk's activities are organised into five programme areas, hydropower, thermal power and renewables, transmission and distribution, utilisation, and strategies and systems. Projects on safety and environment issues are integrated into all the programme areas. Elforsk is not involved in work on nuclear power.

Hydropower is expected to remain the base for Swedish electricity supply. Hydropower plants constructed during the 1940s to 1960s are planned to be renovated with, for example, advanced turbine technology. Several industry research programmes are related to dam safety, hydrology, environment, turbine technology, small hydropower plants, restoration of concrete constructions and hydraulic engineering research. SKr 20.5 million have been allocated by Elforsk and the National Energy Administration to the programmes for a period of three years.

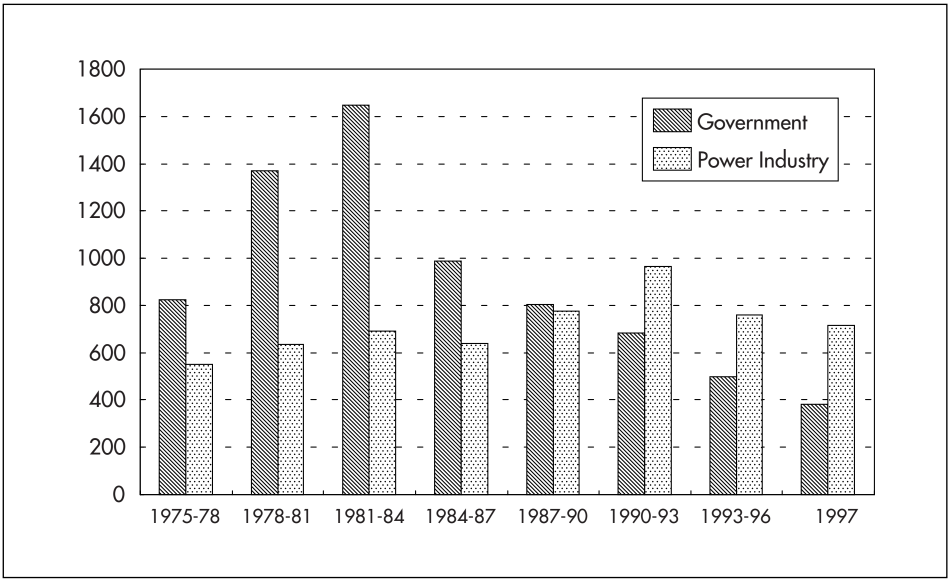
The ELEKTRA programme is a wide-ranging and long-term initiative to further scientific education in electric power technology and its applications. The programme is a major financier of scientific work in electric power technology and a contributor to a high level of competence at the universities concerned. The funding is SKr 23 million per year (1997-1999) and the financing is shared among the National Energy Administration (40%), Elforsk (30%) and ABB (30%).

SUPRA, a new university research programme on high-temperature superconductivity (HTS), was launched in 1998 and co-financed by the National Energy Administration and Elforsk, among others.

The transmission and distribution programme also includes maintenance and renewal of grids, new technologies, quality control, information technology and electromagnetic fields.

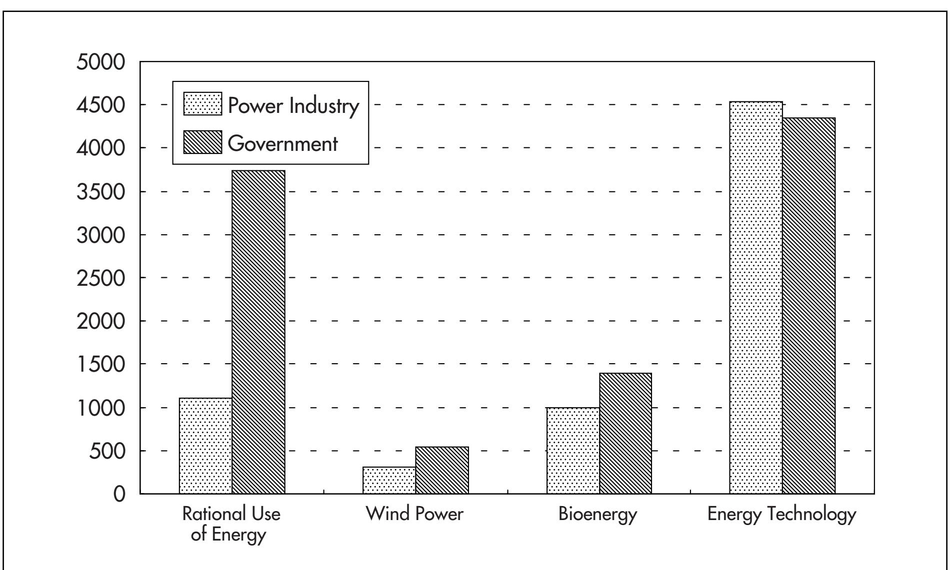
The objective of the interdisciplinary research programme ELAN is to improve knowledge of, and competence in, the electricity supply companies regarding the

Figure 33
Annual Energy Research and Development Expenditures
(Real terms, 1997 SKr million)



Source: Ministry of Industry, Employment and Communications.

