Cogeneration, or Combined Heat and Power (CHP)

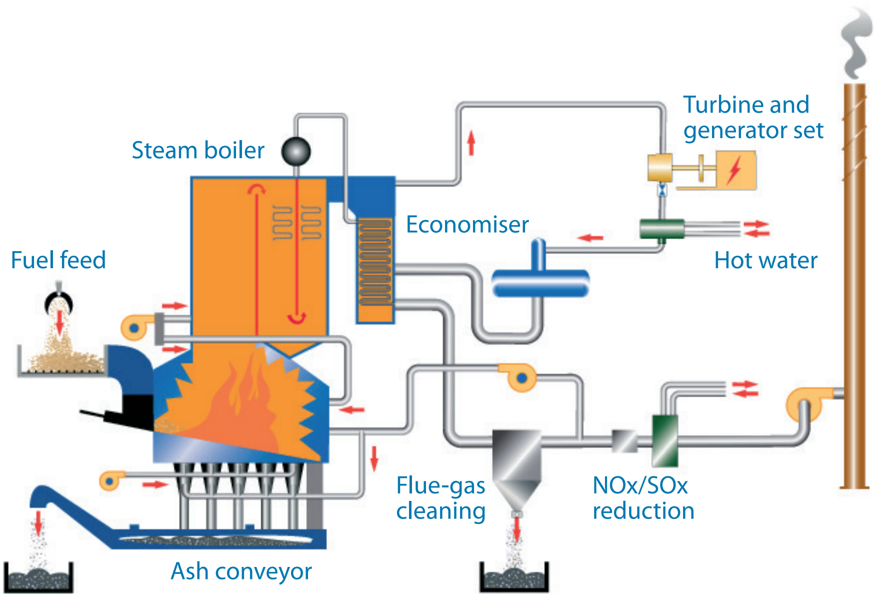
In brief

Cogeneration is a technique where the production of heat and electricity occurs in a single process or power plant.

A modern fossil-fuel power plant transforms about half the primary energy content of its fuel into electricity and rejects the rest as 'waste' heat. Cogeneration, or Combined Heat and Power (CHP), uses a part of that heat to satisfy a heat demand which would otherwise require energy from another source, usually a fuel.

The heat is often in the form of hot exhaust gases, steam or hot water. CHP thus improves the overall efficiency of fuel use and saves on primary energy in comparison to the conventional separate production of power and heat but more significantly, when the carbon content of the waste heat is examined from thermodynamic principles, it is found to be significantly less than other means of providing heat.

COGENERATION PLANT (CHP, COMBINED HEAT AND POWER)



Example of a KMW Energi cogeneration plant for the production of electricity and district heating, with corresponding environmental systems.

Source: KMW Energi, Sweden

When heat from a CHP station is used to heat a number of separate buildings spread over an area using District Heating (DH) pipes, this is known as Combined Heat and Power District Heating (CHPDH).

Thermodynamic analyses show that large utility-scale power plants coupled with district heat offer by far the lowest form of low carbon heat, much better than smaller CHP systems such as engine-based or micro-CHP systems, albeit these systems clearly have a role in dispersed non-city areas.

The technology

Existing cogeneration systems use various technologies. CHP plants operate using a variety of technologies: gas turbines, fuel cells, Stirling engines, gas or diesel engines and combined cycle gas turbines. Natural gas is the most common primary energy fuel, but renewable energy sources and waste can also be used.

The heat produced is available in different forms and at different temperatures. Energy

Fact file

- The development of cogeneration could avoid the emission of some 120 million tonnes of CO_2 in the EU in 2010 and 250 million tonnes in 2020.
- On average, overall energy efficiency of cogeneration plants is around 70 – 80 % in the EU, while their average electrical conversion efficiency is less than 35 - 40 %.
- Newly installed CHP systems can achieve overall energy efficiency levels of up to 90 %, with electrical efficiencies of around 30-55 %.
- The conversion efficiency of CHP plants in practice depends on the technology and on there being a demand for heat from the plant and its application.
- Load factors vary significantly for different applications, with on average approximately 4 000 – 6 000 h for public CHP units (heating) and about 4 – 8 000 h for industrial applications.

conversion efficiency varies considerably among these different systems.

Unlike traditional power stations where waste heat is dissipated at low temperatures in cooling towers, river or sea water, the heat is dissipated instead in the selected processes at a useful temperature.

In general, the electrical efficiency of CHP plants is lower than that of conventional, centralised power plants using the same fuels when producing heat, but is identical if in the electricity-only mode. However, achievable electrical efficiencies are expected to improve, particularly for gas turbines, but also for internal combustion engines and steam turbines.

At present, natural gas is the preferred fuel. Combined cycle gas turbine (CCGT) and gas turbine plants are expected to be the predominant future technology for new large-scale units.

Coal and biomass are mainly, although not necessarily, restricted to steam turbine CHP units and large coal-fired power stations are still expected to be a major fuel source

Ongoing research

Recent development work has tended to focus on small-scale CHP systems because of the large potential market in the residential and commercial sectors.

