

# CHP - a Sustainable Solution for Energy Production

## Combined heat and power production

Combined heat and power (CHP) production, also referred to as cogeneration, is a process simultaneously into both electrical and thermal energy. This means that the heat generated in thermal power production is recovered and used. The CHP process may be based on the use of steam or gas turbines, or combustion engines. The primary energy source can be a wide range of fuels, including biomass, waste and fossil fuels, or geothermal or solar energy.

## Finland - the leading country in cogeneration

The amount of energy Finland saves annually through CHP corresponds to over 10 per cent of all primary energy used in the

country, or 20 per cent of Finland's fossil fuel consumption,

Approximately one third of the electricity consumed in Finland is derived from CHP. Industrial CHP plants and district heating CHP plants respectively accounted for 45 per cent and 55 per cent of the cogeneration. Industry accounts for more than half of Finland's electricity consumption, and almost 40 per cent of this electricity is generated by CHP. Depending on the annual climate conditions, as much as 75 to 80 per cent of district heat is produced by CHP.



### **Extensively used for decades\**

The per capita energy consumption in Finland is among the highest in the OECD countries. This is explained by the important role of energy-intensive industries, such as the pulp and paper industry, in the Finnish economy. As a result, the economical use and secured distribution of energy have always been under special scrutiny in Finland. The country's geographic and climatic features have provided a base for the development of CHP in district heating. Effective energy production is essential, since both the annual heating demand and the annual number of heating hours are high.

### **Early use of industrial CHP**

CHP generation in industry, also known as back-pressure power, arises from the need for heat in an industrial process.

Finland's first industrial CHP plants were built beginning, as early as the beginning of the 1920s and 1930s. CHP generation was chosen because the aim was to find ways to make power generation more reliable and economical. Local energy sources were often used as a starting point.

Industrial back-pressure power generation is mainly based on waste liquors originating from pulp production. Black liquor is suitable for combustion because of the organic wood residues it contains. The pulp and paper industry is not the only one to use residues in the CHP generation. The manufacture of metals and the processes of chemical industry also produce waste fuels that can be turned into heat and power through the CHP process.

### **District heating as part of CHP generation**

Because of the country's northern location, district heating is a natural choice for Finland. Plans for a district heating network were set in motion after the Second World War. The cogeneration of heat and electricity was adapted from the wood processing industry,

offering an efficient energy generation concept for conserving both energy and the environment. Thus the Finnish district heating system has been based on CHP from its beginning.

About half of the building stock in Finland is connected to district heating. In the largest cities, the proportion exceeds 90 per cent, and most office and public buildings in the country use district heating. CHP provides roughly three quarters of the district heat consumed annually. Compared against separate production of electrical and thermal energy, CHP yields savings of about a third of the fuel quantity. Most of the district heating companies are owned by municipalities, but the share of private ownership is increasing.

District heating provides the necessary heat load for CHP, and it holds a great potential for use of renewable sources such as biomass and waste. The European Union's target to double the share of CHP in energy supply cannot be achieved without further development of the district heating sector. Thus, district heating ought to be recognised as an important issue in the agenda of the European Energy Policy.

### **CHP for district cooling**

In a district heating environment, the cooling energy needed in buildings can be produced from the CHP heat. During the winter months the heat can be used for space heating, but in the summer heat is hardly needed. This surplus heat can be utilised to produce district cooling energy with absorption chillers.

District cooling exists today only in three Finnish cities, but the prospects for the future are promising. Helsinki is the most significant district cooling city in Finland. Thirty per cent of the cooling energy is obtained from cold seawater by means of simple heat exchangers.

## CHP Enables Economical Energy Generation

CHP plants are built for financial gain. Therefore CHP generation must produce energy more cheaply than other alternative methods. The profitability of different alternatives must be assessed for the whole life cycle of the power plant. CHP usually requires a larger investment than alternative conventional energy generation technologies, but it consumes smaller amounts of primary energy resources.

As a result, CHP plants are cheaper to operate than condensing power plants, CHP heat can be used either for district heating or for industrial processes. The transmission of heat over long distances is costly. Therefore it is best to build CHP plants close to the communities and factories where the heat will be used.