Figure 34
Energy Research and Development Expenditures by Category
(Accumulated nominal SKr million until 1997)



Source: Ministry of Industry, Employment and Communications.

use of energy and electric applications in buildings. Launched in 1998, it is funded by Elforsk and the Swedish National Energy Administration.

Individual electricity and district heating utilities also conduct research.

ABB

ABB has developed a high-voltage direct current (HVDC) equipment called "HVDC Light", based on semiconductors rather than thyristors. This makes it economical to construct transmission lines with up to 100 MW and 100 kV DC as HVDC lines. A prototype line is being demonstrated on the isle of Gotland in a project to improve the capacity for wind power production. The National Energy Administration is co-financing the demonstration.

ABB has also developed the world's first generator able to supply electricity directly to the high-voltage network without the need for intermediary transformers. The Powerformer can generate electricity at voltages between 20 kV and 400 kV. The new concept yields substantial benefits, such as better system performance, higher efficiency, lower maintenance costs and reduced environmental impact. The National Energy Administration co-finances the demonstration of the Powerformer in one hydro station and one CHP station.

Vattenfall AB

During 1998, Vattenfall AB spent SKr 109 million on research and development for the rationalisation and development of power production, and SKr 52 million on rationalisation and development of transmission and distribution. Approximately SKr 30 million of the total is allocated through Elforsk.

Sydkraft AB

During 1998, group expenditure on research, development and demonstration projects totalled SKr 189 million, of which SKr 125 million were used for the development of new technologies and operations, and continued demonstration of various facilities. Expenditures for research and development to improve safety and availability in Sydkraft's nuclear power plants were SKr 64 million.

Improvements have been made in the use of power lines for data transmission and communications, and a high-speed power line Internet link has been demonstrated, in co-operation with foreign suppliers. Other technologies and means of communication are also being tested, with the aim of achieving efficient customer communications, meter reading, more efficient distribution and the creation of new business opportunities.

EnerSearch, a company jointly owned by Sydkraft AB and IBM AB, has co-ordinated and managed a considerable number of research projects on information technology applications in the energy area. Operations were largely financed by the EU. Preparations are being made for the extension of ownership in EnerSearch to other Swedish and European companies.

Sydkraft AB and Gaz de France have developed a new concept in safe, commercial storage of natural gas, called Lined Rock Cavern. The concept consists of an underground cavern with a specially engineered steel lining. To demonstrate the concept, the first plant in the world is now under construction in Sweden. The project is co-financed by the EU Thermie programme.

Värmeforsk

Värmeforsk is the co-operative body of the Swedish energy, process and manufacturing industry and of energy consultants for research and development of heat technology. It finances research programmes on construction technology, combustion technology and the environment, materials, forest industry, and modern process control systems. Elforsk AB is responsible for the administration of Värmeforsk. The total annual budget of the Värmeforsk research, development and demonstration programmes is about SKr 27 million, of which the National Energy Administration co-finances 40%.

The Swedish Foundation for Strategic Research

The Swedish Foundation for Strategic Research (Stiftelsen för strategisk forskning) was established in January 1994 with a capital of SKr 6 billion. The budget for 1999 was about SKr 1 000 million, of which about SKr 25 million were directed to energy-related activities. The foundation supports scientific, technical and medical research to enhance Sweden's long-term competitiveness.

The foundation is also responsible for funding the Centre for Combustion Science and Technology (CECOST). CECOST was founded in 1996 at the Lund Institute of Technology, in close collaboration with Chalmers University of Technology and the Royal Institute of Technology. The centre receives funding of SKr 53 million from the Foundation for Strategic Research. CECOST addresses a range of problems related to theories, processes and methods concerning fuel-air preparation, the combustion chamber, post-combustion treatment, exhaust gases, combustion residues and pollutants.

