Finland

POLICIES

Background

Sustainability and predictability are characteristic to energy policy objectives. For more than twenty years the Finnish aim has been to produce as much electricity as possible in combined heat and power (CHP) plants, where we nowadays rank among the international top. Also an exceptionally well decentralised and versatile energy system, that is based on both large and small energy production plants and diverse energy sources has been managed to set up. At the same time, a strong energy technology cluster (or an energy cluster) has been created. Finland has been on the international forefront in removing unnecessary regulation and thus created the preconditions for the internationalization and growth of efficiency for the energy companies.

Finland's energy policy rests on three fundamental elements: energy, economy and the environment. It aims to secure the energy supply, competitive price of energy and to keep the arising environmental emissions within the international commitments. International co-operation is recognized to be the single most important factor when influencing the operating environment of energy policy that reduces greenhouse gas emissions. 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. In addition, the price and availability prospects of imported energy and the increased international decision-making have an effect on the energy policy during each programming period.

The energy policy implemented is based on the objectives set in the governmental negotiations and on energy policy documents, among them the Government's Energy Policy Programme. The energy policy carried out is also based on international commitments and other national programmes such as the National Climate Strategy which, together with the supplementing programmes, determines the main energy policy lines of Finland.

In recent years, the role of the EU in steering energy policy has increased. Finland participates in the oil distribution and security of supply systems of the International Energy Agency IEA and is bound, through numerous international organisations, such as the NEA, IAEA and Euratom, to wide-scoped cooperation in the fields of nuclear energy and nuclear surveillance.

In comparison to other industrialized countries, Finland is a leading user of biomass in relation to its total energy consumption (See Fig 1). Another distinguishable feature of Finnish energy policy is its view on nuclear power. After a hiatus of 20 years, Finland has authorized the construction of a new 1600 MWe nuclear power plant. This unit, named

Olkiluoto 3, is estimated to start operation by 2011.

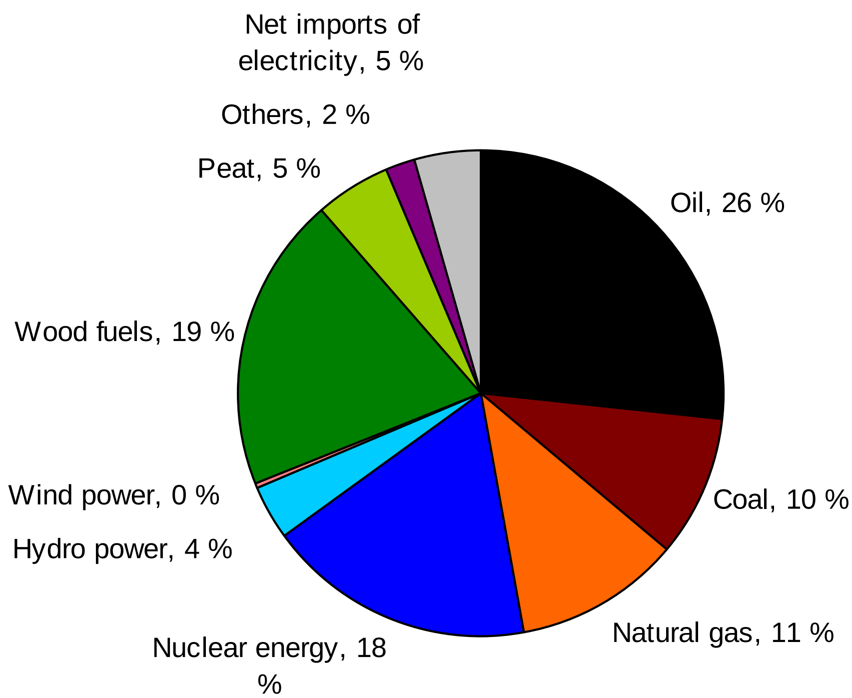

Figure 1. Total energy consumption by energy source in Finland, 2005 (Statistics Finland, 2006)

Current subsidies and objectives

Subsidies for power production were taken into use in Finland in 1997. The latest expansion to the subsidy system was done in 2003 and it considers almost every power production technology based on renewable energy sources with the exception of hydro-electric. Maximum energy investment subsidy levels are 40 % for a new and 30 % for a conventional technology.

Finnish feed-in rates for renewable electricity are modest in comparison to Central European levels:

- The basic amount is 0,42 c/kWh, and
- additional endorsement of 0,69 c/kWh can be applied for, if the electricity is produced out of forest chips or wind.