### High efficiency

CHP plants make the maximum use of fuel energy by producing both electricity and heat with minimum wastage. The plants achieve a total efficiency of 80 to 90 per cent. In conventional condensing power plants the efficiencies remain at 35 to 40 per cent.

### High availability

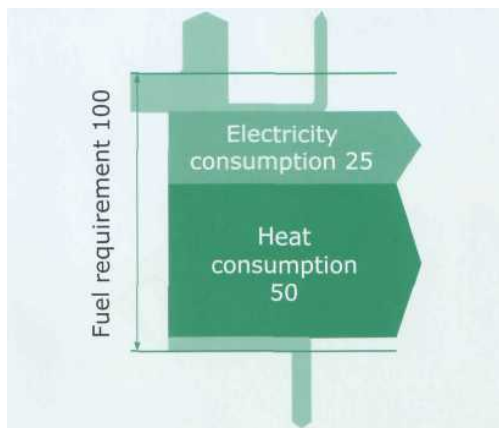
CHP plants have a high level of availability, enabling uninterrupted energy production. At the same time the plants can be highly automated, thus minimising the number of staff required and also cutting the costs of operations and maintenance.

The electricity and heat output can be adjusted in a flexible manner according to need, which may sometimes change at short notice. The reliability of district heating in Finland is 99.98 per cent during the heating season.

On the average, heat supply during the heating period is interrupted only once in six

### CHP production, Fuel efficiency 75 %

Losses from boilers and processes 14      Power transmission losses 4



Heat transmission losses 7

years for each customer, with the outage lasting an average of eight hours.

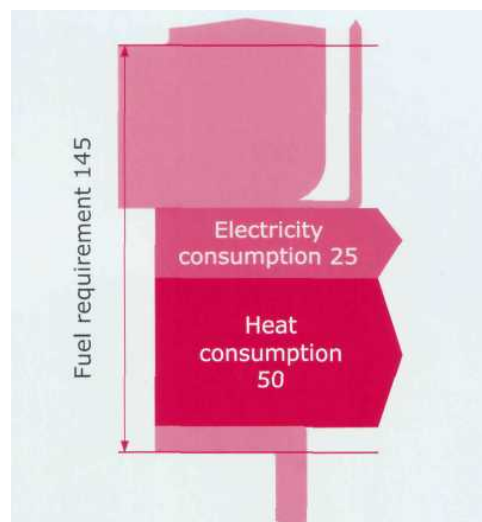
### High fuel flexibility

In CHP generation a wide variety of fuels can be used, including those with a low calorific value and high moisture content, such as industrial wastes and bio fuels. Optimal combinations of fuel can be used at each plant according to the local situation. Commonly used fuels include natural gas, coal, industrial gases, peat and renewables, e.g. industrial wood residues, municipal waste and forest wood. Oil is used sparingly, usually only as a supplement to other fuels.

Traditionally, bio fuels have been used in CHP generation, mainly in connection with forest industry processes. For many reasons, CHP applications are an ideal use for bio fuels. Because their calorific value is low, the transport of bio fuels is costly, so these fuels tend to be local fuels.

### Separate production, Fuel efficiency 52 %

Losses from boilers and processes 53      Power transmission losses 4



Losses from individual boilers 13

## Efficient Energy Production Protects the Environment

The high efficiency levels and low emissions of CHP generation make it an environmentally acceptable solution for energy production. Modern CHP plants take advantage of efficient combustion technology to reduce nitrogen oxide emissions.

The decrease in fuel consumption reduces the burden of energy production on the environment. For instance, carbon dioxide emission from the firing of fossil fuels is reduced at the same rate as the use of fuels is reduced. The same goes for all other emissions, such as sulphur and nitrogen oxides.

Because CHP plants consume less fuel, they are more

environmentally acceptable both in terms of the energy resources they require and the emissions they give off. For example, the reductions in the amounts of fuels used in the plants yield similar reductions in the amounts of emissions of pollutants, such as nitrogen oxides and sulphur oxides.

