# SWEDEN

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1. GENERAL INFORMATION

### 1.1. General Overview

Sweden is a long narrow country in the northern part of Europe and borders Norway in the west, Finland in the northeast and the Baltic Sea in the South and east, as shown in Figure 1. The total length from north to south is 1,600 kilometres and the land area is 410,932 square kilometres. The size of the area is the third in Western Europe after France and Spain. The area is almost twice as big as that of Great Britain. The northwest part of Sweden consists of mountains with a slope towards the east. There are many rivers in the north and lakes are scattered all over the country. Sweden's coast line is more than 2,000 kilometres long.


*FIG. 1. Location of Sweden in Europe.*

The northern boundary is about 250 kilometres north of the north polar circle 66°30´, but because of the Gulf Stream coming from west, the climate is not of a polar type. The average temperature over the year varies between -1.5 °C in the north to 7.8 °C in the south.

The population data in Table 1 show a very slow increase of the population until the mid 90ties and then levelling of at about 8.9 million inhabitants. The population density is 19.7 persons per square kilometres; however, the northern part of Sweden is sparsely populated with smaller than 20% of the inhabitants living in the northern half of the country.

TABLE 1. POPULATION INFORMATION

| | 1960 | 1970 | 1980 | 1990 | 1998 | 1999 | 2000 | Growth rate (%) 1980 to 2000 |
|---|---|---|---|---|---|---|---|---|
| Population (millions) | 7.5 | 8.0 | 8.3 | 8.59 | 8.85 | 8.86 | 8.88 | 0.3 |
| Population density (inhabitants/km²) | 17 | 18 | 18 | 19 | 19.6 | 19.7 | 19.7 | 0.3 |
| Urban population as percent of total | 73 | 81 | 83 | 83 | 83 | 84 | 84 | - |
| Total area 1000 km² (excl. territorial waters) 449.964<br>54% forest land, 16% mountains, 11% wetlands, 9% lakes and rivers, 8% cultivated land, 3% developed area. | | | | | | | | |

Source: IAEA Energy and Economic Database; Data & Statistics/the World Bank; Country Information.

There are no other domestic energy sources except hydro and bioenergy (used mainly in the pulp and paper industry) exploited. There are, however large amounts of low grade uranium, 10,000 metric tonnes of uranium in ores containing between 500 and 2,000 grams uranium per tonne and 300,000 metric tonnes of uranium in still lower grades. There is no economic incitement to exploit such low grade uranium ores and no uranium mines are in use. Fuel for the nuclear power plants is imported.

Most of the hydro electric power is located in the north, and the electricity is transported to the south by several large 400 kV lines. All the nuclear power plants are in the southern part of Sweden as shown in Figure 2. Because of the abundance of rivers and lakes, all thermal power plants (nuclear or fossil) are cooled by sea, lakes or river water. Cooling towers at power plants can not be found in Sweden.

Hydro Power Installed Capacity 31/12/1999
**16192 MW**

Nuclear Power Installed Capacity 31/12/1999
**9452 MW**
Note: Barsebäck was shut down on 30/11/1999

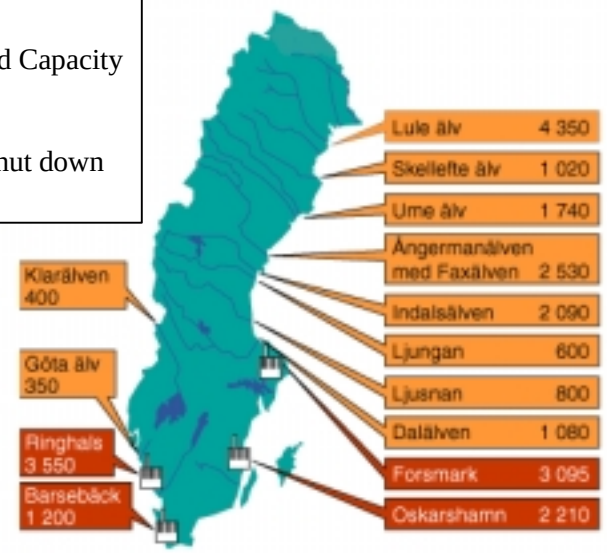


*FIG. 2. Location of Power Stations in Sweden*

### 1.2. Economic Indicators

Table 2 shows the historical Gross Domestic Product (GDP) data. The GDP annual growth trend for the year 1995 to 1999 is 2.7 %.

TABLE 2. GROSS DOMESTIC PRODUCT (GDP)

| | 1970 | 1980 | 1990 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|
| GDP [1] | 34 | 126 | 230 | 237 | 238 | 239 |
| GDP [2] per capita | 4,186 | 15,110 | 26,844 | 26,781 | 26,887 | 26,983 |
| GDP by sector (%): | | | | | | |
| -Agriculture | N/A | 4 | 3 | N/A | N/A | N/A |
| -Industry | N/A | 34 | 34 | N/A | N/A | N/A |
| -Services | N/A | 63 | 63 | N/A | N/A | N/A |

[1] Billions of current US$.
[2] Current US$ per capita.
Source: IAEA Energy and Economic Data Base; Data and Statistics/The World Bank.

### 1.3. Energy Situation

Sweden's energy requirement is covered both by imported energy, primarily oil, coal, natural gas and nuclear fuel and by domestic energy in the form of hydropower, wood and peat plus waste products from the forestry industry (bark and liquors), see Table 3. Originally, all energy was domestic, primarily wood and hydropower. However during the 19th century, coal began to be imported. Coal came to play an important role up until World War II, when oil and hydropower together became the base of the energy supply. The first oil crisis in 1973 demonstrated the risk of being dependant upon oil.

TABLE 3. ESTIMATED ENERGY RESERVES

Exajoule

| | Solid | Liquid | Gas | Uranium [1] | Hydro [2] | Total |
|---|---|---|---|---|---|---|
| Total amount in place | 0.02 | | | 2.18 | 16.97 | 19.17 |

[1] This total represents essentially recoverable reserves.
[2] For comparison purposes a rough attempt is made to convert hydro capacity to energy by multiplying the gross theoretical annual capability (World Energy Council - 1998) by a factor of 10.
Source: IAEA Energy and Economic Data Base.

As early on as during the 60s, a decision had been made to invest in nuclear power. Nuclear power and domestic fuels then came to be responsible for a large part of the substitution for oil, together with the more efficient utilization of energy, primarily in the heating sector. The greatest changes occurring between 1973 and 1997 were that the proportion of oil used in the energy supply fell from 71 to 29 % and that nuclear power rose from 1 to 37 %.

When studying the trend for the supply of energy, it is customary to add the various energy products without regard to their respective "Qualities". Certain energy products, primarily nuclear power and hydropower cannot be utilized by the end-user, instead having first to be converted into a more manageable energy carrier, e.g. electricity or district heating. Conversion losses in nuclear power and hydropower plants have often been ignored. Sweden is now increasingly using the internationally-prevalent calculation method of, in the case of hydropower, calculation the gross production as supplied energy and, in the case of nuclear power, the energy content of the fuel.

In Swedish hydropower stations, losses are about 1% and in the nuclear power plants about 68%, using this method of calculation. If only the net generation of electricity in the hydropower and nuclear power stations is taken into account, Sweden's supply of energy in 1999 was, 439 TW·h compared 587 TW·h according to the new international method of calculation. Table 4 shows the historical energy data.

According to the Administration's forecast for the period until 2002, total energy supply for 2000 is expected to fall to 589 TW·h. This is due primarily to a reduction in the supply of oil, due to high oil prices and a fall in nuclear power output. Despite the fact that hydropower output has been unusually high, it is expected that overall electrical production will fall to 141 TW·h as a result of reduced production of nuclear power. It is expected, on the basis of preliminary statistics and our own

calculations, that Sweden will be a net importer of 4.6 TW·h of electricity during 2000. According to the forecast the total energy supply for 2001 and 2002 is expected to rise to 609 TW·h and 616 TW·h respectively: including respective net imports of electricity of 9 TW·h and 10 TW·h.

TABLE 4. BASIC ENERGY SITUATION

Exajoule

| | | | | | | | | Average annual growth rate (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1970 | 1980 | 1990 | 1998 | 1999 | 2000 | 1960 to 1980 | 1980 to 2000 |
| Energy consumption | | | | | | | | | |
| - Total [1] | 0.94 | 1.87 | 1.91 | 2.12 | 2.11 | 2.15 | 2.05 | 3.63 | 0.35 |
| - Solids [2] | 0.11 | 0.22 | 0.14 | 0.20 | 0.14 | 0.17 | 0.18 | 1.05 | 1.18 |
| - Liquids | 0.53 | 1.21 | 0.94 | 0.58 | 0.61 | 0.63 | 0.65 | 2.91 | -1.86 |
| - Gases | | | | 0.02 | 0.03 | 0.03 | 0.03 | | |
| - Primary electricity [3] | 0.29 | 0.44 | 0.83 | 1.32 | 1.32 | 1.32 | 1.19 | 5.34 | 1.83 |
| Energy production | | | | | | | | | |
| - Total | 0.31 | 0.54 | 0.89 | 1.42 | 1.40 | 1.53 | 1.45 | 5.42 | 2.47 |
| - Solids | 0.01 | 0.14 | 0.07 | 0.09 | 0.05 | 0.08 | 0.09 | 12.28 | 1.36 |
| - Liquids | | | | | | | | -6.79 | |
| - Gases | | | | | | | | | |
| - Primary electricity [3] | 0.30 | 0.40 | 0.82 | 1.33 | 1.35 | 1.46 | 1.36 | 5.18 | 2.56 |
| Net import (Import - Export) | | | | | | | | | |
| - Total | 0.65 | 1.36 | 1.16 | 0.74 | 0.84 | 0.87 | 0.91 | 2.90 | -1.18 |
| - Solids | 0.10 | 0.07 | 0.07 | 0.10 | 0.11 | 0.10 | 0.09 | -1.74 | 1.36 |
| - Liquids | 0.55 | 1.28 | 1.09 | 0.62 | 0.70 | 0.74 | 0.79 | 3.43 | -1.61 |
| - Gases | | | | 0.02 | 0.03 | 0.03 | 0.03 | | |

[1] Energy consumption = Primary energy consumption + Net import (Import - Export) of secondary energy
[2] Solid fuels include coal, lignite and commercial wood
[3] Primary electricity = Hydro + Geothermal + Nuclear + Wind
Source: IAEA Energy and Economic Data Base.