MISTRA

The Swedish Foundation for Strategic Environmental Research, MISTRA, was established in January 1994 with a capital of SKr 2.5 billion. The capital in 1998 was close to SKr 4 billion. The income earned on the capital is used to support strategic environmental research. MISTRA's budget for activities in 1998 amounted to SKr 300 million. It supports strategic environmental research, i.e. research with a long-term perspective directed towards solving major environmental problems, and the sustainable development of society.

A long-term goal of the programme Batteries and Fuel Cells for a Better Environment is to reduce the environmental impact of the transportation sector. MISTRA has made a preliminary allocation of SKr 54 million to the programme, on condition that the industry raise SKr 40 million. Funding should be built up gradually to a maximum level of SKr 14 million per annum from MISTRA, together with SKr 10 million per year from industry.

Pulp and Paper Industry Institute

The Swedish Pulp and Paper Research Institute (STFI) is devoted to the development of the Swedish pulp and paper industry. The industry is highly energy-intensive in all process steps. Energy-related research has been organised in a programme over three years, co-financed by STFI and the National Energy Administration. The programme ended in 1999, and discussions about future activities are currently under way.

The Swedish Steel Producers Association

The Swedish Steel Producers Association finances an industrial research programme. Its energy-related activities currently consist of an energy efficiency programme comprising the most energy-intensive steps in manufacturing iron and steel. This part of the programme is co-financed by the industry and by the National Energy Administration. A new, four-year programme on energy efficiency in heating and processing has recently been initiated. The results are expected to lead to energy savings of up to 30%. The National Energy Administration contributes 25% of the annual SKr 39 million budget.

The Foundation for Metallurgical Research

The Foundation for Metallurgical Research (MEFOS) implements energy-related projects, supported by the National Energy Administration. The projects deal with most steps in the manufacturing of iron and steel.

Svenskt Gastekniskt Centrum AB

Co-operative research and development on gas is undertaken by the Svenskt Gastekniskt Centrum AB. The National Energy Administration co-finances a joint research programme devoted to the development of new technologies for natural gas and biogas. Activities are in three categories:

- End-use technologies.

- Distribution and storing technologies.
- Environmental issues (emissions).

Swedish District Heating Association

The Swedish District Heating Association promotes research and development related to district heating and district cooling. Most district heating enterprises are members of the organisation. Its programme focuses on technology related to hot water, distribution, district heating, measurement and systems. Basic research at universities and problem-oriented research is conducted. The National Energy Administration co-finances these activities.

OTHER NON-NUCLEAR RESEARCH

Energy Systems Studies

This programme seeks to describe and explain how the energy system functions and is affected by man, society, technology and environment. SKr 10 million per year have been allocated to this programme over a period of three years.

Stationary Fuel Cells

In 1998 a university programme on stationary fuel cells was launched, funded by the National Energy Administration and administrated by Elforsk. The programme focuses on user-related aspects and is concerned with both high- and low-temperature technology. A complementary industrial programme, launched in 1999, includes a broad evaluation of different fuel cell technologies for heat and electricity production.

Material Technology for Thermal Energy Processes

The programme aims to improve efficiency, lifetime, and reliability in thermal energy processes. The total funding is SKr 58 million over a period of three years. The National Energy Administration contributes 50%.

Energy from Waste

The research programme Energy from Waste promotes the efficient use of waste as an energy resource. The budget is SKr 20 million over a period of three years. The programme focuses on waste handling, technical and biological research and development, and specific issues related to combustion of waste. The programme is financed by the National Energy Administration.

NUCLEAR FISSION

Nuclear safety research is mainly financed by the Swedish Nuclear Power Inspectorate (Ski), with an annual research budget of SKr 65 million. Electricity prices include allowance for nuclear decommissioning costs and a national research programme. The funds are used to fund research at universities and in industry, as well as participation in international projects, including the EU framework programmes on nuclear fission safety.

The nuclear utilities, through the jointly-owned company SKB AB, finance a research programme to develop a final geological repository for spent fuel. The budget is about SKr 720 million per year including the cost of constructing and operating an extension of the intermediate storage facility for spent fuel (CLAB). Major research installations include the Äspö hardrock laboratory, built in 1990-95, and the Canister Laboratory, inaugurated in 1998 to develop encapsulation technology.

The nuclear utilities are planning and running substantial modernisation programmes for existing reactors, supported where necessary by research and development. The ABB-Atom Company develops nuclear fuel and reactor core component technology and markets their products worldwide. The company is also developing a next generation of BWR reactors for future markets. Its markets for nuclear fuel for BWR as well as for PWR reactors have expanded both in Europe and elsewhere. In recent years, ABB-Atom has mainly focused on modernisation and maintenance of existing reactors. The Studsvik Company develops and markets a variety of nuclear technology products worldwide, including nuclear waste-processing technologies and services.