Air quality assessment in Finland's largest cities indicates that sulphur emissions have been reduced as a direct result of CHP generation and district heating.



The environmental advantages of CHP have been well recognised over the last few years. Nevertheless, financial considerations still play a decisive role in decisions concerning which type of power plant to build. Therefore, the cost of the energy produced in a CHP plant must be competitive with energy generated in other ways.

CHP generation and district heating are favoured by authorities, because they are powerful tools for reducing carbon dioxide emissions. The goal of the Finnish energy strategy is to stabilise carbon dioxide emissions according to the Kyoto Protocol, which states that emissions should be reduced to the 1990 levels by 2010. District heating and CHP schemes saved Finland 8 million tonnes of carbon dioxide emissions in 2004- more than three quarters of Finland's annual reduction target under the Kyoto Protocol.

### Wide scope for CHP applications

Development of CHP technology is currently focusing on scaling down. Smaller plants make feasible a greater utilisation of locally available wood fuels as well as recovered fuel

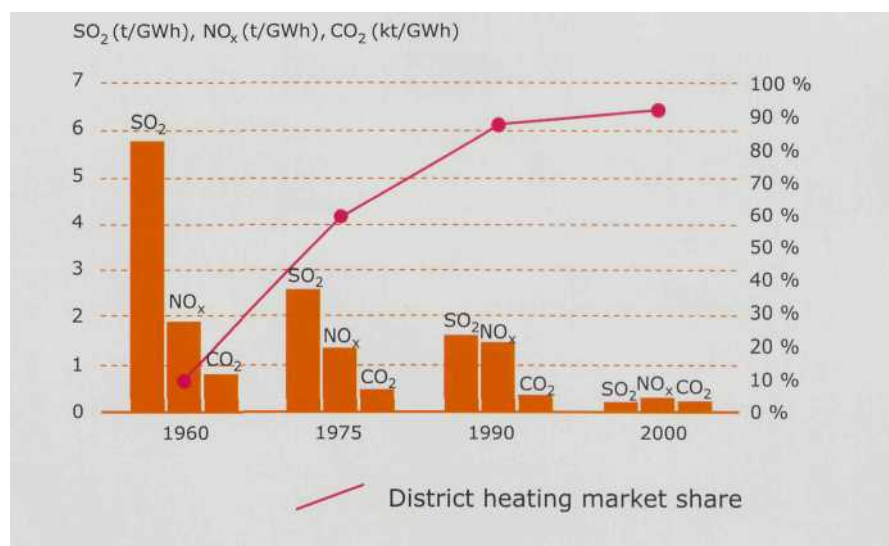
and refuse derived fuel.

Fuel drying technology can be used to boost the thermal output of a cogeneration plant. Also, advanced combustion technologies (e.g. gasification and pressurised concepts) increasing the electricity output of cogeneration plants are being developed with a view to making CHP competitive on a small-scale.

Improvements in CHP power plant technology will lead to an improved power to heat ratio, The combined cycle power plant technology based on the gasification of solid fuels reflects an interesting insight into CHP generation, In this process, the gas can be used in gas turbines and the waste heat from the gas turbine can be used in the steam turbine, The power to heat ratio can be close to one, as opposed to the current values of about 0.5.

There is a significant market potential for using CHP generation in order to convert waste to energy.

**Emissions of energy production and the development of district heating market share in Helsinki**



## Finnish Energy Policy and CHP

Finnish energy policy rests on three fundamental elements: energy, economy and the environment. Securing the energy supply, providing competitively priced energy and keeping environmental emissions within the international commitments are therefore central. The most important factor influencing the operating environment of energy policy is international cooperation, which reduces greenhouse gas emissions. Among other factors having an impact on energy policy are the objectives of reducing environmental hazards and of adapting economic activity to the principles of sustainable development.

CHP has played a major role in Finnish energy policy and is a very important part of our policy also in the future. High-quality CHP is an effective way to produce heat and electricity. It often benefits local and renewable energy sources. These features mean that in Finland, CHP makes a very effective contribution to decreasing greenhouse gas emissions.