### 1.4. Energy Policy

In both the long and the short terms, the objective of Swedish energy policy is to ensure reliable supplies of electricity and other forms of energy carriers at prices that are competitive with those of other countries. It is intended to create the right conditions for cost-efficient Swedish energy supply and efficient energy use with minimum adverse effect on health, the environment or climate. Extension of cooperation in the fields of energy, the environment and climate around the Baltic is also an important objective.

The results of two climate official reports have been published during 2000. During the spring, the Climate Committee published its *Proposal for a Swedish climate strategy*, in which it suggested a national target for Sweden involving reducing the emission of greenhouse gases by 2% between 2008 and 2012, relative to the 1990 level. To achieve this objective, the Committee suggests a programme of work at both national and international levels. One of the elements of the international work is that Sweden should push for the introduction of European trade in emission rights of greenhouse gases. At the national level, work includes information campaigns linked to demonstration projects and investment subsidies. Some proposals also involve tightening up existing regulations.

*Emission Trading: A Way of Achieving the Climate Goal* was published in the spring of 2000. The report concentrates on how a national trading system in emission rights could be established: the Government will be presenting a Bill concerned with climate matters at the end of 2000.

The EU Directorate-General for Energy and Transport has established a number of political priorities for the period 2000–2005. Some of these priorities relate to implementation of the single market for energy and transport, as well as to the question of how development of the transport and energy sectors can be reconciled with environmental requirements.

The objective of implementing the single market for energy and transport is supported by a number of measures, including the gas and electricity market directives. The objectives of the Electricity and Gas Market Directive of the EU are progressively to open up the gas and electricity markets to greater competition, which is expected to benefit European consumers through lower prices. At present, the Commission is working on preparing data and putting forward proposals for how the markets are to be opened up and what rules are to apply on them. The electricity markets in the UK, Norway, Sweden, Finland and Germany are already fully open to competition, i.e. both industrial and domestic consumers can choose their electricity suppliers. Market restructuring is well advanced in Denmark, too, but other EU countries have not progressed as far.

The emphasis of the work on how development of transport and energy can be reconciled with environmental requirements is on a number of areas, including energy efficiency (particularly within the building sector) and on encouragement of the use of renewable energy sources. A draft directive was presented by the Commission in the spring of 2000, intended to encourage the production of electricity from renewable energy sources. The purpose of the directive is to create a frame-work which, in the long term, will help to increase the proportion of electricity produced from renewable energy sources. The Commission's White Paper *Energy for the future – renewable energy sources* sets out the objective of doubling the present proportion of electrical energy from renewable energy sources within the EU from 6% to 12 % by 2010.

For the summit meeting of the Council of Ministers in June 2001, the Commission is planning to put forward a strategy for integrating environmental consideration and sustainable development within the energy sector. It represents a continuation of the progress started in Cardiff in 1998, with the aim of increasingly integrating environmental protection requirements and sustainable development in areas such as energy and transport policy. The environmental aspects will be given priority while Sweden holds the presidency of the EU. The Commission has also published a Communication concerning strengthening the northern dimension of European energy policy. It was noted, that the northern dimension can be utilised to increase security, stability, democratic reforms and sustainable development in northern Europe, as well as to identify and encourage common European interests. During 2000/2001, the Commission is planning to publish a Green Paper on security of supply in the energy sector.

The work of the EU Directorate-General for the Environment includes climate matters. During the year, the Commission has published a communication on *EU policies and measures to reduce greenhouse gas emissions*, as a precursor to ratification of the Kyoto Protocol. It is particularly within the fields of energy, transport and industry that common matters, concerning the whole of the European Union, can be of interest. The Directorate-General for the Environment has also published a Green Paper en-titled *Greenhouse gas emission trading within the EU*, intended to start a discussion on trade in emission rights, including discussion of how such a system might be structured. It is the objective that a trading system should be in operation within the EU by 2005.

During 2000, the Directorate-General for the Environment introduced a European climate change programme, ECCP. The objective of the programme is to bring together all parties involved in work on preparations for common, coordinated policies and measures intended to reduce emissions of greenhouse gases. The programme will be concerned primarily with policies and measures within the fields of flexible mechanisms, energy supply, energy use, transport and industry.

The sixth meeting of the parties to the Climate Convention, COP6, was held in the autumn of 2000. The main objective of this meeting was to enable the parties to make decisions concerning the various matters remaining to be solved, including utilisation of the flexible mechanisms. The meeting considered, for example, what sanctions should be applied to countries that did not fulfil their emission undertakings. Another important issue was how the carbon sinks should be handled. The results of this meeting are decisive for the coming Kyoto Protocol ratification process. As it turned out, the Parties to the Kyoto Protocol did not reach a final agreement on some of the more difficult issues. The negotiations will thus continue in spring 2001.

2. ELECTRICITY SECTOR

## 2.1. Structure of the Electricity Sector

Electricity production started early in Sweden. The first generating plants based on hydro power were established in the 1880s. They were small and intended to supply power to industries and communities in the close vicinity. Hundreds of small hydroelectric power stations were constructed. As the technique of transferring power over longer distances developed, it became possible to exploit the larger rivers for distribution of power to the south of the country.

Many of the companies, which today are responsible for the power supply, were formed at this time. The Government became engaged in the production and distribution of power at this stage. In 1906 Parliament granted funds for the first state owned hydropower project and in 1909 the Swedish State Power Board (now Vattenfall AB) was formed. Since that time, the production of power has been divided practically equal between, on the one hand, the Government through the Swedish State Power Board (Vattenfall AB) and, on the other hand, power companies owned by industries, municipalities and other non-governmental bodies.

1999 was the fourth year of the restructured electricity market in Sweden and Finland. Norway had restructured its electricity market in 1991. During the year, competition on the market increased more than it had done during the three previous years. A good availability of electricity, together with low prices on the electricity exchange, exerted pressure on the utilities to keep their prices down.

Since the restructuring of the industry, there have been a number of changes in respect of ownership of the production utilities in the Nordic countries. Gullspång Kraft and Stockholm Energi merged in September 1998 to form Birka Energi, which means that Sweden now has six main parties dominating the electricity production sector. However, on the common Nordic market as a whole, there are several other production utilities that compete. Swedish Vattenfall, Norwegian Statkraft, Finnish Fortum and German PreussenElektra all want to be leading companies in a future northern European electricity market, and are therefore investing in facilities in their neighbouring countries. This action is manifesting itself in such ways as through takeovers, purchase of shareholdings, alliances and the establishment of subsidiary companies in Sweden and in other countries.

### *2.1.1. The Electrical Producers*

Electricity is generated in plants owned by the state, the municipalities, industries and private companies. Additionally, a small amount of power is generated in small-scale privately owned wind power and hydropower plants. All in all, the state owns approximately 48 percent of the generating capacity, with overseas owners holding approximately 25 percent, the municipalities approximately 20 percent and others approximately 7 percent.

Mergers and acquisitions have gradually reduced the number of large producers during the last 20 years. Through this structural rationalization, the generation of electricity has become strongly concentrated. The six largest power companies accounted for 139.7 TW·h, or 93 percent of Sweden's overall electricity generation, during 1999. In the production statistics shown in Table 5, minority shares have been deducted and leased power has only been included at the company making use of the power. At the beginning of 2000, Stora Enso Energy AB was acquired by the Finnish energy group Fortum via its wholly owned Swedish subsidiary Fortum Energi Sverige AB.

### *2.1.2. The Transmission of Power*

The transmission of power from power plants to customers takes place using the interconnected electricity network. The network is normally divided into three levels; the high-voltage grid and the regional and local networks.

TABLE 5. THE LARGEST ELECTRICITY PRODUCERS

| Producer | Generated output in 1999 (TW·h) |
|---|---|
| Vattenfall | 79.6 |
| Sydkraft | 27.5 |
| Birka Energi | 21.0 |
| Stora Enso Energy | 6.0 |
| Skellefteå Kraft | 3.0 |
| Graninge | 2.6 |
| Total | 2138.7 |

The utility Svenska Kraftnät is responsible for the high-voltage grid, which includes the 220 and 400 kV lines, as well as the bulk of the links with our neighbour-countries. The regional networks are owned and operated by the large power companies' network companies, and generally include lines of 130-40 kV.

The local networks are owned and operated by about 200 network companies, and normally include lines of a maximum of 20 kV. The number of local network companies is gradually decreasing due to the continuing structural rationalisation of network operations. When network companies become larger, this often entails the local and regional networks being co-ordinated within the same network company.

The total length of the transmission line in Sweden is 475 280 km (10 times around the word), thereof 246 990 km underground and 228 280 km airborne cables. The number of customer connected to the network is $5{,}2 \times 10^6$ and the capital value of the transmission line in Sweden is estimated to about $14 \times 10^9$ US$.

