SWEDEN

The country report for Sweden was prepared by CRES. Data on CHP units were provided by Sveriges Lantbrukeuniversitet.

Current situation on CHP and biomass CHP in the national energy sector.

Sweden is the fourth largest country in Europe. Nearly 90% of the land area is under forest or other woodland, bogs, fens and lakes. Some 8% is farms and 3% built-up areas. Most of the population lives in the southern half of Sweden, and about 90% in urban areas. Sweden has an urban industrialised economy in which traditional industries, based on domestic resources of iron ore and wood, still play an important part, coupled with low-cost electricity. Exports, principally industrial products, account for over 30% of GDP.

Energy balances in Sweden (Source: Energy Policies of IEA Countries, 2001)

	1999	%
Population (millions)	**8.86**	
Energy consumption/capita	**4.0**	
Total energy production (Mtoe)	**34.5**	
Coal	-	-
Peat	0.3	0.9
Oil	-	-
Gas	-	-
Biomass & Wastes	8.6	24.9
Nuclear	19.1	55.4
Hydro	6.2	18.0
Solar/Wind/Other	0.4	1.2
Net energy imports (Mtoe)	**15.6**	
Coal	2.2	14.1
Oil	13.3	85.3
Gas	0.7	4.5
Electricity	-0.7	-4.5
Total supply - TPES (Mtoe)	**51.1**	
Coal	2.3	4.5
Peat	0.3	0.6
Oil	14.3	28.0
Gas	0.7	1.4
Biomass & Wastes	8.6	16.8
Nuclear	19.1	37.4
Hydro	6.2	12.1
Solar/Wind/Other	0.4	0.8
Electricity Trade	-0.7	-1.4
Electricity generation	**13.3**	
Electricity generation	155.2	

	1999	%
Total final consumption	**35.4**	
Coal	0.6	1.7
Peat	0.0	0.0
Oil	14.5	41.0
Gas	0.5	1.4
Biomass & Wastes	5.3	15.0
Solar/Wind/Other	0.0	0.0
Electricity	10.8	30.5
Heat	3.8	10.7
Total industry consumption	**13.9**	
Coal	0.6	4.3
Peat	0.0	0.0
Oil	3.7	26.6
Gas	0.3	2.2
Biomass & Wastes	4.4	31.7
Solar/Wind/Other	-	-
Electricity	4.6	33.1
Heat	0.3	2.2
Transport consumption	**8.2**	
Total other sectors consumption	**13.4**	
Coal	0.0	0.0
Peat	-	-
Oil	2.9	21.6
Gas	0.2	1.5
Biomass & Wastes	1.0	7.5
Solar/Wind/Other	0.0	0.0
Electricity	5.9	44.0
Heat	3.5	-

(TWh)

After a recession in the period 1989 to 1993, and following extensive adjustment of economic and social policies, economic growth resumed in 1994 and the economy grew strongly during 1997-1999 at about 3% each year.

About two-thirds of Sweden's energy supply is accounted for by oil and nuclear. Sweden imports about 35% of its energy supply, mostly oil.

Final energy consumption has been relatively stable between 1985 and 1997. Industrial demand for energy in Sweden has risen by about 7% since 1990, but has fallen by nearly 9% since 1973. Transport demand for energy has risen by just over 7% since 1990, and by 45% since 1973.

Final energy consumption of electricity has increased on average at about 3% per year since 1973. The greatest increase is to be found in the residential and service sectors because of a change from oil to electricity for heating, coupled with a greater use of electricity for building services systems. District heating accounts for about 11% of total final energy consumption.

Total energy use in the residential/commercial/service sector has remained relatively stable since 1970 on a temperature-corrected basis, but the composition of energy use has changed over the period. Electricity and, to a lesser extent, district heating, have grown, replacing the use of oil products. The use of biofuels and peat has remained stable over the period. Total use of fossil fuels has fallen by nearly 70% in the period 1970 to 1998.

In 1999, the industry sector accounted for 39% of Sweden's total final energy use. Nearly 80% of the biomass, peat and wastes (about 32% of total industry sector energy) are used in the pulp industry, mainly in the form of black liquors and manufacturing wastes. Natural gas accounted for only 2.2%.

In 1998, final energy use in the industry sector was composed of 27% fossil energy. A relatively small number of industries account for the bulk of energy use. The pulp and paper industry uses about 45%, the iron and steel industry about 14%, and the chemical industry about 7%. These three industries account for two-thirds of total energy use in industry. The mechanical engineering industry, although not regarded as energy-intensive, accounts for almost 8% of energy use in industry because of its high proportion of total industrial output in Sweden.

Sweden is an electricity-intensive country. Per capita use of electricity in 1997, at nearly 16 MWh, was the fourth highest in the OECD (after Norway, Iceland and Canada) and nearly double that of other industrialised European countries such as France, Germany and the UK. Electricity demand growth has been modest since the mid-1980s. Annual growth from 1990 to 1998 averaged around 1%.