The Swedish Government provides SKr 50 million annually for a special programme for co-operation and support to Eastern and Central Europe in nuclear safety and related radiation protection areas. The focus is on the Baltic and Barents regions, mainly Lithuania and the Russian Federation. A special division of SKi implements the programme in co-operation with the Swedish Radiation Protection Institute.

NUCLEAR FUSION

Since 1976 Sweden has participated in the European Fusion Programme. The Swedish National Science Research Council is responsible for the support to fusion research in Sweden.

A company in Sweden (Powdermet) has participated in the development and demonstration of the powder HIP-technology process for manufacturing the first wall materials of a fusion reactor.

Government expenditure on energy research and development has doubled since 1997. The downward trend in government expenditure on energy research and development was reversed by the 1997 Government Bill *A Sustainable Energy Supply*. Since then, funding for energy research and development has doubled. A targeted effort on research, development and demonstration is considered by the government to be the backbone of the long-term strategy for a sustainable energy system. The objective is to increase substantially, over the next ten to fifteen years, the production of electricity and heating from renewable energy sources and to develop commercially profitable technology for greater energy efficiency. Priority is being given to increasing the use of biofuels, but support is also being given to technology related to wind and hydro-electric power and heat storage techniques. Longer-term priorities include technology for fuel cells and batteries, artificial photosynthesis, as well as solar cells and solar heating. Socio-economic energy research is also promoted.

Close attention is given to potential for commercial viability. Special support has been introduced to reduce the risk involved in full-scale testing and demonstration of new energy technology. Close and active co-operation between the state and the business sector is considered fundamental if state efforts relating to research and development are to lead to lasting results.

The Swedish power industry finances extensive research and development. Following the liberalisation of the electricity market, electricity companies have redirected much of their activities towards more market-oriented and less technology-oriented activities, but total industry research expenditure has not decreased. Long-term industry research and development tends to remain jointly financed.

The principal barrier to the commercialisation of the results of research will be low energy prices in Sweden. Since carbon values are already taken into account to some extent by the carbon dioxide tax, and pending international agreement on full internalisation of carbon values, economic viability of technologies seeking to replace fossil fuels will continue to be a difficulty. However, a principal goal of energy research policy is to replace nuclear, so carbon values are not relied on as the sole corrective for poor economics. Accepted external costs arising from the use of nuclear, such as waste disposal, are already fully costed and paid for by the industry. Policies to encourage deployment of new technologies should not introduce distortions into pricing as a means of overcoming underlying commercial weaknesses.

Co-ordination and a focus on government goals will be vital. The government budget for energy research and development is large and there are many institutions participating in the programme. Good co-ordination and a strong focus on achieving energy policy goals are essential. The Ministry of Industry, Employment and Communications and the National Energy Administration must play a key role in ensuring that government goals are achieved through the programme, and have the authority to provide oversight and judgement in all activities on a continuing basis.

Biofuels should not be developed primarily on energy security grounds. Priority for research on biofuels is justified as a means of developing a renewable energy source, but care should be taken to ensure that the research funding and any subsequent development of biofuels are not used as a means for supporting an indigenous fuel for its own sake. Sweden's energy security is assured through its participation in international energy markets for electricity, gas, oil and coal. Energy security would not be a valid basis for supporting biofuels.

Ongoing evaluation on market criteria should be maintained. The time period for the programme is relatively short for achieving some of the goals of the programme. Some of the principal goals, for example power from biomass and ethanol, are areas where considerable work has already been undertaken worldwide. It will be important to have in place a process of continuing progress reviews and to work with industry in assessing progress towards market viability.

RECOMMENDATIONS

The Government of Sweden should:

- ☐ Further streamline the administration of energy research and development; and ensure that the goals of programmes and criteria for project selection are determined by government energy policy objectives, and evaluated against these objectives.

- ☐ Review the research and development programme to ensure that projects undertaken are justified on grounds of their outcomes, and that they give rise to cost-effective energy technologies within targeted time periods; work closely with industry programmes to ensure harmony of objectives and complementarity of outcomes.