**2.2. Decision Making Process**

The Swedish electricity market was deregulated on January 1st 1996. One characteristic of the new, free electricity market is the fact that the distribution networks are open to all and that electricity network operations are conducted separately, both from a financial and legal point of view, to generation, trading and other operations within the group.

The distribution networks constitute a natural monopoly and the network operation is supervised by the Swedish National Energy Administration. The Swedish National Energy Administration also grants permission for the installation of power lines, as well as issuing line concessions. By paying network fees, a customer gains access to the electricity networks of the entire country and can freely choose an electricity supplier.

The generation of electricity is not regulated by law; anyone wishing to do so is free to generate or trade in electricity. Sweden's electricity producers compete for customers with one another, with overseas electricity producers and with electricity traders and brokers.

When decisions must be made on various matters, the Government may appoint a committee. The starting point for the committee's work is set out in its terms of reference. The committee presents its conclusions and proposals in a report. Before deciding its views on the report, the Government circulates it to public authorities, organisations, local government etc. for comments. When the comments have been received, the Government prepares a bill for presentation to Parliament. The bill is then examined by the parliamentary committee responsible for the particular area. When this committee has put forward its proposals, Parliament makes the final decision.

Svenska Kraftnät, as system operator, is ultimately responsible for ensuring that a balance is maintained between the production and consumption of electricity in Sweden. This responsibility also

includes ensuring that the necessary disruption reserve is always available. On the deregulated electricity market, it is only the system operators that have a satisfactory overview of the overall electricity balance. The Swedish Power Association has thus lobbied the government as regards the need to elucidate Svenska Kraftnät's responsibility.

In a governmental decision from December, Svenska Kraftnät was given the task of, among other things, monitoring the available capacity during peak loads and developing market instruments that can contribute to safeguarding the availability of power during peak loads. Svenska Kraftnät has acquired gas turbines with a combined output power of 400 MW from Vattenfall. In order to cover the remaining requirement for rapid disruption reserves, Svenska Kraftnät also has agreements with several power producers regarding a further 800 MW of gas turbine capacity.

One further possibility lies in agreements with industry regarding the disconnection of consumption during times of peak loading. Svenska Kraftnät signed such an agreement with Vargön Alloys at the end of the year.

In 1999, the Swedish National Energy Administration carried out a scenario study of the trend for the energy system until 2010. In this, electricity consumption is forecast, in a reference alternative in 2010, to amount to 154.4 TW·h, excluding electric boilers in heating plants. This corresponds to an increase of 0.7 percent per year.

### 2.3. Main Indicators

Today, most of Sweden's electricity is produced by hydropower or nuclear power, with conventional thermal power production accounting for only about 5 %. Oil-fired cold condensing power plants and gas turbines are used today primarily as reserve capacity during years with low precipitation and resulting low hydropower production. Restructuring of the electricity market has resulted in several reserve power stations being taken out of use for economic reasons. There are also about 500 wind power plants in the country (as of August 2000). As yet, however, their contribution to the country's electricity balance is still very small, amounting to 0.2 % during 1999.

The total installed capacity of the Swedish electricity production system is some-what over 35 000 MW. However, 100 % capacity is never available, and transmission capacity between the north and south of the country is limited. The normal transmission capacity means that 6 300–7 000 MW can be transferred from north to central Sweden, and 3 350 MW from central Sweden to southern Sweden. In 1999, the country produced 154 TW·h of electricity, of which 48 % was produced by hydropower and 46 % by nuclear power. Table 6 shows the historical electricity production data and the installed capacities and Table 7 the energy related ratios.

Electricity is produced in Sweden from hydropower, nuclear power, wind power and conventional thermal power plants. In this context, thermal power refers to combined heat and power production, cold condensing power production and gas turbines, but not nuclear power. Combined heat and power plants are employed in industry, where the heat is used for internal process requirements, and in district heating plants, where the heat is generally supplied to public district heating systems.

At the beginning of the 1970s, most of Sweden's electricity was being produced by hydro-power and conventional thermal power. This was when expansion of nuclear power started, with Sweden's first commercial reactor, Oskarshamn 1, being commissioned in 1972. Since then, the proportion of electricity from nuclear power has grown substantially, so that from 1975 more electricity has been produced in nuclear power plants than in conventional thermal power plants. Swedish Power Association (Svenska Kraftverksföreningen) with almost all power producers as members has published a list of power production resources within its member, see Table 8.

TABLE 6. ELECTRICITY PRODUCTION AND INSTALLED CAPACITY

| | 1960 | 1970 | 1980 | 1990 | 1999 | 2000 | Average annual growth rate (%) 1960 to 1980 | Average annual growth rate (%) 1980 to 2000 |
|---|---|---|---|---|---|---|---|---|
| Electricity production (TW·h) | | | | | | | | |
| - Total [1] | 34.74 | 60.65 | 96.32 | 146.45 | 162.51 | 166.81 | 5.23 | 2.78 |
| - Thermal | 3.65 | 19.05 | 10.96 | 8.11 | 11.56 | 25.40 | 5.65 | 4.29 |
| - Hydro | 31.09 | 41.54 | 58.87 | 73.03 | 80.38 | 85.93 | 3.24 | 1.91 |
| - Nuclear | | 0.06 | 26.49 | 65.30 | 70.10 | 54.80 | | 3.70 |
| Capacity of electrical plants (GWe) | | | | | | | | |
| - Total | | 15.31 | 27.42 | 34.45 | 33.17 | 33.14 | | 0.95 |
| - Thermal | | 4.44 | 7.95 | 7.82 | 6.16 | 5.71 | | -1.64 |
| - Hydro | | 10.86 | 14.86 | 16.59 | 17.32 | 17.63 | | 0.86 |
| - Nuclear | | 0.01 | 4.61 | 10.03 | 9.43 | 9.43 | | 3.64 |
| - Wind | | | | 0.01 | 0.26 | 0.36 | | |

[1] Electricity losses are not deducted.
Source: IAEA Energy and Economic Database.

TABLE 7. ENERGY RELATED RATIOS

| | 1960 | 1970 | 1980 | 1990 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|
| Energy consumption per capita (GJ/capita) | 125 | 232 | 230 | 247 | 238 | 243 | 232 |
| Electricity per capita (kW·h/capita) | 4,542 | 7,849 | 11,327 | 16,432 | 16,259 | 16,280 | 16,377 |
| Electricity production/Energy production (%) | 108 | 105 | 101 | 96 | 101 | 99 | 107 |
| Nuclear/Total electricity (%) | | | 28 | 46 | 48 | 44 | 34 |
| Ratio of external dependency (%) [1] | 70 | 73 | 61 | 35 | 40 | 41 | 45 |
| Load factor of electricity plants: | | | | | | | |
| - Total (%) | | 45 | 40 | 58 | 49 | 56 | 57 |
| - Thermal | | 49 | 16 | 12 | 14 | 21 | 51 |
| - Hydro | | 44 | 45 | 75 | 48 | 53 | 56 |
| - Nuclear | | 64 | 66 | 74 | 80 | 85 | 66 |

[1] Net import / Total energy consumption
Source: IAEA Energy and Economic Database.

TABLE 8. MEMBER COMPANIES' GENERATING CAPACITIES IN MW
STATUS JANUARY 1998

| | Hydro power | Nuclear power | Other thermal power | Wind power | Total |
|---|---|---|---|---|---|
| Vattenfall AB | 8,397 | 5,853 | 1,075 | 19 | 15,344 |
| Sydkraft AB | 2,352 | 2,502 | 1,147 | 7 | 6,008 |
| Birka Energi | 2,329 | 1,289 | 949 | 1 | 4,568 |
| StoraEnso AB | 932 | 291 | 99 | 0 | 1,322 |
| Skellefteå Kraft | 500 | 61 | 37 | 0 | 598 |
| Graninge | 525 | 0 | 36 | 1 | 562 |
| MoDo Kraft | 251 | 0 | 0 | 0 | 251 |
| Tekniska Verken i Linköping AB | 16 | 0 | 222 | 0 | 238 |
| Norrköping Miljö & Energi AB | 12 | 0 | 224 | 0 | 236 |
| Jämtkraft AB | 198 | 0 | 0 | 0 | 198 |
| Västerås Energi & Vatten AB | 45 | 0 | 148 | 0 | 193 |
| Umeå Energi AB | 150 | 0 | 0 | 0 | 150 |
| Uppsala Energi AB | 3 | 0 | 140 | 0 | 143 |
| Karlstad Energi AB | 24 | 56 | 38 | 0 | 118 |
| Other member companies | 67 | 0 | 343 | 5 | 415 |
| Total | 15,801 | 10,052 | 4,457 | 33 | 30,344 |

Source: Country Information.

### 2.4. Impact of Open Electricity Market in the Nuclear Sector

The electricity market is at present under going extensive changes in many parts of the world in terms of altered market conditions, new technology and greater environmental awareness. One of the effects of the EU Electricity Market Directive is that at least 25% of electricity markets in the EU states must be open for competition. The degree of openness varies between states. The electricity markets in Sweden, Finland, Norway, the UK and Germany are fully open to competition, which means that all companies and households are free to choose their electricity suppliers. France, Greece, Portugal and Austria, on the other hand, have merely fulfilled the minimum requirements of the directive. The directive also affects other countries in Europe, and particularly those that have applied for EU membership. Decisions on, or advanced plans for, reform of their electricity markets also exist in several countries outside the EU.

A similar development can be seen in other countries, such as South America, south-east Asia and Oceania. The USA has also started a restructuring process, under which California was the first state to reform its electricity market in 1998.