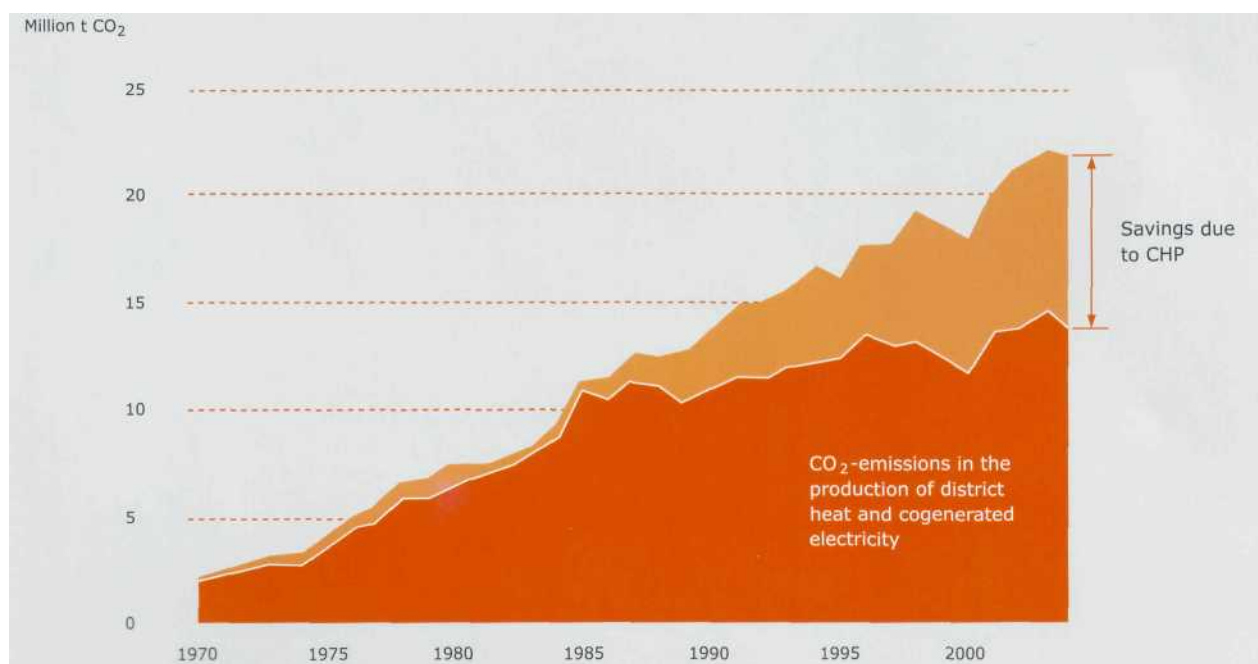
In accordance with the decision of the Government, the national objective for safeguarding energy availability is to promote energy production based on several fuels and procurement sources. The objective of the energy policy is to maintain a versatile, decentralised and balance energy system in the future. For its part, the Government continues to try to ensure an optimally versatile and sufficient availability of electric power and other forms of energy. The focus in this respect is on domestic energy; in other words, on renewable energy sources and biofuels.

The Government will continue to promote the cogeneration of heat and power in the future. The premise of the decisions influencing power procurement is that the consumption of heat is combined as efficiently as possible with the cogeneration of power and heat, paying due attention to the technical and economical aspects. The status of cogeneration is promoted by, for example, considering the overall efficiency of power plants as a factor in

the allocation of emission allowances. By investing in a persistent development of technology, it is possible to create opportunities to face and react to the potentially tightening future obligations to reduce greenhouse gas emissions. Besides technology, the development focuses on the entire operating, implementation and business chains. The renewable energy and energy efficiency technologies remain the important sectors. Intensive and persistent investments in R&D will generate and introduce to the markets new solutions related, in particular, to CHP generation, industrial energy production, decentralised energy production and efficient use of energy.