Small CHP units, of 100 kWe and above, have similar features to large units, while micro-CHP units, particularly of below 20 kWe capacity, are still in the R&D and demonstration phase. Designs include Stirling engines, Organic Rankine cycle and micro-turbines.

At this small scale only internal combustion engines are already on the EU market. The electrical efficiency of such units is around 30 % currently, but improvements can be expected for micro-turbines in future.

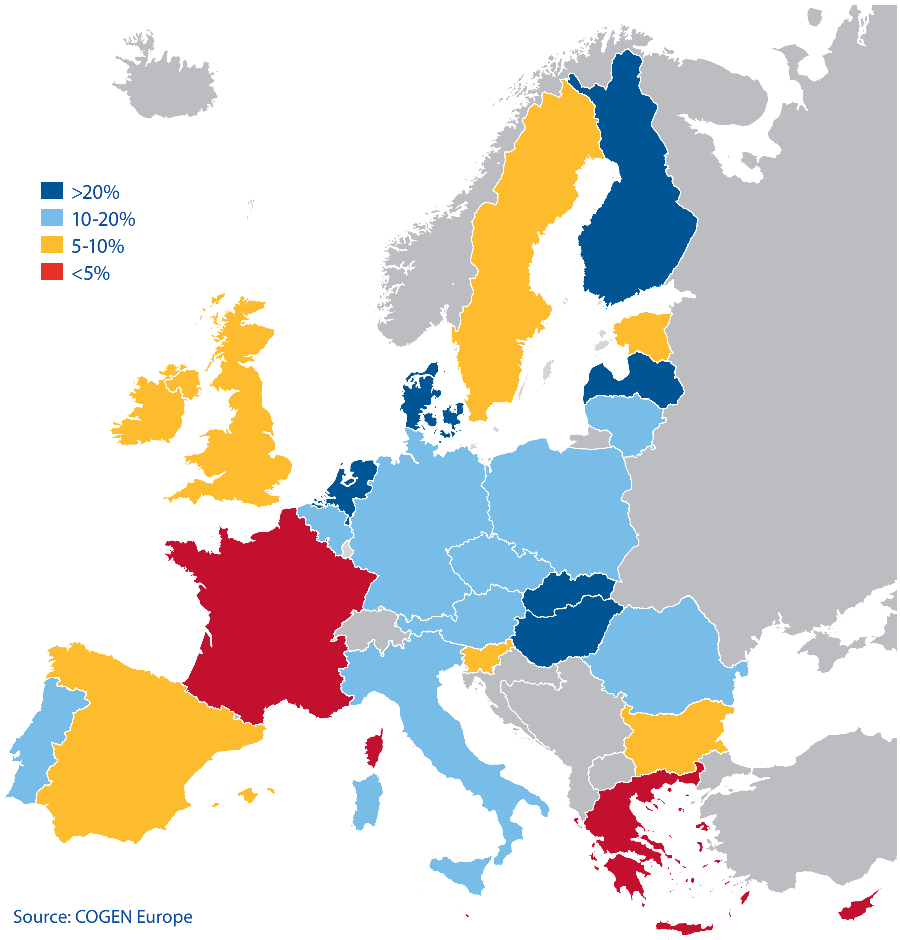
Stationary fuel cells are a particularly interesting development for CHP, as they show high electrical efficiency compared to other options. As well as 34 -50 % electrical efficiency and up to 90 % overall efficiency, they also have operational advantages due to low noise and size, etc. Significant progress is expected with the Molten Carbonate Fuel Cell (MCFC) and the Solid Oxide Fuel Cell (SOFC) for industry and public applications, as well as the Proton Exchange Membrane Fuel Cell (PEMFC) for domestic households (micro-CHP).

However, these are more expensive compared to the engine-based designs.

The industry

The EU has a strong industrial base in manufacturing CHP plants. With the predicted global growth of the CHP market, EU manufacturers should remain key players in future.

SHARE OF COGENERATION IN TOTAL ELECTRICITY GENERATION PER MEMBER STATE, 2007



Source: COGEN Europe

Fact file

- **Deployment costs**
  Specific capital cost for a typical state-of-the-art fossil fuel CHP plant varies between 1 900 euro per kWe for large units (of around 250 MWe capacity) and 2 400 euro per kWe for medium-sized plants (40 MWe).

- For natural gas-based CHP, large CCGT units (100 MWe) cost around 1 100 euro per kWe, while medium-sized gas turbines (10-50 MWe) cost 800-1 200 euro per kWe.

- Specific capital costs for biomass CHP systems vary between 2 400 and 6 000 euro per kWe, although this is predicted to come down by at least 10 % by 2030.

- Small-scale and micro-CHP currently cost around 1 700-2 700 euro per kWe, with fuel cells costing 4 000-12 000 euro per kWe for industrial units and up to 20 000 euro per kWe for household applications.

- **Anticipated greenhouse gas savings**
  If its maximum potential is realised, energy savings through CHP could avoid CO_2 emissions of around 85 million tonnes per year in 2020 and 95 million by 2030.