Restructuring of the electricity markets involves a change from national monopolies, with central planning, to markets exposed to competition. Electricity becomes a form of energy raw material, which can be traded and supplied across borders. Company takeovers in the electricity markets in the Nordic countries have attracted considerable attention in recent years.

Strategic investments are being made by the largest Nordic power utilities, not only in the Nordic countries but in the rest of Europe, while non-Nordic companies, such as the German PreussenElektra and the French EdF, are investing in the Nordic countries.

Import and export of electricity have previously been clear concepts that have been defined on a national perspective. However, as the larger companies increasingly extend their activities across national borders, it becomes less relevant to talk of national electricity markets. Large companies are buying and selling electricity in many other countries besides their original homelands. Development will be towards a common market, with electricity being produced wherever it is physically and economically most appropriate.

## 3. NUCLEAR POWER SITUATION

### 3.1. Historical Development

The first interest in "atomic energy" from the Government was shown in 1947, when AB Atomenergi was constituted as a research organization. Up to 1955, the programme was orientated towards basic research and concentrated on a small natural uranium/heavy water reactor.

In 1956, an official ad hoc commission proposed a forceful R&D programme with the purpose to introduce a national programme for reactors based on natural uranium and heavy water for production of heat and electricity. AB Atomenergi was proposed to be responsible for the programme. It was known that Sweden had large resources of low-grade uranium ore and the idea was to establish an energy policy almost completely independent of other countries.

In 1958, AB Atomenergi moved most of its activities to a newly established national laboratory, Studsvik. A material testing reactor R2 started operation in 1960 and is still in operation (now 50 MW thermal).

Vattenfall, at that time closely connected to the Government, and AB Atomenergi, also State owned, decided in 1957 to build a small reactor for production of heat and electricity. The name was Ågesta and it started in 1964 to produce 65 MW(th). 55 MW was used for heating a suburban of Stockholm and 10 MW for electricity production. The reactor was shutoff in 1974.

Construction of a heavy water power reactor, Marviken and based on slightly enriched uranium with a possibility to change to natural uranium, with an electric output of 140 MW commenced in 1963. The project was stopped in 1970 only a few months before the fuel loading and the reactor has never been used for power production. The project was performed in co-operation between AB Atomenergi and Vattenfall, which were jointly responsible for this project, although AB Atomenergi played the leading role.

Eight non-state owned utilities with Sydkraft in the lead founded in 1955 Atomkraftkonsortiet, AKK (the Atomic Power Consortium) with the purpose to follow the international development of nuclear power. AKK had early direct contacts with utilities and vendors in the US. In 1959 AKK asked for a Governmental approval for a 60 MW BWR project, based on a concept from General Electric, but the project was never realized.

In 1964, AKK received a bid from ASEA for a project based on a BWR concept of Swedish design. The 460 MW turbine was designed by Stal Laval, a turbine manufacturing company closely related to ASEA. The high pressure system was a double rotating turbine with radial flow of the steam. This type of turbine was not possible to develop to the larger sizes, which later on were needed. For deliveries to later nuclear projects, Stal Laval started a co-operation with Brown Bovery Company (BBC) in Switzerland.

AKK was transformed into OKG AB in 1965 with seven owners. OKG ordered in 1966 Oskarshamn 1 from ASEA. Oskarshamn 1 was the first LWR reactor in the world being designed without licence from US vendors. It started commercial operation in 1972.

In 1968, part of AB Atomenergi (mainly the fuel manufacturing) was transferred to ASEA, and a contract between the State and ASEA was signed. The contract also resulted in AB Atomenergi closing its reactor design office. AB Atomenergi has after that developed as a R&D company first with emphasize on nuclear energy, but later also other types of energy sources were included.

The company ASEA Atom was founded with the ownership equally divided between ASEA and the State. The contract about ASEA Atom was in function until 1979, when the ASEA Group became the single owner of ASEA Atom (later on ABB Atom and now Westinghouse Atom).

In 1968, Vattenfall ordered Ringhals 1, a 750 MW BWR from ASEA, and Ringhals 2, a 800 MW PWR from Westinghouse. The outspoken reason for two orders signed with two different vendors, one Swedish and one foreign, was that Vattenfall wanted to establish a real competitive market in Sweden for the future development of nuclear power. Later, Vattenfall ordered two more Westinghouse PWRs to be built at Ringhals.

In 1969 OKG ordered Oskarshamn 2 and Sydkraft ordered Barsebäck 1 with an option for Barsebäck 2. Thus four nuclear power units were ordered from ASEA Atom before the company's first unit had started to operate.

The explanation for this enormous expansion of nuclear power was that during several years there was a yearly increase in the power consumption of 7%. Further development of hydropower was not allowed because of environmental reasons. Neither the State nor the utilities wanted oil fired units to be built because of the increased dependance on oil imports.

During the first half of the 1970s Vattenfall started in co-operation with some non-state owned utilities to build the Forsmark nuclear power plant, where now 3 BWRs are in operation.

The Nuclear Power Inspectorate was functioning on a small scale from the beginning of the 1960s. Also the National Radiological Institute was operating on a small scale with Professor Rolf Sievert as an enthusiastic leader. Both the authorities became more professional at the end of the 1960s, just before the start of the large LWR programme.

Just before the general election in 1976 nuclear power became a main political issue with the Centre Party being critical to the nuclear waste issue. The leader of the Centre Party became Prime Minister with the Government consisting of a non-socialistic coalition.

The new Government arranged a huge investigation of the risks and economies of nuclear power compared to other energy sources in an official ad hoc Energy Commission. In 1977 a unique act about the nuclear waste was accepted by Parliament. According to the new waste act, called the "Stipulation Act", the utilities would not be allowed to load fuel into a new reactor (and several were in the pipe line) before it had been shown that it was possible to arrange a final storage of the waste "in an absolutely safe way". Before Parliament accepted the act a remark was added in the minutes saying that the word "absolutely" should not be interpreted in a "draconian" way.

The result of this political development was that the utilities started Svensk Kärnbränslehantering AB (SKB, the Swedish Nuclear Fuel and Waste Management Company) to develop a comprehensive concept for final storage of high radioactive waste and to make a thorough safety evaluation of the whole concept.

One concept (KBS-1) for the final disposal of reprocessed waste was presented in 1978, followed by another concept (KBS-2) for direct disposal of spent fuel. A further development of this concept (KBS-3) was presented a few years later. Late 1978, the KBS-1 and KBS-2 concepts were accepted by the Government as safe enough (but at that time the Centre Party had left the Government because of the nuclear controversy). Several reactors were allowed to start loading of fuel with reference to this principle decision by the Government, but then came the TMI accident.

A week after the TMI accident, all the political parties agreed to arrange a referendum about the future of nuclear power. A special law was established forbidding the start of all new reactors until after the referendum. The referendum was arranged in March 1980 and some months later Parliament decided in accordance with the result of the referendum to allow the start of all the reactors, which were ready or under construction. It was also decided that nuclear power would be phased out by 2010, if new energy sources were available at that time and could be introduced in such a way that it would not effect the social welfare programme and the employment in the heavy industry. The two last reactors in the programme of twelve started commercial operation in 1985.

A Central Interim Storage Facility for Spent Nuclear Fuel, CLAB, has been in use since 1986 and a Final Repository for Reactor Waste, SFR, has been in operation since 1988. SFR is being used for medium- and low-activity waste. Both these storage facilities can house with minor extensions all the spent fuel and reactor waste produced in Swedish reactors up to the year 2010 and beyond. CLAB is situated in the neighbourhood of the Oskarshamn nuclear power plant and SFR is close to Forsmark nuclear power plant.

The Äspö Rock Laboratory for waste disposal experiments in the bedrock at 500 metres depth was completed in 1995 and is situated close to the Oskarshamn nuclear power plant.

The Chernobyl accident resulted in a new political debate about the Swedish nuclear power programme. Parliament decided in 1988 that the phase out of nuclear power would start in the period 1995 to 1996, with two units to be closed. After a few years, the industry and the labour unions started an intensive debate, because it was shown in official reports that the total cost of an early phasing out (after 25 years operation instead of 40 years, which is the assumed technical life time of the Swedish reactors) would cost the society more than SEK 200 billion. The price of electricity for the electricity intensive industry (paper and steel) would double with the result that between 50,000 to 100,000 persons would loose their jobs. The result was that Parliament in 1991 decided not to start the phase out by 1995.

The legislation in the nuclear field started with a general "Atomic Energy Act" in 1956, followed by a general Radiation Protection Act in 1958. In 1960, an act about emergency planning in case of a nuclear accident was introduced and in 1968 the Third Party Liability Act was established. In

1977 the "Stipulation Act" became effective and in 1980 Parliament passed an act on public control of the safety work at the nuclear power stations. Finally in 1981, an act on the financing of future costs for spent nuclear fuel was passed.

In 1984, the whole system of acts on nuclear power was revised. Only small changes were made in the Radiation Protection Act. The Atomic Energy Act, the Stipulation Act, the act on public control and part of the financing act were combined in one new Act on Nuclear Activities.

The Stipulation Act was superseded by some paragraphs in the new act requiring each owner of a nuclear facility to ensure a comprehensive research and development programme with the aim to conduct the handling and final disposal in a safe manner of all nuclear waste arising in the operation of the facility. The research and development should also cover future decommissioning and dismantling of the facilities. The nuclear utilities are obliged to present a comprehensive R&D programme for all the future waste problems every third year. The nuclear utilities have handed over all the responsibility for the nuclear waste R&D to SKB.