A

ANNEX

ENERGY BALANCES AND KEY STATISTICAL DATA

Unit: Mtoe

SUPPLY

		1973	1990	1997	1998	2005	2010	2015
TOTAL PRODUCTION		**9.3**	**29.8**	**32.5**	**34.2**	**31.6**	**33.7**	**..**
Coal [1]		0.0	0.0	–	–	–	–	..
Peat		–	0.2	0.3	0.3	0.4	0.4	..
Oil		..	0.0	–	–	–	–	..
Gas		–	–	–	–	–	–	..
Comb. Renewables & Wastes [2]		3.5	5.5	7.8	7.9	8.1	9.0	..
Nuclear		0.6	17.8	18.2	19.2	17.4	18.3	..
Hydro		5.1	6.2	5.9	6.4	5.7	5.9	..
Geothermal		–	–	–	–	–	–	..
Solar/Wind/Other [3]		–	0.0	0.3	0.4	0.0	0.2	..
TOTAL NET IMPORTS [4]		**29.6**	**17.8**	**19.1**	**18.9**	**21.0**	**20.0**	**..**
Coal [1]	Exports	0.0	0.0	0.0	0.1	0.1	0.1	..
	Imports	1.7	2.6	2.5	2.3	2.3	2.3	..
	Net Imports	1.7	2.6	2.5	2.3	2.3	2.2	..
Peat	Exports	–	–	–	–	–	–	..
	Imports	–	–	–	–	–	–	..
	Net Imports	–	–	–	–	–	–	..
Oil	Exports	1.4	8.7	9.9	9.0	9.6	9.5	..
	Imports	30.4	24.2	27.2	27.4	28.3	27.3	..
	Bunkers	1.1	0.7	1.3	1.6	1.2	1.4	..
	Net Imports	27.8	14.9	16.1	16.8	17.5	16.4	..
Gas	Exports	–	–	–	–	–	–	..
	Imports	–	0.5	0.7	0.7	1.0	1.0	..
	Net Imports	–	0.5	0.7	0.7	1.0	1.0	..
Electricity	Exports	0.4	1.3	1.1	1.4	–	–	..
	Imports	0.5	1.1	0.9	0.5	0.3	0.5	..
	Net Imports	0.1	–0.2	–0.2	–0.9	0.3	0.5	..
TOTAL STOCK CHANGES		**0.5**	**0.2**	**–0.1**	**–0.6**	**–**	**–**	**..**
TOTAL SUPPLY (TPES)		**39.3**	**47.8**	**51.4**	**52.5**	**52.6**	**53.7**	**..**
Coal [1]		1.6	2.7	2.4	2.4	2.3	2.2	..
Peat		–	0.2	0.3	0.3	0.4	0.4	..
Oil		28.4	14.9	16.1	16.2	17.5	16.4	..
Gas		–	0.5	0.7	0.7	1.0	1.0	..
Comb. Renewables & Wastes [2]		3.5	5.5	7.8	7.9	8.1	9.0	..
Nuclear		0.6	17.8	18.2	19.2	17.4	18.3	..
Hydro		5.1	6.2	5.9	6.4	5.7	5.9	..
Geothermal		–	–	–	–	–	–	..
Solar/Wind/Other [3]		–	0.0	0.3	0.4	0.0	0.2	..
Electricity Trade [5]		0.1	–0.2	–0.2	–0.9	0.3	0.5	..
Shares (%)								
Coal		*4.1*	*5.7*	*4.6*	*4.5*	*4.3*	*4.1*	..
Peat		–	*0.5*	*0.5*	*0.6*	*0.7*	*0.7*	..
Oil		*72.2*	*31.2*	*31.2*	*30.8*	*33.3*	*30.5*	..
Gas		–	*1.1*	*1.4*	*1.4*	*1.9*	*1.8*	..
Comb. Renewables & Wastes		*9.0*	*11.5*	*15.2*	*15.0*	*15.5*	*16.8*	..
Nuclear		*1.4*	*37.2*	*35.4*	*36.5*	*33.0*	*34.0*	..
Hydro		*13.1*	*13.1*	*11.5*	*12.2*	*10.8*	*11.0*	..
Geothermal		–	–	–	–	–	–	..
Solar/Wind/Other		–	–	*0.5*	*0.7*	*0.1*	*0.3*	..
Electricity Trade		*0.2*	*–0.3*	*–0.5*	*–1.8*	*0.5*	*0.8*	..

0 is negligible. – is nil. .. is not available.
Please note: Forecast data for 2005 are based on the 1997 submission.