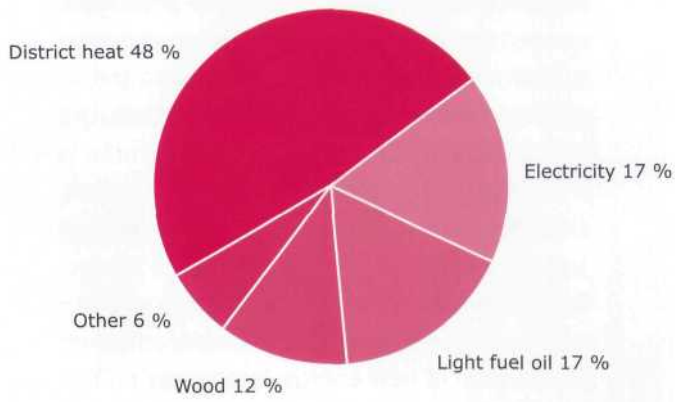
Governmental investment subsidies will be targeted mainly at projects aiming at the introduction of new energy technology on the one hand, and, on the other, at projects associated with an exceptional technological risk, due to the demonstration character of the projects.

### Savings in carbon dioxide emissions due to CHP

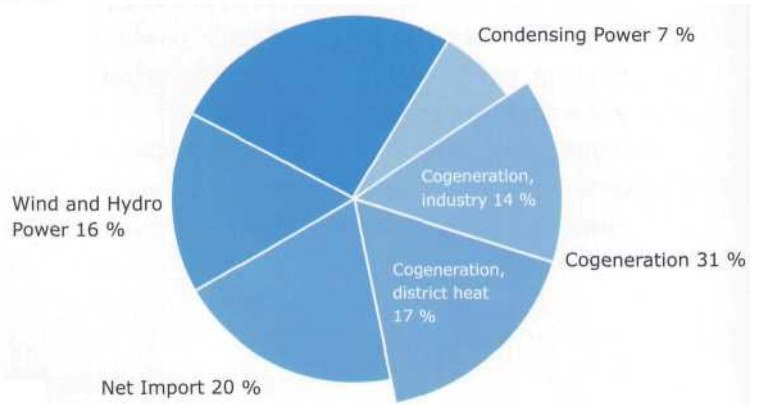


## Charts

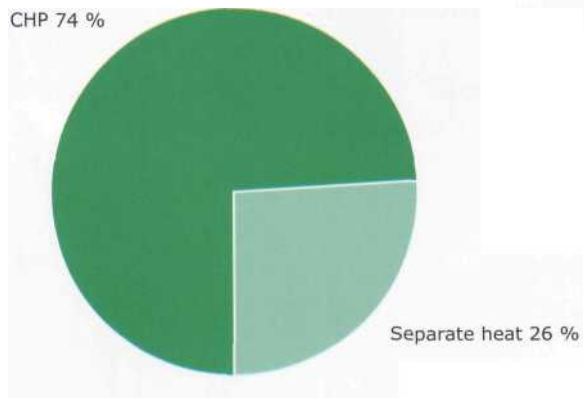
**Market share of space heating  
(year 2004)**



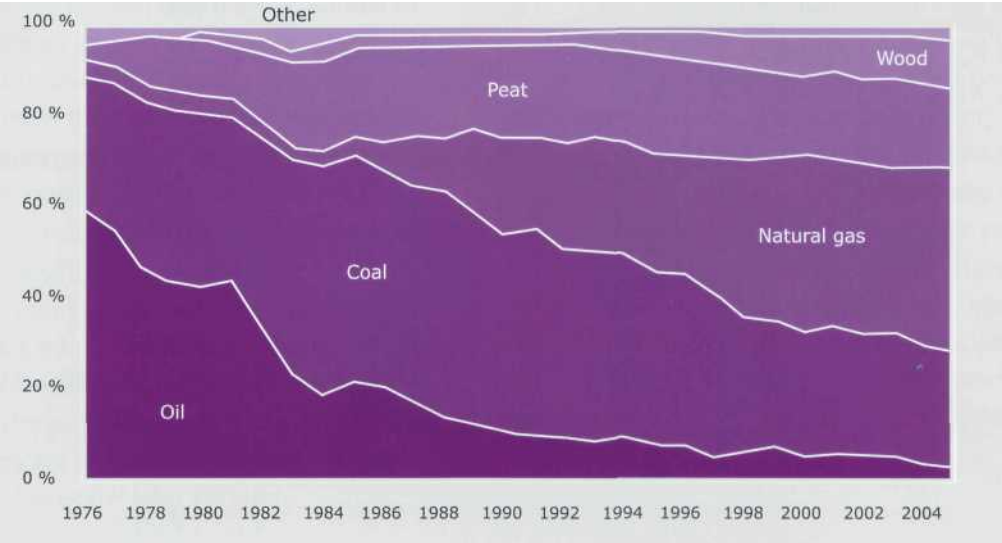
**Electricity supply  
84,9 TWh (year 2005)**