In heat production the tax levels are based partly on CO_2 emissions and are zero if wood fuels or REF are used.

The Renewable Energy Sources Promoting Programme compiled by Finland's Ministry of Trade and Commerce outlines following targets for the use of renewable energy:

- The use of renewable energy should be raised by 30 % from year 2001 to 2010 and
- to 60 % until the year 2025.

PROGRAMS

- National programmes
  - ClimBus 2004 – 2009
  - BioRefine 2007 – 2012
  - Large national R&D projects on gasification (Ultra Clean Gas development)

- International programmes
  - EU 6th Framework projects
  - EU 7th Framework projects

- R&D Projects at VTT

  - Development of advanced synthesis gas production (UCG project)
    - integrated process concepts (pulp and paper industry)
    - 500 kW PDU under extensive testing in 2007 - 08
    - first demo plant expected to be taken into operation in early 2009

  - EU-BiGPower project
    - further improvement of the Novel gasification process
    - catalytic reforming and hot gas filtration
    - gasification coupled to 2nd gen engines, turbines and fuel cells

  - EU-LahtiStreams IP
    - further development of gasification based Waste to Energy power plant technology
    - whole chain approach
      - waste processing and production of SRF (Solid Recovered Fuel)
      - further development of SRF gasification and gas cleaning
      - improvement of filter performance
      - mercury control
      - utilisation/disposal of solid residues (bottom ash, filter dust)

  - Waste gasification

        - PDU gasification tests with autoshredder residues
        - fuel gas to calcining kilns by CFB gasification of plastic waste
        - improvement of the economics of FBG by advanced ash management

    - Fundamental research activities for 2008 – 2010
        - Ash behaviour and reactivity in syngas applications
        - Fundamentals of catalytic reforming and hot gas filtration
        - New gas sampling and analysis methods
        - Evaluation of gasification based biomass to hydrogen processes

INSTITUTES

- **VTT** (Technical Research Centre of Finland), PO Box 1601; FIN-02044 VTT; www.vtt.fi
- **TKK** (Helsinki University of Tehnology, Dept. of Chemical Technology), P.O. Box 6100 FIN-02015 TKK Finland, http://pt.hut.fi/teke/english/index.html
- **Åbo Akademi University, Faculty of Chemical Engineering**, Biskopsgatan 8, FI-20500 Åbo, Finland, http://www.abo.fi/fak/ktf/cmc/main.html

INDUSTRIES

- **Foster Wheeler Energia Oy**, P.O. Box 45, FIN-00401 Helsinki, fwenergy@fwc.com, www.fwc.com/power/
    - CFB and BFB gasifiers (atmospheric-pressure and pressurised)
- **Carbona Oy**, Kaupintie 11; FIN-00440 HELSINKI, carbona@carbona.fi
    - U-gas gasifier, low-pressure bubbling fluidised-bed gasifier
- **Condens Oy**, Talkkunapolku 6; FIN-13100 HÄMEENLINNA, www.condens.fi, ilkka.haavisto@condens.fi
    - heat recovery systems, Novel gasifiers and CHP plants
- **Puhdasenergia Oy**, Pyynikintie 25, 33230 Tampere, info@puhdasenergia.com, www.puhdasenergia.com
    - downdraft gasifiers and small modular CHP plants

IMPLEMENTATIONS

Lahti Kymijärvi Plant

Kymijärvi power plant (owned by Lahden Energia Oy) in Lahti Finland has operated successfully biomass and waste derived fuel fired gasifier from the beginning of 1998.

Table 1. Lahti, Kymijärvi gasifier in brief.

Plant	Kymijärvi CHP plant, Lahti, Finland
Gasifier manufacturer	Foster Wheeler Energia Oy, Finland
Type of technology	atmospheric pressure CFB gasifier, no gas clenaing, gas co-fired in PC boiler
Capacity of the gasifier	60 MW_{th} (40-90 MW_{th} depending on fuel)
Annual availability of the gasifier	96.1...99.3 % (1998-2001)
Feedstocks	Wood chips, wood waste, saw dust, shavings, demolition wood, SRF (Solid Recovered Fuel), plastic waste
Commissioning	in the end of 1997
Investment	11.4 M€ (EU Thermie 3 M€)

The Kymijärvi power plant was started in 1976. Originally, the plant was heavy-oil-fired but in 1982 was modified for coal firing. The boiler is a Benson-type once-through boiler. The steam data is 125 kg/s 540 °C/170 bar/540 °C/40 bar and the plant produces electric power and district heat to the Lahti city. The maximum power capacity is 167 MWe and the maximum district heat production is 240 MW. The annual operating time of the boiler is about 7000 h/a. In the summer, when the heat demand is low, the boiler is shut down. In the spring and autumn, the boiler is operating in low capacity, with natural gas as the main fuel. In 1986, the plant was furnished with a gas turbine connected to the heat exchanger preheating the boiler feed water.