Electricity generated in Sweden is produced mainly from hydro and nuclear power plants (93% of total production in 1998) with a roughly similar contribution from each source in a typical year. The remainder is produced by CHP plants (6% of total production in 1998) and, to a lesser degree, from oil condensing power, gas turbines and wind power. Industrial CHP production is based mainly on biofuels while electricity produced in DH plants is 40% coal-fired. Around 1.3 TWh were produced from biofuels in 1998. The ranking of production capacity according to variable cost yields a similar order: hydropower is the cheapest option, followed by nuclear, CHP in industry, CHP associated with district heating, coal, oil and gas turbines.

Just over 15% of Sweden's total primary energy supply is classified as combustible renewables. During 1997, the use of biofuels and peat amounted to about 8 Mtoe, of which about 5 Mtoe are used internally in the forest industry for heat and some electricity production. Single-family houses use a stable 1 Mtoe of renewable energy, mainly logs from their own forestlands. In the district heating sector, the use of biofuels and peat has almost doubled to about 2.2 Mtoe over the five years to 1997. Biofuels now meet more than 50% of the supply for DH grids. Reducing the costs of using biofuels was established explicitly as an important objective in the 1997 energy policy legislation.

RTD and Demonstration projects on biomass CHP

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

- ❖ Thermal processes for electricity production: total funding of SKr 60 million for a four-year period, financed by the National Energy Administration.
- ❖ Fluid bed combustion and gasification: total funding of SKr 37.8 million over a period of three years. The programme is largely financed by the Swedish National Energy Administration.

Two different concepts of biomass-based CC technologies have reached the demonstration phase. Sydkraft AB has carried out a technically successful demonstration of the pressurised concept developed by Foster-Wheeler in a CHP plant in Värnamo. Parts of this programme are co-financed by the National Energy Administration and the French utility EDF. An atmospheric gasification concept has been developed by the Swedish engineering company Termiska Processer AB in cooperation with universities. The work has been partly financed by the National Energy Administration. The atmospheric gasification concept is being demonstrated in the UK. Biomass gasification technologies are, however, not currently competitive on the liberalised electricity market in Sweden.

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

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

Legislation and support mechanisms

Taxes on fossil fuels promote the use of biofuels for heat production. There are three different levies on energy products: energy tax, carbon dioxide tax and sulphur tax. The energy tax is levied on fossil fuels and electricity and has been collected for several years. The carbon dioxide and sulphur taxes were introduced in 1991. Biofuels in CHP are promoted by investment aid. Investment subsidies for district heating grids indirectly reinforce the promotion of biofuels.

Existing biomass CHP plants

Industrial CHP production is based mainly on biofuels while electricity produced in district heating plants is 40% coal-fired. Around 1.3 TWh were produced from biofuels in 1998.

- **Vaxjo**

The Municipality of Vaxjo is located right in the middle of Southern Sweden. Already in 1980, the municipally owned utility, Vaxjo Energi A/B (VEAB) converted the power plant “Sandvik” from pure oil burning to combined oil and biomass burning. Today the Sandvik power plant is producing all the heat consumed by the city of Vaxjo and approximately 35% of the needed electricity. More than 95% of the fuel is biomass, like wood chips, bark and

peat. Total available power output is 37 MW and the total available heat output is 63 MW. The Sandvik plant produces around 160 GWh of electricity and 350 GWh of heat yearly.

- **Uppsala**

The Kraftvärmeverket i Uppsala is a CHP plant located in Uppsala operating since 1985. It uses mixed peat and sawdust briquettes in a CFB boiler and operates 4000-5000 h/a. The annual production is 350 GWh of grid electricity and 850 GWh of district heat. The capacity of the furnace is 65 MW_{fuel}.

- **Sala**

The Kraftvärmeverket i Sala was constructed in 2000. It is located in the town of Sala and uses wood pellets, woodchips and sawdust as fuel in a CFB boiler. The production of district heat is 22 GWh and the grid electricity annually is about 10 GWh. The capacity of the furnace is 32 MW_{fuel}.

- **Linköping**

The Tekniska Verken Ltd is located in the Linköping and is owned by its municipality. Bark, woodchips (forest residues) and sawdust are used in a stoker furnace. The district heat production is 540 GWh/y, and the grid electricity produced 216 GWh/y. The furnace capacity is 65 MW_{fuel}.

- **Enkoping**

The ENA Kraft AB, constructed in 1994, is owned by AB Enköpings, Värmeverk Mälarenergi AB and is located in Enkoping. The technology used is a grate furnace, fuelled with woodchips (forest residues), bark and sawdust, coupled with a steam turbine. The annual production of grid electricity is 70 GWh and the production of district heat is 200 GWh per year.

- **Stora Fors Enso**

The Ronny Sjöberg CHP plant, constructed in 1985, is an integrated part of the board mill supplying its process steam and electricity. The technology used is a fluidized bed boiler, with 55 MW_{th} capacity, coupled with a steam turbine. The CFB boiler was designed for burning coal but during the years the amount of biofuel has increased and is now 100%. The fuel consists of woodchips, bark and pellets. The annual production of grid electricity is 393 GWh.