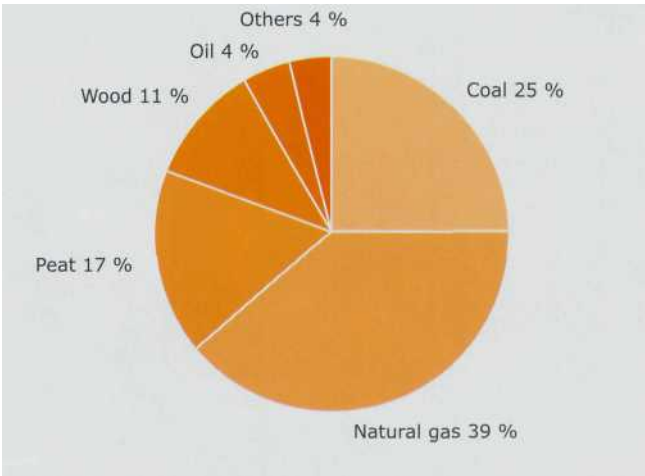
**District heat production  
31,2 TWh (year 2005)**



**Fuel consumption in production of district heat and CHP**



**Fuel consumption in production of district heat and CHP 54,0 TWh (year 2005)**



## Combined Cycle Technology of a High Efficiency

### Helsinki Energy

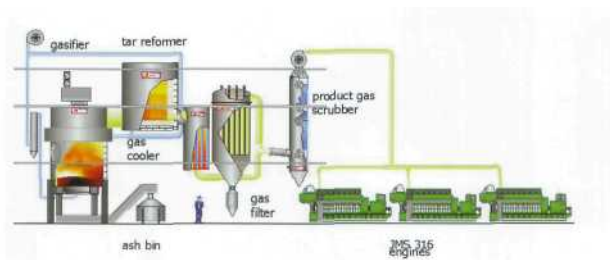
Owing to their production technology, the Vuosaari gas-fired power plants in Helsinki are among the world's most efficient and cleanest power plants. The Vuosaari power plants utilise the combined cycle technology, in which gas turbine and steam turbine processes have been combined. When compared to conventional power plant technology, the combined cycle achieves higher efficiency in electricity generation and a higher electric power output in proportion to the district heat output.

In combined heat and power generation, the Vuosaari power plants reach an efficiency exceeding 90 per cent, i.e. less than 10 per cent of the energy generated from the fuel is lost. The energy losses are mainly heat losses via flue gases and cooling water as well as internal heat losses,

<b>Power output</b>	<b>630 MW</b>
<b>District heating output</b>	<b>580 MW</b>
<b>Use of natural gas</b>	<b>650 -800 million m<sup>3</sup>/a</b>



## A Small-scaled CHP Plant Based on Gasification



The Novel gasifier is a new type of fixed-bed gasifier based on forced fuel flow, which also makes it suitable for low-bulk-density fibrous biomass fuels. The gasifier can be operated with a wide range of biomass residues having a moisture content from 0 to 55 per cent and a particle size from sawdust to large chips.

### Kokemaen Lampo Oy

The first small-scale CHP plant based on Novel fixed-bed gasification was constructed in 2004. The plant is equipped with a complete gas-cleaning train consisting of a gas reformer, a filter and an acid/base scrubber for removing residual nitrogen compounds. Three 0.6 MW<sub>e</sub> gas engines are installed for power production and a gas boiler for heat recovery.