The boiler uses 1850 GWh/a (270.000 tons/a) of coal and about 100 GWh/a of natural gas. The boiler is not equipped with a sulphur removal system. However, the coal utilised contains only 0.3 to 0.4% sulphur. The burners are provided with flue gas circulation and staged combustion to reduce NOx emissions. The biomass/SRF gasifier was connected to the boiler at the end of 1997. The arrangement is illustrated in Figure 1.

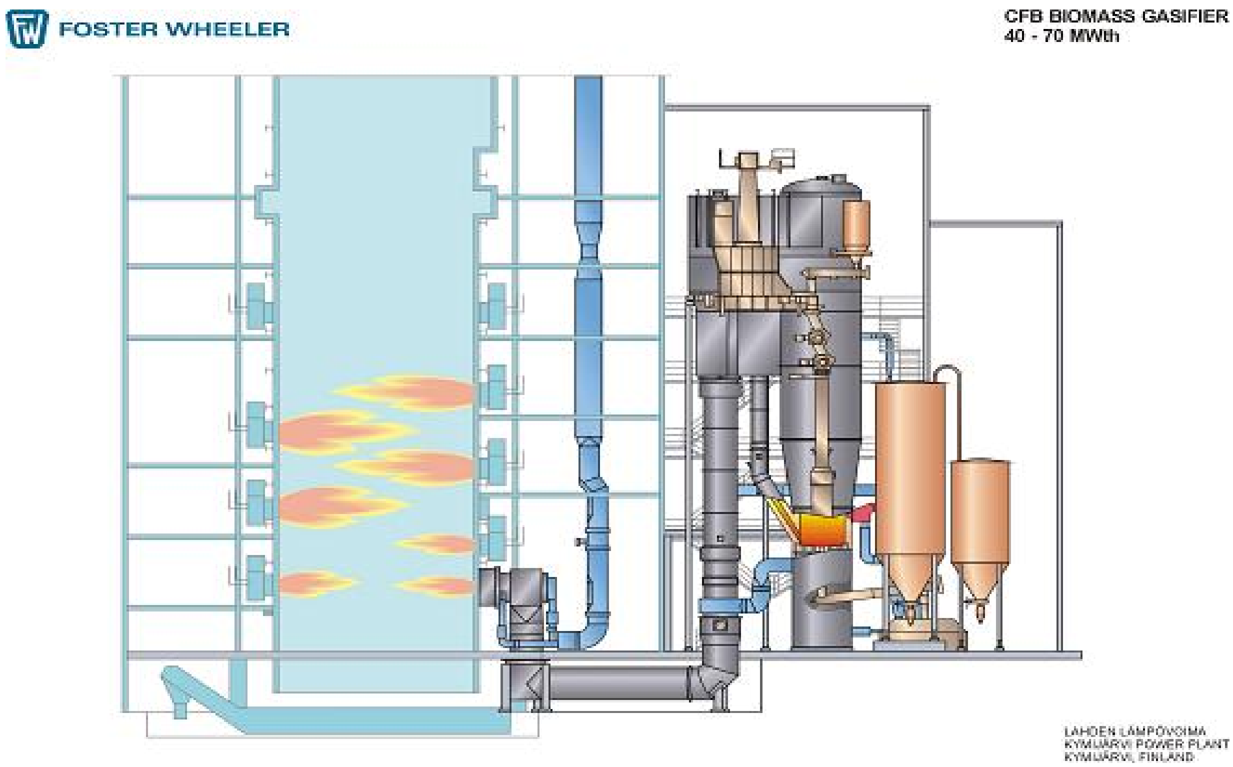

Figure 1. The Lahti Energia Oy Kymijärvi gasifier.

