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# Chapter 1

## Factual information

### 1.1 Geographical description

Sweden enjoys a mostly temperate climate despite its northern latitude, mainly due to the Gulf Stream. In the south of Sweden leaf-bearing trees are prolific, in the north pines and hardy birches dominate the landscape. In the mountains of northern Sweden a sub-arctic climate predominates. In the part of the country north of the Arctic Circle the sun never sets during the summer, and in the winter night is unending.

East of Sweden is the Baltic Sea and the Gulf of Bothnia, providing a long coastline, and yet further mellowing the climate. To the west are the Scandinavian mountain chain, a range that separates Sweden from Norway.

The southern part of the country is chiefly agricultural, with forests covering an increasing percentage of the land the further north one goes. Population density is also higher in southern Sweden, with centers being in the valley of lake Mälaren and the Öresund region. The inland of the northern part is quite mountainous with the highest peak being Kebnekaise at a height of 2111 meters.

The total land area of Sweden is 410,934 km<sup>2</sup>, making it Europe's fifth largest nation as measured by area. Stretching about 1'700 km in the north-south direction, but a more modest 450 km in the east-west direction. The major natural resources are timber and ore. The northern part is home to the largest rivers in Sweden, providing a major resource for hydro-power.

### 1.2 Demographics

As of approximately August 12, 2004, the population of Sweden for the first time exceeded 9,000,000, according to Statistics Sweden. The main part of the population, around 7 Million, lives in urban areas around the major cities. The population is divided on 4.1 Million households, and the main population areas are in the southern part around Stockholm, and south thereof. The population is expected to rise slightly to about 9.3 Million in 2030. The number of people per household has decreased from 2.6 in 1970 to about 2.1 in 1990, the trend is towards further decrease. As in the rest of the western world Sweden is facing an aging population.

Sweden has an extensive childcare system that guarantees a place for all young children from 1-5 years old in a public day-care facility. From ages 6-16, children attend compulsory comprehensive school. After completing the ninth grade, 90% attend upper secondary school for either academic or technical education. The number of students attending University has risen dramatically during the 1990's. In 2000 the number of full time students attending University was well above 240'000.

Swedes benefit from an extensive social welfare system, which provides for childcare and maternity and paternity leave, a ceiling on health care costs, old-age pensions, and sick leave among other benefits. Parents are entitled to a total of 480 days paid leave between birth and the child's eighth birthday, with 30 days reserved specifically for each parent. A ceiling on health care costs makes it easier for Swedish workers to take time off for medical reasons.

### 1.3 Economical Situation

The Gross Domestic Product was 27'900 Euro/person in the year 2000, compared to 22'500 Euro/person in the EU-15. In year 2000 70% of the GDP was generated within the service sector, whereas industry stood for 28% and the agricultural sector for 2%. The service sector employs 79% of the work active population, industry 19% and the agricultural sector 2%. Approximately 40% of the work active population is employed in the public service sector. Main exports include products from the manufacturing industry, paper, pulp and raw materials. Household expenditure show a rising trend and follows the growth of the Gross Domestic Product.

### 1.4 Energy

Energy usage is heavily linked with economical growth. In the coming years the Gross Domestic Product is expected to rise with 3.0% in 2005 and 2.7% in 2006, thus, one can expect an increased energy consumption simultaneously. As in many OECD countries oil stand for the major part of the supplied energy in Sweden, see table 1.1. Being without a domestic source for oil, Sweden has to rely on imports. Further, the fuel for the eleven nuclear reactors in operation also comes from the outside. The main sources of energy available from within are large amounts of hydro power and biomass.