According to the Financing Act from 1981, the nuclear utilities have to pay a fee per produced kW·h to a state fund. The fund shall cover all future costs for handling and final storage of all waste and for decommissioning of all the facilities. The average fee during the last five years has been 0.02 SEK per kW·h nuclear power.

1999 will go into history as the year when Barsebäck 1, one of Sweden’s 12 reactors, became the first to be definitively shut down.

### 3.2. Status and Trends of Nuclear Power

Sweden has eleven nuclear units representing a total capacity of 9.4 GW(e). In 2000, the electricity generated by the nuclear power plants amounted to 54.8 TW·h and supplied some 40% of the total electricity production of the country. Nuclear power generation in Sweden during 1999 was 70.2 TW·h, about the same as during 1998 and 3.3 TW·h less than the record year of 1991. Table 9 shows the status of the Swedish Nuclear Power Plants.

The annual output of the three Oskarshamn units was 15.0 TW·h, the second highest ever. The result corresponds to 10 percent of Sweden’s overall electricity generation. The operating results of the first and third units were very good, while the availability of Oskarshamn 2 was lower than usual due to a long overhaul period during the summer.

The two units at Barsebäck generated 6.1 TW·h. The availability of both units was lower than usual due to extended overhaul periods.

The four units at Ringhals generated 25.3 TW·h, which was slightly higher than in 1998 (24.9 TW·h). This corresponds to almost 17 percent of Sweden’s overall electricity generation. The availability of Ringhals 1 was lower than usual due to an extended overhaul period, but very high for the other three units, more than 90 percent for each unit.

At Forsmark, too, the operating result was very good. For all three units, the availability was over 91 percent. Forsmark 1 was best, with an availability close to 97 per-cent, a new Swedish record. The total generated output was 23.7 TW·h, corresponding to almost 16 percent of the country’s overall electricity generation.

The long overhaul shutdowns at Oskarshamn 2, Barsebäck 1 and 2 and Ringhals 1 were due to similar problems with the moderator tank caps of the reactors.

The mean value of the energy availability of the twelve Swedish units was approximately 83 percent, which can be compared with 75 percent, which is an average figure for the world’s nuclear power units of equivalent type.

TABLE 9. STATUS OF NUCLEAR POWER PLANTS

| Unit/Station | Type | Capacity | Operator | Status | Reactor Supplier |
|---|---|---|---|---|---|
| BARSEBÄCK-2 | BWR | 600 | BKA | Operational | ABBATOM |
| FORSMARK-1 | BWR | 968 | FKA | Operational | ABBATOM |
| FORSMARK-2 | BWR | 964 | FKA | Operational | ABBATOM |
| FORSMARK-3 | BWR | 1155 | FKA | Operational | ABBATOM |
| OSKARSHAMN-1 | BWR | 445 | OKG | Operational | ASEASTAL |
| OSKARSHAMN-2 | BWR | 605 | OKG | Operational | ABBATOM |
| OSKARSHAMN-3 | BWR | 1160 | OKG | Operational | ASEASTAL |
| RINGHALS-1 | BWR | 830 | VAB | Operational | ABBATOM |
| RINGHALS-2 | PWR | 875 | VAB | Operational | WEST |
| RINGHALS-3 | PWR | 915 | VAB | Operational | WEST |
| RINGHALS-4 | PWR | 915 | VAB | Operational | WEST |
| BARSEBÄCK-1 | BWR | 600 | BKA | Shut Down | ASEASTAL |
| AGESTA | PHWR | 10 | VAB | Shut Down | ABBATOM |
| Marviken | PHWR | 130 | VAB | Never started | ASEA |

| Unit/Station | Construction Date | Criticality Date | Grid Date | Commercial Date | Shutdown Date |
|---|---|---|---|---|---|
| BARSEBÄCK-2 | 01-Jan-73 | 20-Feb-77 | 21-Mar-77 | 01-Jul-77 | |
| FORSMARK-1 | 01-Jun-73 | 23-Apr-80 | 06-Jun-80 | 10-Dec-80 | |
| FORSMARK-2 | 01-Jan-75 | 16-Nov-80 | 26-Jan-81 | 07-Jul-81 | |
| FORSMARK-3 | 01-Jan-79 | 28-Oct-84 | 05-Mar-85 | 18-Aug-85 | |
| OSKARSHAMN-1 | 01-Aug-66 | 12-Dec-70 | 19-Aug-71 | 06-Feb-72 | |
| OSKARSHAMN-2 | 01-Sep-69 | 06-Mar-74 | 02-Oct-74 | 01-Jan-75 | |
| OSKARSHAMN-3 | 01-May-80 | 29-Dec-84 | 03-Mar-85 | 15-Aug-85 | |
| RINGHALS-1 | 01-Feb-69 | 20-Aug-73 | 14-Oct-74 | 01-Jan-76 | |
| RINGHALS-2 | 01-Oct-70 | 19-Jun-74 | 17-Aug-74 | 01-May-75 | |
| RINGHALS-3 | 01-Sep-72 | 29-Jul-80 | 07-Sept-80 | 09-Sep-81 | |
| RINGHALS-4 | 01-Nov-73 | 19-May-82 | 23-Jun-82 | 21-Nov-83 | |
| BARSEBÄCK-1 | 01-Feb-71 | 18-Jan-75 | 15-May-75 | 01-Jul-75 | 30-Nov-99 |
| AGESTA | 01-Dec-57 | 17-Jul-63 | 01-May-64 | 01-May-64 | 02-Jun-74 |

Source: IAEA Power Reactor Information System as of 31 December 2000.

### 3.3. Current Policy Issues

The "Nuclear Power Decommisioning Act" become law in January 1998. The Act allows the government, within a specified framework, to decide that the right to operate a nuclear power plant will cease to apply at a certain point in time. Such a decision infers the right to compensation by the state for losses incurred.

In February 1998, the government decided to revoke the operation license for Barsebäck unit 1, effective July 1st. On May 14th the government decided on a stay of excursion, i.e. that the government decision from February 5th with regard to the closure of Barsebäck 1 would not apply until further notice. During summer and the autum, a dialogue was conducted between Sydkraft (owner of Barsebäck NPP) and the Government in order to find a voluntary solution. Barsebäck Kraft AB is now part of, and owned by Ringhals AB and both are owned and by Vattenfall and operated by Ringhals AB.

In compliance with the "Decommissioning of Nuclear Power Act", the operating licence for Barsebäck 1 should have expired on 1 July 1998. However, this decision was prevented some months previously when Sweden's Supreme Administrative Court ruled in favour of suspension. The legal review of the government's decision continued in the Supreme Administrative Court and the European Commission, to which Sydkraft had reported the matter for contravening EU competition laws. Neither were Sydkraft and the government able to reach a voluntary agreement during 1998.

On 16 June 1999, the verdict of the Supreme Administrative Court was announced, enabling the government to close a reactor at Barsebäck at the end of November that year. In the autumn, negotiations to achieve a voluntary solution were resumed, with the participation of the state, Sydkraft and Vattenfall.

On 30 November 1999, a settlement was reached – the framework agreement – in respect of Barsebäck. The settlement applies to both reactors at Barsebäck and entails Sydkraft receiving compensation of an equivalent volume of power generated by the Ringhals nuclear power plant, at the same cost and environmental impact, as well as Vattenfall being financially compensated by the state for the power generation it relinquishes. Barsebäck 1 was closed on 30 November 1999.

The closure of this nuclear power plant will have a substantial impact on the environment. Barsebäck's output of approximately 4 TW·h per year will primarily be replaced by imports from coal-fired plants in Denmark and Germany. In doing so, emissions of car-bon dioxide in our surroundings will increase, corresponding to more than a doubling of the Swedish electricity sector's emissions of carbon dioxide. Besides sharply increased carbon dioxide emissions, the fallout in Southern Sweden of acidifying substances, such as sulphur and nitrogen, will also increase.

The original concessions to construct and operate the twelve nuclear units were all given by the government without any time limit. The previous Nuclear Act stipulates that a nuclear power unit shall be closed when and if the safety standard is evaluated not to be high enough or if the waste development programme is judged not to be appropriate. The evaluation must be made by the safety authorities and a decision by the government to close a unit only of political reasons was not enough according to the previous Nuclear Act.

A mixed ownership of nuclear power has been accepted from the construction of the first nuclear units. Today Vattenfall, a company that is owned by the state to 100%, owns about half of the nuclear capacity. The other half of the nuclear installations are owned by privately or municipality owned utilities. Some of these are registered on the Stockholm Exchange and some of the shares are owned by foreign utilities.

Since 1988, all the nuclear power units have filtered vented containments. The efficiency of the filters has to be so high that a there would be no need for permanent evacuation in the neighbourhood of a reactor even in the case of a severe core accident.

In 1992, SKB presented a comprehensive programme for final disposal of spent nuclear fuel. The report describes a method and a preferred alternative for encapsulation and final disposal in a deep repository. Experts at universities and specialist companies as well as the regulatory authorities SKI and SSI thoroughly scrutinized and analyzed the plans presented in the report. The plans were then accepted by the government in December 1993 as a basis for SKB's future work in the field.

The deep repository is intended to be built on a site where the prospects for safety are very good. Many sites in Sweden are deemed to be capable of conforming to high standards. For this reason, the interest displayed by a municipality to host a deep repository, as well as the municipality's industrial infrastructure, also play an important role for the choice of site.

During 1994, SKB conducted feasibility studies as an initial step in the siting of the deep repository. Two studies, both at municipalities in the far north of Sweden, have been completed. The result is that both sites probably fulfil the technical criteria for building a deep repository.

However, in order to obtain a broader body of data, SKB have continue to conduct feasibility studies at other sites as well.