Approximately 300 GWh/a of different types of biofuels and solid recovered fuels (SRF) are available in the Lahti area. On an annual basis this amount is enough to substitute for about 15% of the fuels burned in the main boiler. Table 1 gives analysis data for the gasifier fuels and coal used in 2001.

The SRF is produced from origin classified refuses, coming from households, offices, shops and construction sites. The processing of SRF was started by the municipally owned waste management company in 1997. The SRF consists of 5–15 wt-% plastics, 20–40 wt-% paper, 10–30 wt-% cardboard and 30–60 wt-% wood. In addition to these fuels listed above, demolition wood waste and shredded tires have also been used as fuels in the gasification plant.

The gasifier at Kymijärvi power station is a CFB gasifier (Figure 1) supplied by Foster Wheeler. The atmospheric CFB gasifier is very simple. The system consists of a refractory-lined reactor where the gasification takes place, of a uniflow cyclone to separate the circulating material from the gas and of a return leg for returning the circulating material to the bottom part of the gasifier. The operating temperature in the reactor is typically 800 to 1000 ^{o}C depending on the fuel and the application. The fuel is fed into the lower part of the gasifier above a certain distance from the air distribution grid. The product gas for combustion is led directly from the gasifier through the air preheater to two burners, which are located below the coal burners in the boiler. The gas is combusted in the main boiler and it replaces part of the coal.

Table 2. Analysis data for the fuels used in 2001.

		wood	glue wood	municipal sludge	SRF	Wood+ gluelam+SRF	Coal
LHV, w.b.	MJ/kg	7.61	15.84	7.12	16.04	11.48	25.14
Sulphur, d.b	wt-%	0.03	0.01	0.93	0.08	0.05	0.36
Ash, d.b	wt-%	3.77	1.19	46.92	6.3	3.79	14.66
trace components	d.b						
Cl	ppm-m	87	115	178	2580	1700	93
Na	ppm-m	146	1830	1570	1190	725	1700
K	ppm-m	1710	720	1820	670	910	3110
Br	ppm-m	< 3	< 3	< 3	< 3	< 3	< 3
F	ppm-m	3	< 3	39	43	12	25
As	ppm-m	0.3	0.3	3.2	1.4	0.6	5.5
Cd	ppm-m	0.4	0.1	0.8	0.1	0.2	< 0,02
Cr	ppm-m	15	10	45	21	26	23
Cu	ppm-m	5.2	3.5	160	20	29	7.1
Ni	ppm-m	3.4	2.2	26	8.5	8.2	6.1
Hg	ppm-m	< 0.2	< 0.2	0.6	0.3	0.2	0.2
Tl	ppm-m	0.1	0.1	0.1	< 0,05	0.1	< 0,05
Zn	ppm-m	110	19	390	74	120	15
Pb	ppm-m	1.3	0.9	14	4.3	7.5	3.6

The operating experience of the gasifier during the years 1998–2002 has been excellent. On annual basis, the gasifier availability has been between 96.1–99.3%. With regard to the gasification plant itself, the few problems have been related mostly to the use of shredded tires as a fuel in the gasifier. On several occasions the wire content of tires (there is no additional separation of metal wires with magnet after shredding) was so high that accumulated wires blocked the ash extraction system and the gasifier had to be shut down. Otherwise, with all other fuel fractions, the operation of the gasification process was good.

Concerning the gasification process itself, the results have met the expectations. The operating conditions as regards temperatures, pressures and flow rates have been as designed and the process measurements as regards the product gas, bottom ash and fly ash composition have been very close to the calculated values. Due to the high moisture content (up to 58%) of the gasifier fuels, the heating value of the product gas has been low, typically only 1.6–3.2 MJ/m3n. The gasifier availability figures are given in Table 3 and the annual statistics for the gasified fuels in Table 4.

The stability of the main boiler steam cycle has also been excellent. The large openings that were made for the low Btu gas burners have not caused any disturbances into the water/steam circulation. Furthermore, as regards the operation of the product gas burners, the product gas combustion has been stable even though the moisture content of the solid fuel has been mostly high and the heating value of the gas very low. The stability of the main boiler coal burners has been normal despite of the fact that the product gas burners were integrated very close to the lowest level coal burners.

Table 3. Operation figures of the Lahti gasifier plant in 1998–2001 (design values: operation time 6500 hours/a and energy production 300 GWh/a).

	1998	1999	2000	2001
Gasifier availability, %	99.3	98.9	97.1	96.1
Energy Produced, GWh	223	343	295	449

Table 4. Gasifier fuel distribution and annual consumption in 1998–2002.