Energy Balance	Energy (TWh)	
Total supplied	<b>624</b>	
Losses and unusable	<b>218</b>	
Used energy	<b>406</b>	
-Electric	130	
-District heating	50	
-Oil	142	
-Gas	6	
-Coal	17	
-Biofuels	61	
Usage by sector	Energy (TWh)	Prognosed change (2005)
Industry	<b>154</b>	+1.9%
-Paper and pulp	72	
-Steel	23	
-Chemical	12	
Housing and Services	<b>157</b>	±0%
Domestic transport	<b>95</b>	+7%

Table 1.1: Energy balance for 2003, taken from [1]

The consumption for the largest consumer, the housing and services sector, is strongly weather dependent, and about two thirds are used for heating and hot water supply. For example, in 2003 the temperature was 4% higher than average, which had the effect that the total energy consumption was somewhat lower than usual. At present the increase in the number of households and the fact that many new homes are being built is expected to further increase the total energy demand.

### 1.5 Electricity

A total of 145.1 TWh was used domestically, or 16'207 kWh per person. Historically, the main part of the electric energy used in Sweden comes from hydro-power, which saw it's largest expansion in the 1960's. Nowadays, roughly half of the production comes from hydro-power, and the other

half from eleven nuclear reactors, see table 1.2. Only about 10% comes from other thermal sources mainly.

There are three main actors, producing more than 90% of the used electricity. They are in order of installed power:

- Vattenfall AB, a company fully owned by the Swedish government.
- Sydkraft, a subsidiary of EON, a large German company.
- Fortum, a company with interests in Sweden and Finland mainly.

The demand varies during a year, peak load typically occur cold winter mornings in January or February. In 2003 the load peaked at 26'400 MWh/h on January 31. The minimum load usually occurs during the holiday period in July, for 2003 the minimum load was 13'189 MWh/h. Peak load coincides badly with the spring flood in the rivers, meaning that storing large amounts of water in dams is very important.

The data for 2003 reflect the fact that it was a dry year and the production from hydro-power was lower than usual.

Generation form	Installed capacity (MW)	Part of supplied electricity
Hydro-power	<b>16'143</b>	39.9%
Nuclear	<b>9'441</b>	49.5%
Other thermal power	<b>7'378</b>	10.1%
-condensing	2'108	(included above)
-CHP district	2'572	(included above)
-CHP industry	979	(included above)
-gas turbines etc	1'719	(included above)
Wind	<b>399</b>	0.5%
<b>Total</b>	<b>33'361</b>	<b>100%</b>

Table 1.2: Installed capacity, and production for 2003, taken from [3]

Source	Electric energy (TWh)
Nuclear	65.5
Hydro	52.8
CHP	7.6
Industrial back-pressure	5.2
Cold condensing	0.6
Wind	0.6
<b>Total (Domestic supply)</b>	<b>132.3</b>
<b>Import</b>	<b>12.8</b>
Sector usage of the electric energy	
Housing and Services	72%
Industry	55%
Domestic transport	3%

Table 1.3: Produced electric energy for 2003, taken from [1]

In 2003 the usage of electricity was higher than the production and, as a result there was a net import, coming mainly from Denmark and Finland. The reason for the high import figures for 2003 is the fact that the production from both hydro and nuclear-power was lower than normal. The estimates for 2005 is a net import of 3.7 TWh, and for 2006 2.4 TWh, if the precipitation and

the availability of the nuclear reactors assume normal levels. The Nordic market (Sweden, Norway, Finland and Denmark) is deregulated and synchronized, and therefore has a large capacity of transfer between the individual countries. The Nordic net also has large transfer capabilities (via DC connections) to Germany (2550 MW), Russia (1610 MW), and Poland (600 MW). Sweden's neighbour to the west, Norway, supplies more than 95% of its electricity demand with hydropower, and its generating capability is therefore heavily depending on the weather, and strong connections with neighbouring countries, mainly Sweden. Therefore, there are links of totally 4885 MW (Norway to Sweden, and 4155 MW Sweden to Norway) connecting the two countries.

Sweden has some energy intensive industry, such as smelters and the paper and pulp industry. The electric energy consumption in the paper and pulp industry stood for 40% of the electricity used in the industrial sector in 2003.