- The corresponding cumulative avoided CO_2 emissions for the period 2010 to 2030 would be 1 400 million tonnes.

- **Security of supply**
  Achieving the maximum potential for CHP could also reduce projected fossil fuel use by 30 million tonnes of oil equivalent (Mtoe) in 2020 and 35 Mtoe by 2030.

- The cumulative fossil fuel avoidance for the period 2010 to 2030 would be 500 Mtoe if this maximum potential is realised.

“The energy-saving potential of cogeneration is currently under-utilised in the European Union (EU).”

European Commission

As a fuel, natural gas dominates the European CHP market (about 40 %), followed by solid fossil fuels at 35 %. Renewable fuels, mainly biomass, but also combustible waste, are becoming increasingly important and have now reached 12 % of the market.

CHP systems have significantly penetrated EU industry, producing approximately 16 % of industry’s final heat demand. The other important CHP application is in district heating and cooling (DHC) systems, where 68 % of supply is CHP based. This presently supplies only about 10 % of the European heat market, and it is this market which could be significantly expanded, since it is difficult to see how existing fossil fuel heating can be replaced without using district heat pipes, fed at least in part from power station waste heat, but also increasingly renewables such as solar, wind and geothermal along with industrial waste heat. Furthermore district heat offers an economic means to store renewable energy, whereas it is not economic to store electricity in large quantities.

European Commission forecasts assume further growth in the industrial heating segment, to about 23 % by 2030. There is a much greater potential for considerable further growth in DHC-based cogeneration.

Biomass-based CHP is predicted to show significant growth, mainly in DHC systems but also in industry. It is estimated that the installed capacity of biomass CHP in the EU-27 could grow to 42 GWe by 2020 and 52 GWe by 2030, accounting for around 4.7 % and 5.3 % of the EU’s projected gross electricity consumption by 2020 and 2030 respectively. It is also assumed that around two-thirds of biomass-based power plants will be CHP facilities.

Distributed power generation is forecast to grow, mainly after 2020. Excluding fuel cell based CHP and assuming mainly natural gas fuelled units, the estimated maximum potential for such CHPs in the EU-27 is up to 9 GWe by 2020 and 15 GWe by 2030. This represents about 1 % and 2 % of projected EU gross electricity consumption by 2020 and 2030 respectively.

Fossil fuel CHP capacities in the EU-27 could reach up to 150 GWe by 2020 and 200 GWe by 2030, including distributed power generation, accounting for around 15 % and 18 % of EU electricity consumption respectively.

If all 50 % of building heating could be provided by CHP district heating, the electrical capacity of installed CHP could double to over 200 GW., .

Barriers

A low level of harmonisation across the EU in terms of regulations, together with relatively high start-up costs, are also slowing development, as well as barriers to grid access and system integration, coupled with lower electricity prices following market liberalisation

Some Member States have already seen regulatory developments: Belgium has green certificates and cogeneration quotas, Spain has issued a decree on the sale of cogeneration electricity and Germany has passed a law on cogeneration. The lack of coherent policies in other Member States, however, has delayed significant increases in CHP installation.

Competitiveness is also an issue. Since CHPs are driven by heat demand, in some applications they only run efficiently during part of the year or part of the day.

Market uncertainties about fuel prices have also inhibited investment recently. Market liberalisation has exposed both new and old CHP systems to very competitive conditions, where short-term profitability is the governing factor.

Regulatory issues regarding grid access and connection are inhibiting the growth of medium-sized CHP systems, while grid connection and integration could be an even greater problem for the large scale growth of micro-CHP.

Needs

Favourable policy and regulatory frameworks are needed to enable new investments in CHP and this requires political support. Progress is also needed in the integration and management of the electricity distribution grid.

In order for DHC to develop, there is a need for new, lower cost pipeline structures and less disruptive methods for laying networks, as well as accurate techniques to measure heat consumption.

Meanwhile, micro-CHP and fuel cells require targeted R&D, to support commercialisation of the technologies. Demonstration projects and financial mechanisms should stimulate the mass production of micro-CHP and fuel cells, as well as build up their service infrastructure.

Research also needs to focus on better biomass technology efficiency and co-firing of biomass and coal. A thorough review of the portfolio of thermal and electricity storage technologies, and improved cooling systems, should also be conducted.

For the sector to grow, stable long-term fuel and electricity prices are needed.

Installed capacity

At present (2010 figures), installed CHP capacity in the EU-27 is about 104.9 GWe, which accounts for about 11.7 % of electricity demand. There are wide variations between Member States, though, with CHP producing 45.3 % of electricity in Denmark and just over 35 % in Finland and the Netherlands.

European Commission baseline estimates for the growth of installed CHP capacity in the EU-27 foresee it reaching 160 GWe in 2020 and 169 GWe in 2030.

The right conditions could see faster growth, with the EU reaching its maximum CHP potential of 185 GWe by 2020 and 235 GWe by 2030. This represents about 18 % and 21% of projected EU gross electricity consumption by 2020 and 2030 respectively.

For further information:

SETIS section on Cogeneration

http://setis.ec.europa.eu/technologies/chp