Fuel		1998	1999	2000	2001	2002
Biomass	%	71	57	63	61	56
SRF	%	22	23	29	26	31
Plastic	%	-	13	7.4	12	11
Paper	%	-	6.0	0.1	0.3	2
Railway sleepers	%	5.5	0.1	0.2	-	-
Shredded tires	%	1.5	0.9	-	-	-
Total	kton	80	106	92	116	104

The only residue from the gasifier is bottom ash, which consists mainly of sand and limestone. Furthermore, small amounts of solid impurities such as metal pieces, pieces of concrete, glass, etc. have been found in bottom ash. Typically, the carbon content in gasifier bottom ash is less than 0.5 per cent. No signs of chlorine have been seen in the analyses.

With regard to the trace metals, the following elements have been analysed: As, Cd, Cr, Cu, Ni, Pb, Zn and Hg. Elements like chromium (Cr), copper (Cu) and zinc (Zn) have been found in the range of hundreds of ppms. When shredded tires were used as a fuel in gasifier, the zinc content in gasifier bottom ash increased to the level of 3000 ppm. All other analysed elements were in the range of a few ppms or tens of ppms. The major part of the elements escaped the gasifier in the gaseous phase or in the fine fly ash particles.

Besides the standard analyses, leachability tests have also been made for the bottom ash. According to the tests, the trace metal leachabilities have been low. As a result of low trace metal contents and low trace metal leachabilities, the gasifier bottom ash is disposed today as planned at the beginning of the project.

The main boiler emissions were perhaps under the greatest interest as regards the measurement program of the monitoring phase. In summary, it can be stated that the changes in the emissions were very small. The main boiler is not equipped with $DeNO_x$ or $DeSO_x$ plants and the emission limit values for the emissions were as follows: NO_x 240 mg/MJ (as NO_2) and SO_x 240 mg/MJ. Table 4 summarises the effect of the co-combustion of the gasifier product gas on the main boiler emissions.

The dust content in the flue gas after the ESP decreased approximately 10–20 mg/m^3n. The most probable reason to this has been the increase of the flue gas moisture content, which has enhanced the operation of the ESP. Perhaps the most positive phenomenon has been the decrease in the NO_x emission. According to the measurements the NO_x content of the main boiler decreased typically approximately 10 mg/MJ, equalling the decrease of 5 to 10% from the base level. This was evidently due to the cooling effect of the low Btu, high moisture product gas in the bottom part of the boiler. Obviously, due to the cooling effect, the forming of thermal NO_x was lower in the coal burners located at the lower part of the boiler. Furthermore, because of the extremely low sulphur content of biofuels, the main boiler SO_x emission decreased approximately 20–25 mg/MJ. In contrast, because of the very low chlorine content (0.01%) of the main boiler coal, the HCl content of flue gas increased approximately by 5 mg/MJ when the gasifier was in operation. The reason for this was the use of SRF fuel and shredded tires in the gasifier. Both of these fuels are known to contain chlorine. As regards the CO emission and the carbon content in fly ash of the main boiler, no changes could be seen.

Table 5. The effect of gasifier to the main boiler emissions.

Emission	Change caused by gasifier
NOx	Decrease by 10 mg/MJ (= 5 to 10 %)
SOx	Decrease by 20 - 25 mg/MJ
HCl	Increase by 5 mg/MJ
CO	No change
Particulates	Decrease by 15 mg/m3n
Heavy metals	Slight increase in some elements, base level low
Dioxins	No change
Furans	No change
PAH	No change
Benzenes	No change
Phenols	No change

With regard to the heavy metal stack emissions, increases in some elements could be seen, but because of the very low base levels in coal combustion, the changes that were measured were in practice very small. As regards dioxins, furans, polyaromated hydrocarbons, chlorinated phenols and chlorinated benzenes, no changes could be seen compared to the results from 100% coal combustion.

Lahti Energia is also planning to construct a new 100 % of SRF fuelled Waste to Energy plant based on gasification. The planned plant is based on two parallel gasification trauins each equipped with product gas cooler and gas cleaning by hot gas filter. Capacity of both gasification trains will be 80 MW_{th} resulting in total capacity of 160 MW_{th} of the whole plant. Figure 2 presents the principle of (one gasifier train and boiler) of the planned WtE plant.