<b>Power output</b>	<b>1.8 MW</b>
<b>District heating output</b>	<b>4.3 MW</b>
<b>Heat output to the fuel dryer</b>	<b>429 kW</b>
<b>Fuel capacity</b>	<b>7.2 MW</b>

## Combined Activities to Achieve Profitability

### Vapo Oy

Construction of the power plant and expansion and upgrading the pellet plant in Ilomantsi were completed in November 2005. The power plant is equipped with a fluidised bed boiler. The pellet plant project included construction of a new material reception unit, a new dryer, a third pellet production line, a conveyor system and silos. The power plant, pellet plant and dryer are operated from the same control room. The fuels used are milled peat and wood. The fuel consumption is around 75 GWh per year.



<b>Process heat capacity</b>	<b>8 MW</b>
<b>Power capacity</b>	<b>3.5 MW</b>

### Pellet plant Production

Wood pellets 70,000 tonnes/a

### Volume of raw material

Sawdust 500,000 m<sup>3</sup>/a

<b>Power plant</b>	
<b>Fuel capacity</b>	<b>23 MW</b>
<b>District heating capacity</b>	<b>8 MW</b>

## From Hard Coal to Biomass

### Porvoon Energia Oy

The Tolkkinen power plant has been retrofitted from hard coal to biomass. The company wanted both to reduce the use of coal and to achieve an environmentally better solution. The chain grate boiler was modernised to the fluidised bed technology in 2000, which gave a good opportunity to use all kind of wood and wood residues as fuel. At the same time the combustion air, flue gas, ash handling, fuel feeding devices and automation were reconstructed. A flue gas scrubber with heat recovery, which will improve the district heating efficiency by more than 7 MW, is under construction in 2006.

<b>Fuel capacity</b>	<b>54 MW</b>
<b>Steam capacity</b>	<b>46 MW</b>
<b>Power capacity</b>	<b>7 MW</b>
<b>District heating capacity</b>	<b>25 MW</b>



## Energy For a Paper Mill and District Heating Network



### Kymin Voima Oy

The power plant of Kymin Voima Oy is owned by Pohjolan Voima Oy and Kouvolan Seudun Sahko Oy. Located at UPM Kymi Paper mill, the power plant utilises a bubbling fluidised bed boiler. It produces energy both for the mill and for the district heating networks of Kouvola and Kuusankoski. The fuels used are bark, forest residues, sludge, peat, gas and oil. Fuel consumption amounts to 2,100 GWh per year.

<b>Electricity output</b>	<b>76 MW</b>
<b>Process steam</b>	<b>125 MW<sub>th</sub></b>
<b>Hot water for the mill</b>	<b>15 MW<sub>th</sub></b>
<b>District heat</b>	<b>40 MW<sub>th</sub></b>

## Forssa Power Plant Relies on Wood

### Vapo Oy

The Forssa Bio Power Plant is the first CHP district heating plant in Finland (1996) to be fuelled entirely by wood. In industrial applications, wood has been widely used. The fuel is burnt in a fluidised bed boiler. The technology permits the use of practically all other available fuels. The primary fuel is waste generated in the woodworking industry; e.g. sawdust and bark together with forest chippings and building waste. Wood incineration causes no sulphur emissions and the nitrogen oxides emissions are very low.



<b>Power output</b>	<b>17 MW</b>
<b>District heating output</b>	<b>48 MW</b>

## Versatile Power Plant



### Oy Ahlholmens Kraft Ab

The power plant AK2-unit is owned by Oy Ahlholmens Kraft Ab. The unit is very flexible, with process heat and district heat produced according to demand in parallel with the production of electricity. District heat is produced with an efficiency of over 80 per cent, and is thereby environmentally friendly. The district heat is used to heat the city of Pietarsaari and the UPM pulp mill in Pietarsaari.

The main fuels are coal and bio-fuels. The bio-fuels are bark, wood chips, other bi-products from the wood refining process and peat.

<b>Power capacity</b>	<b>240 MW</b>
<b>Process steam capacity</b>	<b>100 MW</b>
<b>District heat</b>	<b>60 MW</b>