After evaluation of the feasibility studies and completion of supplementary studies, site investigations with surface and borehole studies are planned to be conducted on at list two additional sites.

I f the results are good, SKB intends to proceed on one of the sites with detailed characterization in tunnels to obtain the necessary supporting material for an application for a licence to build the deep repository.

To start with, the deep repository will only be put into operation for deposition of a small quantity of spent fuel. Approximately 5-10% of the fuel will be deposited in this initial phase, starting in 2008 at the earliest. After an evaluation and a renewed licensing round, the repository will be expanded to full scale.

All the costs for managing and disposing of Sweden's nuclear waste shall be paid by the owners of the nuclear power plants. This also applies to the costs of decommissioning the nuclear power plants and disposing of the decommissioning waste.

To ensure that adequate funds will be available in the future, a special charge is levied on nuclear power production. It is paid to the Nuclear Power Inspectorate, SKI, and is deposited in interest-bearing accounts in the Bank of Sweden.

### 3.4. Organizational Chart

The structure of the nuclear-electric sector in Sweden is shown in Figure 3.

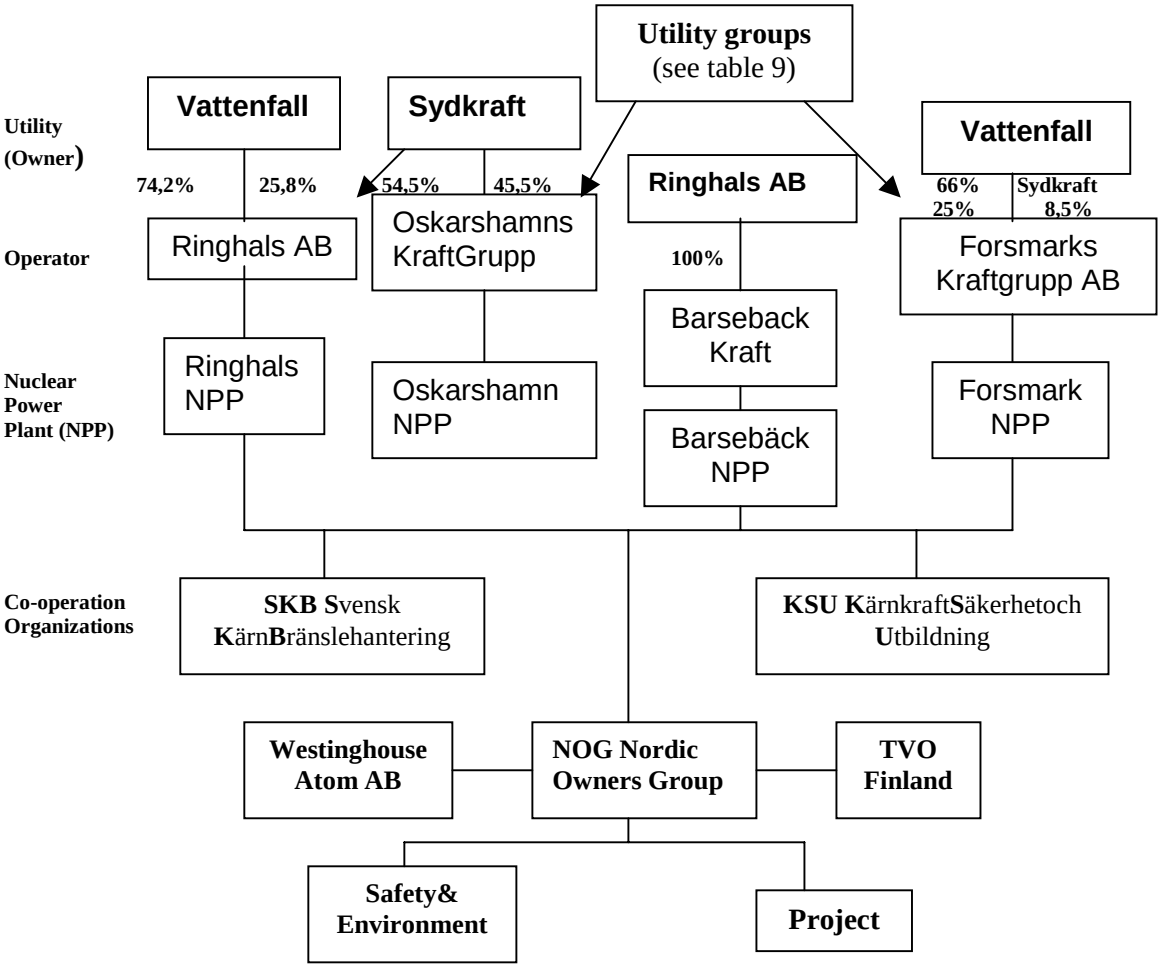


*FIG. 3. Structure of the nuclear-electric sector in Sweden*

Vattenfall AB is a limited company owned to 100% by the state. The Government can influence the operation of the company through the chairman of the board, who is elected by the government. Matters concerning Vattenfall AB are handled by the Ministry of Industry and Commerce.

Sydkraft and all other utilities Vattenfall excluded, are owned by municipalities, large industries, institutional investors or other types of shareholders. Sydkraft and some other utilities are registered on the Stockholm Exchange. Table 10 shows the ownership of the nuclear power plants.

TABLE 10. NPP OWNERSHIP

| Power plant | Owned by |
|---|---|
| Ringhals NPP | Ringhals AB (100%)[a] |
| Barsebäck NPP | Ringhals AB (100%) |
| Oskarshamn NPP | Sydkraft AB (54.5%), Birka Energi (35.5%) and Fortum/Finnish company (10%) |
| Forsmark NPP | Vattenfall AB (66%), Sydkraft AB (8.5%) and Mellansvensk Kraftgrupp AB[b] (25.5%) |

[a] Ringhals AB is (100%) owned by Vattenfalll AB
[b] Mellansvensk Kraftgrupp is owned by AB Skandinaviska Energiverk (19.9%), Fortum Kraft (2.3%), Skellefteå Kraft (1.9%) and Sydkraft AB (1.4%).

Svensk Kärnbränslehantering AB, SKB, (Swedish Nuclear Fuel and Waste Management Company) and Kärnkraftsäkerhet och Utbildning AB, KSU, (Nuclear Training and Safety Centre) are jointly owned by the utilities and/or the nuclear power operator companies.

The Nordic Owners Group (NOG) was established in January 2000. NOG is an informal organization between Swedish and Finnish nuclear power operators and Westinghouse Atom for principal and long-term safety issues.

Statens Kärnkraftinspektion, SKI (Swedish Nuclear Power Inspectorate) and Statens Strålskyddsinstitut, SSI (Swedish National Institute of Radiation Protection) are responsible for the implementation of the Act on Nuclear Activities and the Radiation Protection Act respectively. Both the authorities report to the Ministry for Environment. Thus there is no co-ordination of all nuclear activities at the ministry level. Only the government as a whole or Parliament takes the responsibility for such a co-ordination.

## 4. NUCLEAR POWER INDUSTRY

### 4.1. Supply of NPPs

ABB Atom (former ASEA Atom and currently Westinghouse Atom) has designed and delivered nine BWRs in Sweden and two in Finland. All the reactors were designed without any license from the US. ABB Atom used to have an indoor capability including architect engineering, but during the 1980s, the utilities in Scandinavia took the main responsibility for co-ordination of the nuclear power projects. VBB-VIAK (former VBB) has been responsible for the building design and building construction co-ordination on behalf of some of the utilities or ABB Atom.

The reactor fuel, the control rods and the control rod drives have been manufactured by ABB Atom. The control rooms and most of the electric components have been manufactured by sister organizations to ABB Atom within ABB (earlier ASEA). The turbines and all types of heat exchangers have been manufactured by ABB (former ASEA Stal in Sweden and Brown Boveri Company in Switzerland). Sandvik AB is a Swedish manufacturer of fuel canning tubes and steam generator tubes.

The latest reactor design of ABB Atom is BWR 90+, an advanced BWR plant design built on the operation experiences of Forsmark 3 and Oskarshamn 3. The net electric output is in the range of 1 350 MW.

Two Swedish building and civil engineering companies have been involved in the construction of the nuclear power plants in Sweden and Finland: NCC and SKANSKA. In 2000, ABB Atom became part of BNFL's Westinghouse Electric Company.

### 4.2. Operation of NPPs

The operators and some of the owners of Swedish nuclear power plants are shown in Figure 3. Some additional information about the power utilities is given in Table 9. It should be mentioned that all the operators are relatively independent of their mother organizations when it comes to technical capability.

Maintenance services are supplied by Westinghouse Atom AB (previously ABB Atom) Westinghouse Atom AB - Tekniska Röntgencentralen, Alstom Power (previously ABB Stal) and several other Swedish companies. Major maintenance service companies in Germany, France and UK are often engaged at the Swedish nuclear power plants.

Kärnkraftsäkerhet och Utbildning AB, KSU (Nuclear Training and Safety Centre) has seven full scale nuclear power plant simulators in operation and is responsible for the training of the nuclear power operators. KSU also provides nuclear power plant technicians with complementary education on a university level in nuclear power related topics. KSU participates in the work on nuclear safety performed within the Swedish utilities and co-ordinate these efforts. KSU also provides information regarding operating experience in the Swedish plants internationally. KSU is owned jointly by the Swedish utilities (Vattenfall 50%, OKG 25% and Barsebäck Kraft 25%) and will be reorganised during 2001 and some of the current simulators will be moved and rebuilt on their respective NPP site.