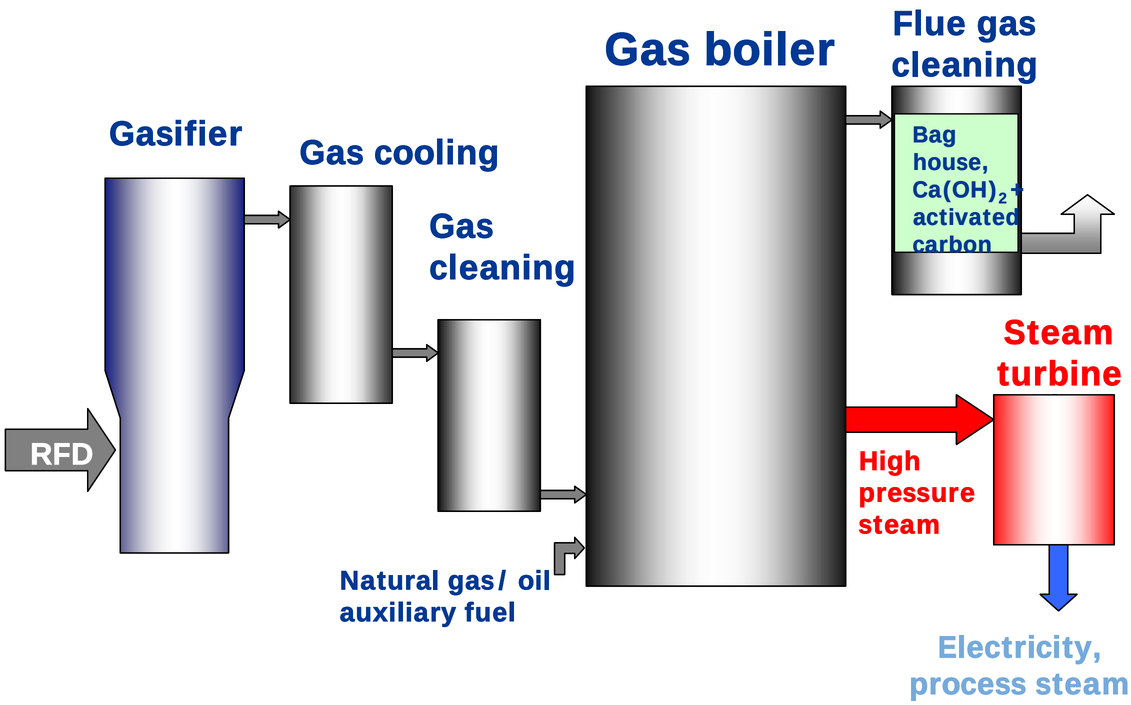

Figure 2. A schematic figure of the planned new gasification based WtE plant in Lahti

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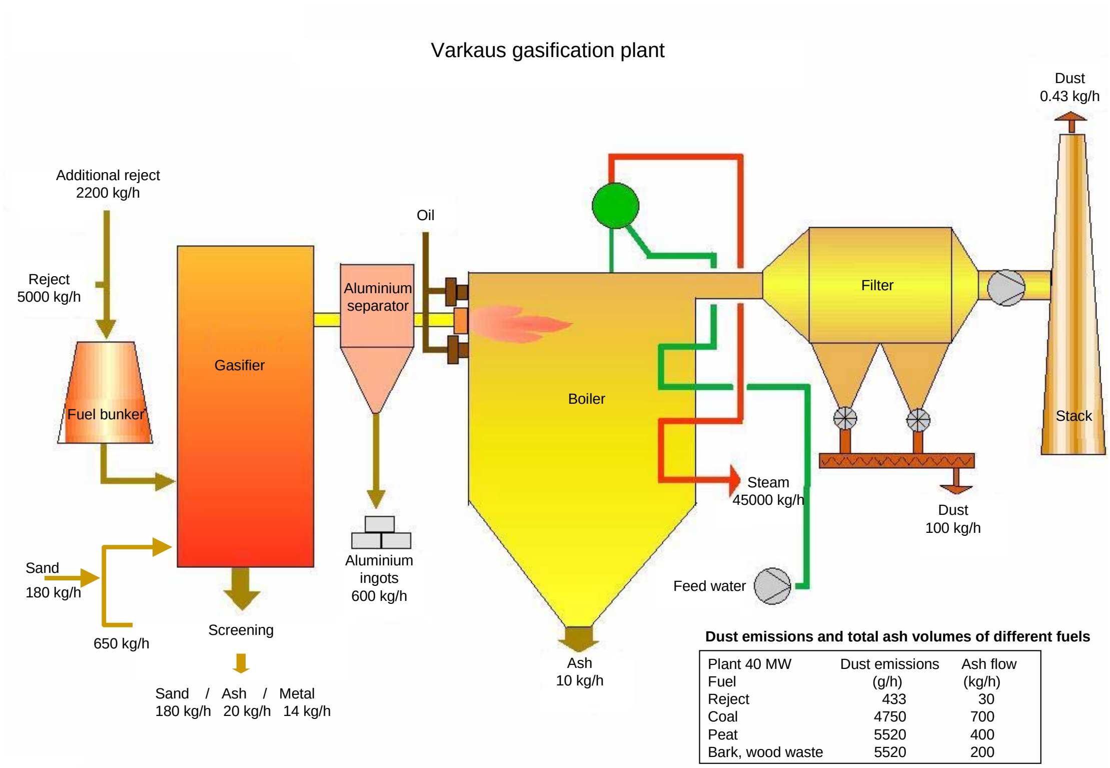
Varkaus gasification plant