- **Norrköping**

In 1994 Tampella Power has commissioned a circulating fluidized bed boiler for Norrköping Energi AB's Handeloverket CHP plant near Norrköping in southern Sweden. The boiler is one of the station's three boilers and can be fired for 100% on wood chips. The original plant is from 1982. The CFB boiler has a thermal capacity of 125 MW. The original plan was to burn 40% wood chips and 60% bituminous coal and to increase the percentage of wood later on. Right from the test runs, however, 90% of the fuel used has been wood chips.
The three different boilers have the same steam data. The steam flow is obtained when two of the three boilers are in operation. The gross electric production becomes 80.1 MW_e. With three boilers in operation the electricity production can be raise to 90 MW_e, steam can be supplied to an older 10 MW_e turbine and additional steam is available in the case that the heat demand in the DH system gets higher. The own consumption of the plant is 4.8 MW_e and the net electrical output of the plant in the actual situation with heat output for DH is 75.3 MW. Only the 50% of this amount 37.6 MW_e can be allocated to the CFB boiler.

- **Dava**

The Dava CHP plant is one of the world's most energy-efficient plants using MSW and forestry residues as fuel. Its total output is 65MW, of which 10 MW is supplied as electricity to the local grid. A combination of innovative solutions makes the plant so efficient that it extracts almost all of the energy value of the fuel. For the first time in a plant of this kind, compressor heat pumps are being used to recycle the heat contained in the flue gases. Excess heat from electricity production is also recovered.

- **Eksjo**

  The Eksjo plant, a conventional biomass and waste heating plant, has hot water boiler designed for 16 bar pressure as many of the Swedish heating plants and sawmills. By converting some of the hot water into steam without rebuilding of the boiler, electricity

generation has been made available with limited investment costs. **The Eksjo plant has a** power generation capacity of 920 kW and produces 5.5 GWh/year of electricity, mainly for its own purposes.

- **Eskilstuna CHP Plant**
  The project is a small plant at Eskilstuna in Sweden, which uses biomass fuels, such as wood. It has a capacity of 38 MW_e and 71 MW_{th}. A further 15 MW of heat will come from the flue gases. The new plant was ordered in 1998 and began supplying electricity to the grid in December 2000. It is owned by Eskilstuna Energi och Miljio AB (EEM) and will be used for a combination of electricity generation and district heating.
- **Laholm**
  The Trädgårdsstaden project, which started in 1991 and began operation in 1993, was established to heat a new housing development using a CHP system fuelled by biogas. Situated just outside the center of Laholm in Sweden, 50-60 apartment blocks are supplied with both electricity and heat from the CHP plant, which processes around 35 ktons/y of waste (30 ktons/y of manure, sourced from farms in the vicinity of Laholm and around 5 ktons/y of organic waste from industry). The project is a co-operation between SHK ENRGI AB, the Municipality of Laholm and The Swedish Council for Building Research. Since 1993 the biogas plant has provided 3000-4000 m^3/day of gas. The installed capacity is 450 kW of electricity and 650 kW of heat.
- **Hedensbyn**
  Located at Hedensbyn in Skelleftea, this is the largest biomass-fuelled CHP facility operated by the Swedish company Skelleftea Kraft. It has a capacity of 35.6 MW_e and 62.9 MW_{th} for the DH system. Fuelled with unprocessed biomass residues, incorporates an integrated pellet-manufacturing process which produces around 30 t/h of biopellets for sale as fuel.
  The circulating fluidized bed Pyroflow compact boiler is fuelled with unprocessed biomass residues, such as wood chips and bark. When planning the CHP plant, the turbine was designed for steam extraction, enabling the steam process to be used for drying the biofuel used for pellet production.
  Sawdust is also used for pellet production and this provided at around 56 tons/h with a moisture content of about 55%.

- **Sigtuna- UpplandsVasby Sweden**
  The Brista Kraft AB was established to supply the area with clean energy and to utilize the resources available in the area. Only 10 % of the energy content in the annual growth of the forests around the plant is used. A small amount of fuel is shipped from Esthonia. At the plant the chipped biofuel, with moisture content of 55% is transported to a storage building with room for 13000m^3 fuel. The technology used in the plant is optimized for the moisture content in the fuel used; therefore no drying process is needed. The fuel is fed automatically to the boiler when required.
  The steam boiler is a fluidized bed type with a capacity of 12 MW_{th}. The particle collection equipment comprises an electrostatic precipitator to separate the dust from the flue gases. Ashes are taken back to the forest, to keep the nutrient balance. The steam turbine is connected to a generator with a capacity of 44 MW_e. The electricity produced is fed to the grid. After the steam turbine, the steam is brought to a heat exchanger for DH (capacity: 85 MW_{th}). The temperature of the water when fed to the DH system is 90-120 ^oC and it is returned at 40-60 ^oC. In a normal year the production amounts to about 390 GWh of heat and 160 GWh of electricity.
- **Vasthamn, Sweden**

The Energi Produktion AB (HEAB) owns the Vasthamn CHP plant. The plant produces all the corporation's heat as well as much of its power. It has a 220 MW boiler which supplies steam to a steam generator. The turbine produces 64 MW_e. The exhaust from the steam turbine are fed into two stages DH condensers. This supplies 129 MW_{th} for the DH network