### 4.3. Fuel Cycle

Swedish utilities import all their need of uranium and enrichment services. Westinghouse (previously ABB Atom) manufactures reactor fuel both for BWRs and PWRs. Half of the deliveries are to utilities abroad. The Swedish utilities buy part of their fuel elements from abroad. The spent fuel from all the Swedish nuclear power plants is transported by boat to the central interim storage CLAB. The facility started operation in 1985 and is situated close to the Oskarshamn nuclear power plant.

Some low level waste is finally deposed of at local dumps and some of it is incinerated at Studsvik. All other waste from reactor operation is transported to SFR, the final repository for radioactive operational waste, in operation since 1988. SFR is located close to the Forsmark nuclear power plant. Most of the waste from decommissioning of the reactors will be disposed at SFR.

Svensk Kärnbränslehantering AB, SKB (Swedish Nuclear Fuel and Waste management Company) has built and owns the CLAB, SFR and the Äspö Hard Rock Laboratory. SKB is acting on behalf of the nuclear utilities in conducting the extensive research and development and demonstration work with regard to the remaining facilities for final disposal of long-lived spent nuclear fuel. SKB is also responsible for co-ordination and investigations regarding the costs for nuclear waste and future decommissioning. SFR and CLAB are operated by Forsmark Kraftgrupp and OKG respectively on behalf on SKB. SKB is jointly owned by the Swedish utilities (Vattenfall 36%, Forsmark Kraftgrupp 30%, OKG 22% and Barsebäck Kraft 12%).

### 4.4. Research and Development

AB Atomenergi started in the late 1950s the national nuclear power laboratory at Studsvik. Later it was transformed to a general energy laboratory but now most of the activities at the site are managed by Studsvik AB, still heavily involved in the nuclear area. One of the main tools is the materials test reactor R2 (50 MW) with extensive material laboratory facilities. Studsvik AB is today a commercial organization not owned by the state any more. Studsvik AB offers components, services and consulting. Today there is no central planning of the research and development activities in the nuclear field in Sweden.

Most of the reactor safety research and development is directed by the nuclear power operators and by SKI and SSI. It is performed at universities - also abroad -, Studsvik, at the Vattenfall central laboratory and at other research institutes.

SKB has been directing a large research programme for developing safe waste disposal methods. The research has been conducted in collaboration with universities, institutes of technology, research institutions in Sweden and abroad.

### 4.5. International Co-operation

Most of the Swedish contacts with IAEA and OECD/NEA are through official channels managed in the nuclear field by SKI and SSI.

KSU analyses and evaluates operating experience gained at other nuclear power worldwide which can benefit the operation of the Swedish plants. KSU have also been the main communication channel between the Swedish utilities and the nuclear safety organizations WANO and INPO.

SKB has a broad network of international contacts. Formal co-operation agreements exist with the following organizations:

| | |
|---|---|
| CEC/EURATOM | EU |
| TVO/IVO | Finland |
| CEA/ANDRA | France |
| JNFL | Japan |
| AECL | Canada |
| Nagra | Switzerland |
| USDOE | USA |

The following organizations have signed agreements of participation in the Aspö Hard Rock Laboratory project: Atomic Energy of Canada Limited (AECL); Power Reactor & Nuclear Fuel Development Corporation (PNC) of Japan; Central Research Institute of Electric Power Industry (CRIEPI) of Japan; ANDRA of France; TVO of Finland;, NIREX of UK; USDOE and Nagra of Switzerland.

## 5. REGULATORY FRAMEWORK

### 5.1. Safety Authorities and the Licensing Process

*Statens Kärnkraftinspektion, SKI (Swedish Nuclear Power Inspectorate)*

SKI is responsible for supervising the implementation of the Act on Nuclear Activities in Sweden. SKI reports to the Ministry of Environment and has the following overall tasks :

- Ensuring that Swedish nuclear installations have adequate defence-in-depth methods that prevent serious incidents or accidents originating from technology, organization or competence. In addition, the dispersion of nuclear substances must also be prevented or limited if an accident should occur.
- Adequately protecting nuclear installations and nuclear substances under Swedish jurisdiction against terrorist activities, sabotage or theft.
- Ensuring that the Swedish government, in co-operation with the competent international safeguards agencies, is provided with adequate information on and control over nuclear substances and nuclear technology, which are held, used and traded, and which come under Swedish jurisdiction. This must be done to ensure that such substances or technology will not be used in any way contrary to Swedish legislation and Sweden’s international obligations in the area of non-proliferation.
- Carrying out the final disposal of spent nuclear fuel and nuclear waste in such a way that any possible leakage of radioactive substances should, within various periods of time, be expected to

remain under tolerable levels. Future generations should not be exposed to greater health and environmental risks than are tolerated by society today.

- Ensuring that the nuclear industry carries out comprehensive and appropriate research and development programmes to achieve the safe handling and final disposal of spent nuclear fuel. Methods must also be developed for decommissioning and dismantling nuclear installations, and sufficient funds should be set aside for such future expenses.
- Keeping decision-makers and the general public well informed about nuclear risks and safety, and about supervision and the final storage of spent nuclear fuel and nuclear waste.
- Actively contributing to developing and strengthening efforts in the areas of international nuclear safety and non-proliferation, particularly within the framework of the European Union (EU). As a member of the EU, Sweden should actively work for increased and effective environmental measures in neighbouring countries, especially in the Baltic area and in central and Eastern Europe.

Also, SKI shall:

- Provide a clear definition of safety requirements.
- Control compliance with requirements by supervision focussing on processes influencing safety.
- Report and inform. SKI shall issue regular reports on the safety status of plants and the quality of licensee safety work, and, in general, implement active public information services with regard to events and circumstances within its area of regulatory responsibilities
- Initiate improvements in safety and non-proliferation whenever justified by operating experience, research and development.
- Maintain and develop competence. SKI shall promote maintenance and development of competence for safety at licensees, SKI, and nationally.
- Maintain emergency preparedness at SKI. SKI shall be prepared to advise emergency management authorities in order to limit detrimental health effects and social consequences in case of radioactive releases or situations where there is a threat of such releases.

**Licensees are responsible – SKI supervises.**

By law, anyone conducting nuclear activities has the full and undivided responsibility for taking the necessary steps to ensure safety, to meet non-proliferation requirements and to ensure that spent nuclear fuel and nuclear waste are managed and disposed of safely. SKI should monitor the way in which licensees meet these responsibilities by establishing a clear, independent picture of the safety situation at the facilities and of the quality of the licensees' safety work.

**Comprehensive international work.**

SKI has extensive bilateral and international co-operation, in particular through the IAEA (International Atomic Energy Agency), OECD/NEA (Nuclear Energy Agency), WENRA (Western European Nuclear Regulators Association), the EU Commission and ESARDA – European Safeguards Research and Development Association. SKI's allocation for 2001 was SEK 83 million for administrative expenses and approximately SEK 67 million for nuclear safety research expenses. Fees from the nuclear power industry finance SKI's operations. Allocated funds are channelled to SKI through the national budget according to normal routines. SKI has also an extensive assistance programme to the East through its project organization SIP (Swedish International Projects Nuclear Safety) and the Swedish Support Programme on Nuclear Non-proliferation in Central and Eastern Europe and Central Asia.

**An authority within the Ministry of Environment.** SKI is grouped under the Ministry of Environment. SKI's board is appointed by the government and consists of politicians and experts, and is chaired by the Director General of SKI. SKI has three advisory committees: the Reactor Safety Committee, the Safeguards Committee and the Research Committee. SKI has approximately 120 employees.

### 5.2. Main National Laws and Regulations

1. Nuclear Power Decommissioning Act (Jan. 1998)

2. Act on Nuclear Activities (1984, latest amendment by May 2000.
   Ministry: Environment
   Authority: SKI

3. Radiation Protection Act (1988)
   Ministry: Environment
   Authority: SSI

4. Act on Financing of Future Expenses for Spent Fuel (1981, latest amendment 1986).
   Ministries: Finance and Environment
   Authority: SKI

5. Nuclear Liability Act (1968, latest amendment 1995)
   Ministry: Justice
   Authority: The Private Insurance Supervisory Service.

The costs of managing and disposing of the spent nuclear fuel shall be paid by owners of the nuclear power plants. The costs are financed by today's electricity production and must not burden future generations. This also applies to the costs of decommissioning and disposing of the decommissioning waste. To ensure that adequate funds will be available in the future, a special charge is levied on nuclear power production. It is paid to SKI and is deposited in interest-bearing accounts in the Bank of Sweden. The charge is fixed annually by the Government and is based on a cost calculation submitted by SKB to SKI. All costs for the necessary systems and facilities are included, i.e., transportation system, CLAB, SFR, encapsulation plant and deep repository for spent fuel and other long-lived waste. The calculations also includes costs for research, development, demonstration and information about the waste issue.