Unit: Mtoe

DEMAND

FINAL CONSUMPTION BY SECTOR

	1973	1990	1997	1998	2005	2010	2015
TFC	**35.3**	**32.1**	**35.5**	**35.3**	**37.9**	**38.6**	**..**
Coal [1]	0.9	1.0	0.8	0.7	1.7	1.4	..
Peat	–	0.0	0.0	0.0	–	–	..
Oil	24.8	14.0	14.7	14.5	14.9	14.3	..
Gas	0.1	0.4	0.4	0.4	0.5	0.6	..
Comb. Renewables & Wastes [2]	3.5	4.6	5.4	5.4	5.5	6.2	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	0.0	0.0	0.0	–	–	..
Electricity	6.0	10.4	10.6	10.6	11.5	11.9	..
Heat	–	1.7	3.6	3.7	3.8	4.1	..
Shares (%)							
Coal	*2.6*	*3.3*	*2.2*	*1.9*	*4.4*	*3.7*	..
Peat	–	–	–	–	–	–	..
Oil	*70.4*	*43.7*	*41.4*	*41.0*	*39.5*	*37.2*	..
Gas	*0.3*	*1.1*	*1.2*	*1.2*	*1.3*	*1.5*	..
Comb. Renewables & Wastes	*9.8*	*14.4*	*15.2*	*15.3*	*14.4*	*16.1*	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	–	–	–	–	–	..
Electricity	*16.2*	*32.2*	*29.7*	*30.1*	*30.3*	*30.7*	..
Heat	–	*5.3*	*10.1*	*10.5*	*10.1*	*10.7*	..
TOTAL INDUSTRY [6]	**15.5**	**13.3**	**14.5**	**14.2**	**15.5**	**16.7**	**..**
Coal [1]	0.9	1.0	0.8	0.7	1.7	1.4	..
Peat	–	0.0	0.0	0.0	–	–	..
Oil	8.3	3.5	4.0	3.8	3.8	4.1	..
Gas	0.0	0.3	0.3	0.2	0.3	0.4	..
Comb. Renewables & Wastes [2]	2.9	3.7	4.4	4.4	4.5	5.3	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	–	–	–	–	–	..
Electricity	3.4	4.6	4.6	4.7	4.9	5.1	..
Heat	–	0.2	0.4	0.4	0.4	0.4	..
Shares (%)							
Coal	*5.7*	*7.6*	*5.5*	*4.8*	*10.7*	*8.4*	..
Peat	–	–	*0.1*	–	–	–	..
Oil	*53.4*	*26.5*	*27.6*	*26.7*	*24.5*	*24.7*	..
Gas	*0.1*	*1.9*	*2.0*	*1.7*	*2.1*	*2.3*	..
Comb. Renewables & Wastes	*18.9*	*27.7*	*30.6*	*31.2*	*28.7*	*31.5*	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	–	–	–	–	–	..
Electricity	*21.9*	*35.0*	*31.8*	*33.0*	*31.5*	*30.4*	..
Heat	–	*1.3*	*2.5*	*2.5*	*2.5*	*2.7*	..
TRANSPORT [7]	**5.5**	**7.4**	**7.9**	**7.9**	**8.6**	**8.2**	**..**
TOTAL OTHER SECTORS [8]	**14.3**	**11.5**	**13.2**	**13.2**	**13.7**	**13.6**	**..**
Coal [1]	0.0	0.0	0.0	0.0	0.0	–	..
Peat	–	–	–	–	–	–	..
Oil	11.2	3.3	3.1	3.0	2.8	2.3	..
Gas	0.1	0.1	0.2	0.2	0.2	0.2	..
Comb. Renewables & Wastes [2]	0.5	1.0	1.0	1.0	1.0	1.0	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	0.0	0.0	0.0	–	–	..
Electricity	2.4	5.5	5.7	5.7	6.3	6.5	..
Heat	–	1.5	3.2	3.4	3.4	3.7	..
Shares (%)							
Coal	*0.3*	*0.4*	–	–	–	–	..
Peat	–	–	–	–	–	–	..
Oil	*78.7*	*28.9*	*23.6*	*22.7*	*20.3*	*17.1*	..
Gas	*0.7*	*1.0*	*1.2*	*1.3*	*1.3*	*1.4*	..
Comb. Renewables & Wastes	*3.6*	*8.4*	*7.4*	*7.4*	*7.4*	*7.0*	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	–	–	–	–	–	..
Electricity	*16.6*	*47.9*	*43.2*	*43.2*	*46.0*	*47.4*	..
Heat	–	*13.4*	*24.5*	*25.4*	*25.0*	*27.1*	..