Corenso United Oy Ltd. has built a gasification plant for energy production and aluminium recovery at its coreboard mill in Varkaus. The plant enables the complete exploitation of used packages containing wood fibre, plastic, and aluminium. It is the first plant in the world able to recycle aluminium, while simultaneously exploiting the plastic contained in the packages to produce energy.

Plant	Varkaus Coreboard Mill, Varkaus, Finland
Gasifier manufacturer	Foster Wheeler Energia Oy, Finland
Type of technology	Atmospheric pressure BFB gasifier, Al separation, gas fired in a specially designed gas fired boiler
Capacity of the gasifier	50 MW_{th}
Production of aluminium	about 2500 t/a
Feedstock	Aluminium containing plastic reject material from liquid packaging recycling process (27 000 t/a)
Commissioning	2001
Investment	17 M€ (public financing 3 M€)



Plant 40 MW Fuel	Dust emissions (g/h)	Ash flow (kg/h)
Reject	433	30
Coal	4750	700
Peat	5520	400
Bark, wood waste	5520	200

In Corenso's gasification plant, the fibre material in multi-layer packages is recycled in coreboard, the aluminium being recycled as raw material for foil. The remaining plastic is gasified to create energy. The metal and packaging bands in the loads of collected raw material are sent to the metal industry for recycling. Thus, everything is recovered.

The cost of the new plant being built was around EUR 17 million. Finland's Ministry of Trade and Industry has allocated about EUR 3 million to the project. The investment includes the gasifier, an aluminium recovery unit and a new boiler designed specially for gasification gas.

In the beginning the gasification plant generated about 40 MW of heat, with an estimated annual total energy production in the region of 165 GWh. The capacity of the gasifier has later been upgraded to 50 MW. An additional benefit will be the resulting improvement in air quality. The plant was taken into commercial operation in autumn 2001 and has since then operated with high availability (monthly gasifier availabilities > 90-95 %).

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Kokemäki Novel-gasification plant

Condens Oy and VTT have developed a new type of fixed-bed gasifier, which is based on forced fuel flow and consequently allows the use of low-bulk-density (of the order of 150

- 200 kg/m^3) fibrous biomass residues. Condens Oy is offering the Novel-technology both for heat alone and for combined heat and power applications. The gas cleaning train based on VTT's catalytic gas cleaning know-how followed by special wet scrubbing has been demonstrated in the pilot plant and is efficient enough to allow the use of gas in turbo-charged gas engines.

The main features of the NOVEL CHP process are:

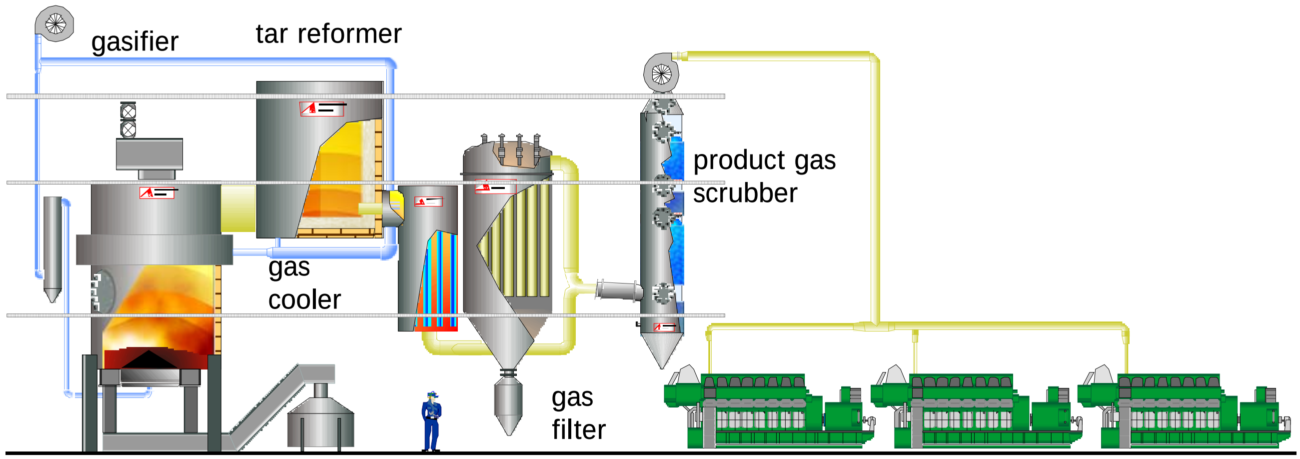
- Power output 0 – 3 MW_e
- Fuel moisture 0 – 30 %
- Power production 30 - 36 % of the fuel capacity depending on the initial moisture of the fuel
- Wide plant control range by using several engines and different engine sizes
- Heat production 60 % of the fuel capacity

The construction work of the first full-size NOVEL CHP plant was completed in April 2005 at the town of Kokemäki, Finland. The plant is equipped with a complete gas cleaning train consisting of a gas reformer, filter and acid/base scrubber for residual nitrogen compounds removal. For power production Jenbacher engines and a gas boiler for heat recovery are utilized. The other main characteristics of the Kokemäki plant are:

- Fuel drying by waste heat from the existing Kokemäki district heating plant
- Wood fuel
- Fuel capacity 7. 2 MW (6.2 MW, when the boiler is not in operation)
- Power output 1.8 MW_e (with three engines)
- District heat output 4.3 MW (3.1 MW, when the boiler is not in operation)
- Heat output to the fuel dryer 429 kW
- Total investment cost 4.5 M€

Further R&D activities at Kokemäki Novel CHP Plant:

- EC BiGPower: slip stream testing of 2nd generation catalytic gas clean-up and scrubbing water recycling (Oct. 2005 … Sept 2008)
- Testing with waste-derived fuels and agrobiofuels within other projects



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BIONEER gasifier

Before the Novel gasifier was developed in late 1990's, an updraft gasifier called BIONEER had been in commercial use in Finland since mid- 1980's. The BIONEER gasifier is a simple one-stage updraft moving bed gasifier, producing tarry LCV fuel gas. Between 1985 and 1986, when fuel oil prices were high, eight commercial BIONEER plants, with capacities ranging from 4 to 5 MWth, were commissioned, five in Finland and three in Sweden. Four plants are operated with wood or wood and peat mixtures while the rest are operated with peat only. Most of the gasifiers are still in operation at small district heating plants to provide circulating hot water. The BIONEER plants are completely automated and operated with minimal personnel costs.

The gasifier consists of a refractory lined vessel with a rotating cone-shaped grate. Biomass fuel is fed from the top, wherefrom it flows downwards through drying, pyrolysis, gasification and combustion zones. The residual ash is discharged from the bottom by the rotating grate. The temperature of the combustion zone is regulated by humidifying gasification air. Air and steam are fed as the gasification media through the grate. Since updraft gasification produces a raw gas with significant amount of tar, the gas cannot be either transported long distances or directly used in IC engines. In the existing BIONEER plants the gas is burnt in a close coupled boiler to generate steam and hot-water for district heating. During the mid 80's, VTT and BIONEER conducted extensive tests with a variety of feed stocks (ex. Wood chips, forest wastes, peat, straw, RDF pellets, and coal and RDF mixed with wood chips) in a 1.5 MWth pilot plant located at BIONEER's Hämeenlinna works. A typical gas composition with 41% moisture content wood chips consists of 30% CO, 11% H_2, 3% CH_4, 7% CO_2, and 49%

N2, with a HHV of 6.2 MJ/m^3n. The tar content of dry product gas is estimated to be in the range of 50 to 100 g/m^3n.