### 5.3. International, Multilateral and Bilateral Agreements

*AGREEMENTS WITH THE IAEA*

| | | |
|---|---|---|
| • Amendments of Article VI & XIV.A of the IAEA statute | Ratified: | 13 July 2001 |
| • EURATOM/IAEA NPT related safeguards agreement INFCIRC/193 | Entry into force: | 1 June 1995 |
| • Improved procedures for designation of safeguards inspectors | Following EU policy. | |
| • Additional Protocol (GOV/1998/28) | Signature: | 22 September 1998 |
| • EURATOM | (Ref. EU ongoing negotiations) | |
| • Agreement on privileges and immunities | Entry into force: | 8 September 1961 |

*OTHER RELEVANT INTERNATIONAL TREATIES ETC.*

| | | |
|---|---|---|
| • NPT | Entry into force: | 9 January 1970 |
| • Convention on physical protection of nuclear material | Entry into force: | 8 February 1987 |
| • Convention on early notification of a nuclear accident | Entry into force: | 30 March 1987 |
| • Convention on assistance in the case of a nuclear accident or radiological emergency | Entry into force: | 25 July 1992 |
| • Conventions on civil liability for nuclear damage | Ratification of Paris Convention: | 27 January 1992 |
| • Joint protocol | Entry into force: | 27 April 1992 |
| • Protocol to amend the Vienna convention on civil liability for nuclear damage | Not signed | |
| • Convention on supplementary compensation for nuclear damage | Not signed | |
| • Convention on nuclear safety | Entry into force: | 24 October 1996 |
| • Joint convention on the safety of spent fuel management and on the safety of radioactive waste management | Entry into force: | 18 June 2001 |
| • ZANGGER Committee | Member | |
| • Nuclear Export Guidelines | Adopted | |
| • Acceptance of NUSS Codes | Summary: Codes well suited for national safety rules. Compatible with Swedish law and other rules. | 12 June 1990 |
| • Nuclear Suppliers Group | Member | |
| • EURATOM treaty | Member | |

*MULTILATERAL AGREEMENTS*

- Exchange of ministerial notes between Sweden, Denmark, Finland and Norway about guiding principles for contacts about nuclear safety concerning nuclear plants at the borders between Denmark, Finland, Norway and Sweden. (SÖ 1977:48)

*BILATERAL AGREEMENTS*

- Agreement between the government of Sweden and the government of Switzerland for co-operation in the Peaceful uses of Atomic Energy. (SÖ 1969:1)
- Treaty with Finland about co-operation in the field of the peaceful use of atomic energy. (SÖ 1970:8)
- Agreement with the Soviet Union (now with Russia) about co-operation in the field of the peaceful use of atomic energy. (SÖ 1970:9)
- Agreement with Canada concerning the uses of nuclear material, equipment, plants and information transferred between Sweden and Canada. (SÖ 1981:89-90)
- Agreement with Australia on conditions and control for nuclear transfers for peaceful purposes between Australia and Sweden. (SÖ 1982:86-87)
- Exchange of notes with Finland in the field of nuclear power (SÖ 1983:1)
- Agreement with the United States of America about the peaceful use of nuclear power. (SÖ 1984:66)
- Treaty with Denmark about exchange of information about the Barsebäck Nuclear Power Plant. (SÖ 1986:15)
- Treaty with Denmark about exchange of information and notice about Swedish and Danish nuclear facilities etc. (SÖ 1987:12)
- Treaty with Finland about exchange of information and notice about Swedish and Finnish nuclear facilities etc. (SÖ 1987:16)
- Treaty with Norway about exchange of information and notice about Swedish and Norwegian nuclear facilities etc. (SÖ 1987:26)
- Treaty with the Soviet Union (now with Russia) about notice in the case of a nuclear power accident and about exchange of information about nuclear facilities. (SÖ 1988:5)
- Treaty with Germany about notice in the case of a nuclear power accident and about exchange of information about nuclear power facilities.

## REFERENCES


[1] Energy in Sweden, www.stem.se

[2] Energy in Sweden Fact and figures, www.stem.se.

[3] Electric Power in Sweden 1999, : www.kvf.se.

[4] Data & Statistics/The World Bank, www.worldbank.org/data.

[5] IAEA Energy and Economic Database (EEDB).

[6] IAEA Power Reactor Information System (PRIS).

## Appendix

## DIRECTORY OF MAIN ORGANIZATIONS, INSTITUTIONS AND COMPANIES INVOLVED IN NUCLEAR POWER RELATED ACTIVITIES

*NATIONAL ATOMIC ENERGY AUTHORITY*

Ministry of the Environment
S-103-33 Stockholm
Sweden
Tel: +46 8 405 10 00
Fax: +46 8 24 16 29
Telex: 15499 MINENS

Swedish Nuclear Power Inspectorate
Statens Kärnkraftinspektion (SKI)
S-106 58 Stockholm
Sweden
Tel: +46 8 698 84 00
Fax: +46 8 661 90 86
Telex: 11961 SWEDATOM S
http:www.ski.se/

Swedish Radiation Protection Institute
Statens Strålskyddsinstitut (SSI)
S-171 16 Stockholm
Sweden
Tel: +46 8 729 71 00
Fax: +46 8 729 71 08
Telex: 11771 SAFERAD S
http://www.ssi.se/

Board of the Swedish Nuclear Waste Fund
C/o Kammarkollegiet, Box 2218
S-103 15 Stockholm, Sweden
Tel: +46 8 700 08 00
Fax: +46 8 20 38 81

*OTHER NUCLEAR ORGANIZATIONS*

Swedish National Council for Nuclear Waste
(KASAM)
c/o Ministry of the Environment
SE-103 33 Stockholm, Sweden
Tel: +46-8 405 17 92
Fax: +46- 8 20 10 66

*MAIN POWER UTILITIES*

Vattenfall AB
S-162 87 Stockholm
Sweden
Tel: +46 8 739 50 00
Fax: +46 8 37 01 70
www.vattenfall.se/ or www.vattenfall.com

Sydkraft AB
S-205 09 MALMÖ,
Sweden
Tel: +46 40 25 50 00
Fax: +46 40 97 60 69
http://www.sydkraft.se/

Birka Energi AB
S-115 77 Stockholm
Sweden
Tel: +46 8 671 70 00
Fax: +46 8 671 70 60
http://www.BirkaEnergi.se

*NUCLEAR POWER PRODUCTION COMPANIES AND SUBSIDIARIES*

Ringhals AB
S-430 22 Väröbacka,
Sweden
(operator of Ringhals NPP and owner
of both Ringhals NPP and Barsebäck NPP)
Tel: +46 340 66 70 00
Fax: +46 340 66 51 84
www.ringhals.se

Barsebäck Kraft AB
Box 524
S-246 25 Löddeköpinge, Sweden
(operator of Barsebäck NPP)

Tel: +46 46 72 40 00
Fax: +46 46 77 57 93
www1.sydkraft.se/bkab

OKG AB
S-573 83 Oskarshamn
Sweden
(operator of Oskarshamn NPP)

Tel: +46 491 860 00
Fax: +46 491 869 20
http://www.okg.se/

Forsmark Kraftgrupp AB
S-742 03 Östhammar
Sweden
(operator of Forsmark NPP)

Tel: +46 173 810 00
Fax: +46 173 551 16
http://www.forsmark.se/
www.forsmark.com (valid from Dec. 01)

Svensk Kärnbränslehantering AB (SKB)
Box 5864
S-102 40 Stockholm, Sweden

Tel: +46 8 665 28 00
Fax: +46 8 661 57 19
http://www.skb.se/

Kärnkraftsäkerhet och Utbildning AB (KSU)
Box 1039
S-611 29 Nyköping, Sweden

Tel: + 46 155 26 35 00
Fax: +46 155 26 30 74
http://www.ksu.se/

*SUPPLIERS OF NPPS, COMPONENTS AND SERVICES*

Westinghouse Atom AB
S-721 63 Västerås,
Sweden

Tel: +46 34 70 00
Fax: +46 21 18 71

Tekniska Roentgencentralen AB
Box 121
SE-183 22 Täby, Sweden

Tel: +46 8 630 81 00
Fax: +46 8 630 82 01

Alstom Power Sweden AB
S-612 72 Finspång
Sweden

Tel: +46 122 810 00
Fax: +46 122 197 000

Sandvik AB
S- 811 81 Sandviken
Sweden

Tel: +46 26 26 00 00
Fax: +46 26 26 13 50

Studsvik AB
S-611 82 Nyköping
Sweden

Tel: +46 155 22 10 00
Fax: +46 155 26 30 00
http://www.studsvik.se/eng/eng-index.asp

SQC Kvalificeringscentrum AB
Box 519
SE-183 25 Täby, Sweden

Tel: +46-8 638 71 10
Fax: +46-8 638 71 20

Det Norske Veritas
Nuclear Technology AB
Box 49306
SE-100 29 Stockholm, Sweden

Tel: +46-8 587 940 00
Fax: +46-8 651 70 43

| | |
|---|---|
| ES-konsult<br>Gustavslundsvägen 151 G<br>SE-167 51 Bromma, Sweden | Tel: +46 8 634 22 40<br>Fax: +46 8 634 22 55<br>www.eskonsult.se/others/company.htm |

*UNIVERSITIES*

| | |
|---|---|
| Chalmers University of Technology<br>GÖTEBORG | http://www.chalmers.se/ |
| Dalarna University College<br>FALUN | http://www.du.se/ |
| Göteborg University | http://www.gu.se/ |
| Karlstad University | http://www.kau.se/ |
| Linköping University | http://www.liu.se/ |
| Luleå University of Technology | http://www.luth.se/ |
| Lund University | http://www.lu.se/ |
| Örebro University | http://www.oru.se/ |
| Royal Institute of Technology<br>STOCKHOLM | http://www.kth.se/ |
| Stockholm University | http://www.su.se/ |
| Umeå University | http://www.umu.se/umu/ |
| Uppsala University | http://www.uu.se/ |
| Växjö University | http://www.vxu.se/ |

*INTERNATIONAL ORGANIZATIONS*

| | |
|---|---|
| International Commission on Radiological Protection (ICRP) | http://www.icrp.org/ |
| Stockholm International Peace Research Institute (SIPRI) | http://www.sipri.se/ |

*OTHER ORGANISATIONS*

| | |
|---|---|
| Natural Science Research Council (NFR) | http://www.nfr.se/ |