## 1.6 Environmental issues

All energy production carries environmental costs, in terms of emissions and/or large area demands. Let us mention some of the specific costs for Swedish conditions.

Environmental issues regarding nuclear power.

The storage of spent nuclear fuel is a crucial issue in Sweden, like in all countries utilizing nuclear energy. As of now (spring 2005) no decision has been taken on where to store the spent fuel. Studies are being made on the final storage of the spent fuel and other radioactive waste materials.

Environmental issues regarding hydro-power.

There are 13 larger rivers in Sweden, of these, three are kept unregulated in order to maintain natural river ecosystems, and preserve cultural values. In all of the major rivers annual migration of fish occur, in order to reproduce, from the sea and upstream. Hydro-power stations hinder this migration, even if special constructions have been made to allow the fish to migrate, these seldom function satisfactory. Also, the construction of dams may considerably deteriorate natural ecosystems with considerable loss of biodiversity and/or biomass. Environmental concerns have nowadays effectively stopped all plans for new hydro projects, except refurbishment and upgrading of existing plants. Some attempts to allow for mini and micro hydro stations are also being criticized, mainly from locals.

There is a decision in Sweden to phase out nuclear power production, see 3.2, when it is possible to do so to still meet the demand and considering the need to keep jobs and the welfare intact. When the nuclear energy is phased out, we might face new environmental issues coming from the production replacing the nuclear.

The environmental impacts from other sources are minor in absolute number since they only contribute a small portion of the power produced. There are growing concerns about the impact coming from windpower, both regarding the acceptance, and issues for wildlife. One thing worth mentioning is the relatively high need of transporting material for biofuels, something which contribute to the release of particles and green house gases in the atmosphere. An increase in the use of biofuels may also inflict a cost for biodiversity and may result in monocultures if grown in large scale.

# Chapter 2

## Trends

### 2.1 Past

In the past, 1970's and before, the hydropower installations were used to supply the basic need of electricity, there were also some thermal installations. When nuclear energy was introduced, in the 70's and 80's, the situation changed. Now, the nuclear energy is used to supply the basic need and hydropower, which also produce large amounts of power, is used to balance the need and supply.

In the 1960's there was a large amount of new hydro-power installations being built, something which caused protests. Then, it was decided to leave three large rivers unregulated to protect environmental interests. This decision meant that a potential 12 TWh was left untapped [7].

### 2.2 Present

As in many countries the total need of energy is constantly increasing. From the user side there is a strong trend to move away from oil-dependency for heating to use either central district heating or indirectly using electric power, in e.g. heat pumps. This means that the consumption of oil is decreasing, but the consumption of electric power is increasing, at the same time the government's policy is to reduce the use of electric energy. At the same time, household appliances on stand-by can consume a substantial amount of power, and, since the number of household appliances is increasing, there is a further increase in the demand for electrical energy.

A recent report mentions that about 11 TWh extra hydro-power could be generated if existing regulated rivers were used more efficiently and existing stations upgraded with new technology. Out of these 11 TWh about 5 TWh is economically feasible with the price of electricity today [7].

There is a strong trend in Sweden toward centralized district heating, that can, in principle, also produce electricity. The fuels for these stations are mainly biomass and waste material. An interesting situation now occur, the electric market is deregulated, but the district heating market is not. The government is encouraging the use of central district heating while discouraging the use of heating with electric energy, thus driving customers from a deregulated to a market with monopoly.

Today, no new hydro-power stations are commissioned, but a lot of refurbishment and upgrading are taking place. In 2003 a total increase of 73 MW installed power originated from mainly refurbished existing stations. The same is true for the remaining nuclear reactors. At present, the nuclear plants are being upgraded resulting in an increase in power which almost cover the power lost in the shutdown of Barsebäck 1 and 2. In 2003 the upgrade of the nuclear reactors added an extra 23 MW generating power.