Unit: Mtoe

DEMAND

ENERGY TRANSFORMATION AND LOSSES

	1973	1990	1997	1998	2005	2010	2015
ELECTRICITY GENERATION[9]							
INPUT (Mtoe)	**8.2**	**26.7**	**28.7**	**30.4**	**28.5**	**29.2**	**..**
OUTPUT (Mtoe)	**6.7**	**12.6**	**12.8**	**13.6**	**12.9**	**13.3**	**..**
(TWh gross)	78.1	146.0	149.4	158.2	150.0	155.1	..
Output Shares (%)							
Coal	*0.6*	*1.2*	*1.9*	*2.0*	*3.3*	*1.7*	..
Peat	–	*0.0*	*0.1*	*0.0*	*0.1*	*0.1*	..
Oil	*19.4*	*0.8*	*2.6*	*2.1*	*4.1*	*2.5*	..
Gas	–	*0.3*	*0.4*	*0.3*	*0.9*	*2.2*	..
Comb. Renewables & Wastes	*0.5*	*1.3*	*1.9*	*2.0*	*3.1*	*3.0*	..
Nuclear	*2.7*	*46.7*	*46.8*	*46.5*	*44.4*	*45.2*	..
Hydro	*76.7*	*49.7*	*46.2*	*47.0*	*43.9*	*44.1*	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	*0.0*	*0.1*	*0.2*	*0.3*	*1.3*	..
TOTAL LOSSES	**3.4**	**16.3**	**16.3**	**17.5**	**14.7**	**15.1**	**..**
of which:							
Electricity and Heat Generation[10]	1.5	12.2	12.6	13.5	11.0	11.2	..
Other Transformation	1.0	1.3	1.2	1.3	1.2	1.4	..
Own Use and Losses[11]	1.0	2.8	2.5	2.6	2.5	2.6	..
Statistical Differences	**0.6**	**–0.7**	**–0.4**	**–0.3**	**–**	**–**	**..**

INDICATORS

	1973	1990	1997	1998	2005	2010	2015
GDP (billion 1990 US$)	166.56	229.76	242.39	249.37	290.40	319.05	..
Population (millions)	8.14	8.56	8.85	8.85	8.97	9.00	..
TPES/GDP[12]	0.24	0.21	0.21	0.21	0.18	0.17	..
Energy Production/TPES	0.24	0.62	0.63	0.65	0.60	0.63	..
Per Capita TPES[13]	4.83	5.58	5.81	5.93	5.86	5.96	..
Oil Supply/GDP[12]	0.17	0.06	0.07	0.06	0.06	0.05	..
TFC/GDP[12]	0.21	0.14	0.15	0.14	0.13	0.12	..
Per Capita TFC[13]	4.34	3.76	4.02	3.99	4.22	4.28	..
Energy-related CO_2 Emissions (Mt CO_2)[14]	88.7	52.7	54.0	54.9	58.1	54.7	..
CO_2 Emissions from Bunkers (Mt CO_2)	3.5	2.1	4.2	5.0	3.9	4.6	..

GROWTH RATES (% per year)

	73–79	79–90	90–97	97–98	98–05	05–10	10–15
TPES	1.9	0.8	1.1	2.0	0.0	0.4	..
Coal	1.6	3.9	–1.9	–0.3	–0.7	–0.5	..
Peat	–	–	1.9	21.1	1.2	–	..
Oil	–0.6	–5.4	1.1	0.6	1.2	–1.4	..
Gas	–	–	4.5	–1.0	4.9	–0.6	..
Comb. Renewables & Wastes	1.8	3.1	5.1	0.8	0.5	2.1	..
Nuclear	46.7	11.3	0.4	5.2	–1.4	1.0	..
Hydro	0.3	1.6	–0.7	7.6	–1.7	0.8	..
Geothermal	–	–	–	–	–	–	..
Solar/Wind/Other	–	–	27.6	45.5	4.3	32.0	..
TFC	0.4	–1.1	1.4	–0.5	1.0	0.4	..
Electricity Consumption	3.5	3.2	0.3	0.6	1.1	0.7	..
Energy Production	8.0	6.6	1.3	5.0	–1.1	1.3	..
Net Oil Imports	0.4	–5.8	1.1	4.5	0.6	–1.4	..
GDP	1.8	2.0	0.8	2.9	2.2	1.9	..
Growth in the TPES/GDP Ratio	0.1	–1.2	0.3	–0.8	–2.1	–1.5	..
Growth in the TFC/GDP Ratio	–1.3	–3.0	0.7	–3.3	–1.2	–1.5	..

Please note: Rounding may cause totals to differ from the sum of the elements.