## 2.3 Future

In the future demand is expected to further increase. How this increased demand is met depends heavily on political decisions and subsidies. The Swedish government has a pronounced policy to increase the contribution from renewable resources. The goal is often expressed as an additional 10 TWh from renewable resources in 2010, or 2015. The term "renewable" sometimes apply mainly to wind-power, and sometimes to other resources as well. The intent is that this increase will be driven by trading with green electricity certificates, discussed in chapter 4. There are untapped resources in hydro-power which could be used, but due to environmental concerns, they are likely to be left unused. Further, there is a potential in wind-power in Sweden, but the industry is not likely to support expansion of wind-power too much since it cannot be regulated. As for solar, the potential is very small in Sweden, especially in the winter when the demand peaks. Sweden has, at this stage, no geothermal power producing plants.

# Chapter 3

## Policy

### 3.1 Present

The largest company operating on the electricity market, Vattenfall AB, is fully owned by the Swedish government. The government is now using this ownership to more actively control future investments. Their estimate that Vattenfall AB can stand for 5 TWh out of the 10 TWh increase in renewables e.g. by supporting large scale, sea based, windpower [8].

### 3.2 Future

In 1980 there was a referendum in Sweden concerning the future of nuclear power. Then, it was decided to terminate the use of nuclear power as an energy source, but no definite time limit was given. The last two reactors, Oskarshamn 3 and Forsmark 3, were commissioned in 1985, five years after the referendum. The policy was that the first reactor be shut down before 1 July 1998, and the second before 1 July 2001. However, closure of the second reactor was conditional upon the replacement of the lost generating capability from renewable sources and reduced usage. Then, in 1999, the first reactor Barsebäck 1 was shut down. A short term energy program introduced in 1998, running until 2002, resulted in 2 TWh of new production and decreased use. The estimate from the energy efficiency program was approximately 0.48 TWh [5]. This year the government is introducing a two year program to stimulate effictivisation of energy use, and conversion to renewables, by spending 2 billion SEK. 100 MSEK is to be used to sponsor installation of solar cells, an investment that is estimated to double the installed power [8]. There is no support towards investments in large scale hydropower installments, but small scale developments can get support. Now, in 2005, discussions on closing the next reactor are held. The debate is mainly on how to replace the power lost from the shutdown of more reactors. To further strengthen the Nordic net and guarantee a supply of electric energy a new transmission cable to Finland is being discussed. Finland is at present building a new nuclear reactor to meet the increased demand domestically there as well as giving a substantial export capability.

### 3.3 Critical Review

## Chapter 4

# Peculiarities

The Nordic market was deregulated in 1996. Since then, the cost of electricity for consumers have risen, see table 4.1. However, it is hard to say if that is a direct consequence of the deregulated market, or if it depends on other factors.

Year	System prize (SEK/kWh)
1996	26,3
1997	14,6
1998	12,3
1999	11,8
2000	10,8
2001	21,4
2002	24,6
2003	33,5
2004	26,4

Table 4.1: Development of the spot prize in the Nordic electricity market (Nordel) before taxes, one Euro is roughly 9 SEK.

To reduce greenhouse gas emissions and stimulate locally renewable electric energy to be produced, green electricity certificates were introduced 1 May 2003. Producers have to have their capacity certified to sell green electricity certificates to consumers, and get a certificate for every produced MWh. The aim of introducing GEC was to stimulate production from renewable resources such as wind, biofuelled CHP solar and hydro. Today 74% of all GEC originate from biofuelled power stations, wind-power stands for 8% and hydro for 18%. For hydro-power the requirements are

- small scale, less than 1500 kW
- in continued operation since 1 July 2001
- or a totally new station
- for large scale hydropower stations (more than 1500 kW), only refurbishment leading to an increase in the rating gives the right to get green electricity certificates, and then, only the increase in produced electric energy actually gives green electricity certificates

Every consumer is then obliged to buy a portion of their consumption from power produced in stations who have green electricity certificates. At present, consumers are obliged to buy 7.4% green electricity certificates, this number is to increase continuously to 16.9% in 2010. The concept of green electricity certificates is to be made permanent [8].

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