Footnotes to Energy Balances and Key Statistical Data

1. Includes lignite and peat, except for Finland, Ireland and Sweden. In these three cases, peat is shown separately.
2. Comprises solid biomass and animal products, gas/liquids from biomass, industrial waste and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
3. Other includes tide, wave and ambient heat used in heat pumps.
4. Total net imports include combustible renewables and waste.
5. Total supply of electricity represents net trade. A negative number indicates that exports are greater than imports.
6. Includes non-energy use.
7. Includes less than 1% non-oil fuels.
8. Includes residential, commercial, public service and agricultural sectors.
9. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
10. Losses arising in the production of electricity and heat at public utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of 33% for nuclear, 10% for geothermal and 100% for hydro.
11. Data on "losses" for forecast years often include large statistical differences covering differences between expected supply and demand and mostly do not reflect real expectations on transformation gains and losses.
12. Toe per thousand US dollars at 1990 prices and exchange rates.
13. Toe per person.
14. "Energy-related CO_2 emissions" specifically means CO_2 from the combustion of the fossil fuel components of TPES (i.e. coal and coal products, peat, crude oil and derived products and natural gas), while CO_2 emissions from the remaining components of TPES (i.e. electricity from hydro, other renewables and nuclear) are zero. Emissions from the combustion of biomass-derived fuels are not included, in accordance with the IPCC greenhouse gas inventory methodology. TPES, by definition, excludes international marine bunkers. INC-IX decided in February 1994 that emissions from international marine and aviation bunkers should not be included in national totals but should be reported separately, as far as possible. CO_2 emissions from bunkers are those quantities of fuels delivered for international *marine* bunkers and the emissions arising from their use. Data for deliveries of fuel to international *aviation* bunkers are not generally available to the IEA and, as a result, these emissions have not been deducted from the national totals. Projected emissions for oil and gas are derived by calculating the ratio of emissions to energy use for 1998 and applying this factor to forecast energy supply. Future coal emissions are based on product-specific supply projections and are calculated using the IPCC/OECD emission factors and methodology.

B

ANNEX

INTERNATIONAL ENERGY AGENCY "SHARED GOALS"

The Member countries* of the International Energy Agency (IEA) seek to create the conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants.

In order to secure their objectives they therefore aim to create a policy framework consistent with the following goals:

1 **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2 Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3 **The environmentally sustainable provision and use of energy** is central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should where practicable have regard to the Polluter Pays Principle.

4 **More environmentally acceptable energy sources** need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of

* Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

IEA Members wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5 **Improved energy efficiency** can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6 **Continued research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7 **Undistorted energy prices** enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8 **Free and open trade** and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9 **Co-operation among all energy market participants** helps to improve information and understanding, and encourage the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at their 4 June 1993 meeting in Paris.)

C

ANNEX

GLOSSARY AND LIST OF ABBREVIATIONS

In this report, abbreviations are substituted for a number of terms.

ampere	unit of electrical current.
bcm	billion cubic metres.
BWR	boiling water reactor.
CHP	combined production of heat and power; sometimes, when referring to industrial CHP, the term "co-generation" is used.
GDP	gross domestic product.
GHG	greenhouse gases (see footnote 4).
GW	gigawatt, or 1 watt $\times 10^9$.
LPG	liquefied petroleum gas; refers to propane, butane and their isomers, which are gases at atmospheric pressure and normal temperature.
mcm	million cubic metres.
Mt	million tonnes.
Mtoe	million tonnes of oil equivalent; see toe.
MW	megawatt of electricity, or 1 Watt $\times 10^6$.
MWe	megawatt electrical capacity.
MWh	megawatt-hour = one megawatt × one hour, or one watt × one hour $\times 10^6$.
MWt	megawatt thermal capacity.
NO_x	oxides of nitrogen.
OECD	Organisation for Economic Co-operation and Development.
OPEC	Organisation of the Petroleum Exporting Countries.
PCI	pulverised coal injection.
PJ	petajoule.
PPP	purchasing power parity: the rate of currency conversion that equalises the purchasing power of different currencies, i.e. estimates the differences in price levels between different countries.

PWR	pressurised water reactor.
R&D	research and development, especially in energy technology; may include the demonstration and dissemination phases as well.
SKr	Swedish krona = 100 ore.
TFC	Total Final Consumption of energy; the difference between TPES and TFC consists of net energy losses in the production of electricity and synthetic gas, refinery use and other energy sector uses and losses.
toe	tonne of oil equivalent, defined as 10^7 kcal.
TPA	third party access.
TPES	Total Primary Energy Supply.
TW	terawatt, or 1 watt $\times 10^{12}$.
TWh	terawatt $\times$ one hour, or one watt $\times$ one hour $\times 10^{12}$.
UNFCCC	United Nations Framework Convention on Climate Change.

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