

# What's the importance of cogeneration? <sup>1</sup>

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## Summary

Mature technologies are now available for the combined production of electricity and heat (cogeneration). They can use fossil or nuclear energy carriers, as well as biomass.

In a proper comparison (serving the same energy needs through both alternatives), cogeneration uses 15-20% less energy, and contributes an equivalent amount of emission reductions, compared to the production of electricity and heat in separate facilities, i.e. a thermal power plant and a modern boiler. In this case, the comparison needs to be based on the same fuel. When cogeneration is combined with a fuel switch – from coal to gas, the impact of switching fuel is more important than the impact of cogeneration, due to the favourable characteristics of gas compared to coal. The advantage of cogeneration also decreases with higher efficiency of future power plants.

Cogeneration is above all meaningful for applications where there is a large and continuous (not just seasonal) demand for heat close to the cogeneration facility. If there is no demand for heat from a cogeneration facility, its efficiency for the production of electricity will be lower than for optimised thermal power stations. Larger cogeneration facilities have in general lower production costs than smaller units. But on the other hand, transport of heat to users takes longer and is more expensive.

Cogeneration provides 6% of heat in Germany. Each year, about 55 TWh<sup>2</sup> is produced. German cogeneration facilities operate less frequently in condensation regime<sup>3</sup>, in comparison to other European countries. With a market share of 10% electricity produced from cogeneration facilities, Germany's performance is about average. Denmark is leading. But in Denmark, cogeneration facilities operate a considerable amount of time in the condensation regime. Moreover, the development of individual heat supply on the basis of gas has been inhibited in Denmark by regulation for a long time.

Government supports the further development of cogeneration. In case of district heating,

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<sup>1</sup>[www.sealnet.org](http://www.sealnet.org) in cooperation with [www.energie-fakten.de](http://www.energie-fakten.de); originally published July 21, 2005 in the German language by [www.energie-fakten.de](http://www.energie-fakten.de). English translation and editing by SEAL

<sup>2</sup>1 TWh = 1 billion kWh

<sup>3</sup>i.e. without simultaneous use of heat

this will not be possible, due to the reducing heat demand for dwellings, based on more stringent regulations for isolation and energy performance. For local heat production, there are growing possibilities if technology further develops (e.g. fuel cells). The already significant portion of cogeneration in industrial energy supply (electricity and steam) can increase further. Above all, the power to heat ratio (more electricity and less heat produced by cogeneration) increases significantly, compared to older facilities.

## **Cogeneration – the concept**

Cogeneration means the combined production of electricity and heat in an energy conversion facility. Technically, it means that part of the heat (steam, hot air) for the production of electricity in steam or gas turbines, or residual heat from combustion engines or fuel cells is used for room heating or as process heat in industry or commerce. Basically, the cogeneration principle could be used in any generation facility. It makes only sense, though, when there is a demand for the heat. The heat demand should be large, and continuous over a large part of the year.

## **Cogeneration techniques**

A broad range of mature technologies is available for cogeneration. They can use all energy carriers, from biomass or hydrogen in small facilities, such as mini-CHP units and fuel cells, to coal and nuclear energy in facilities of any desired size.

## **Advantages of cogeneration**

The advantage of the combined production of heat and power results from the more efficient use of fuel, and corresponding reductions in the emissions of  $SO_2$ ,  $NO_x$  and  $CO_2$ .

One often misleadingly compares the efficiency of cogeneration around 85% with the efficiency of power generation facilities (i.e. condensing power plants) in the order of 40%. For a correct comparison, one must take the weighted average of the efficiency of power and heat production and compare it with the efficiency of cogeneration.

With separate production of heat in modern boilers, efficiency will be significantly above 85%, and with condensing gas boilers even close to 100%. For condensing power stations, such as gas-fired combined-cycle plants, whose market share can only increase, efficiency approaches 60%. As a result, the advantages of cogeneration have a tendency to decrease.

The advantages of the combined production of heat and power relate often less to the improved technical efficiency. More often, the fuel switch from coal to gas produces the bigger advantage, based on the ecological advantages of natural gas.

With a proper comparison between separate or combined production of heat and power in modern facilities, the energy advantage amounts to 15-20%, which is still significant from an ecological viewpoint. Where feasible, this advantage should be exploited.

## **Appraisal of electricity and heat (equipment versus supply duty)**

Heat requirement needs in any case to be served locally. The local heat demand will determine the feasibility and therefore the application of cogeneration. For the economic exploitation of the cogeneration facility, in addition to producing cogeneration electricity, the condensing heat will be converted to electricity at times of low heat demand. However, since the cogeneration facility is a technical compromise between the production of power and heat, the use of a cogeneration plant for the generation of electricity only will be less ecologically efficient than the production of electricity in a condensing power plant.

The FW 308 guideline<sup>4</sup> establishes an accepted calculation rule for the valuation and differentiation of cogeneration electricity and electricity produced by condensing heat in cogeneration facilities.

## **Meaningful applications of cogeneration**

Meaningful applications can be found primarily where electricity production can be combined with a long-term stable and constant heat production, that is competitive in the heat market. Such production also contributes to the demand for electricity, which varies as well throughout the year, but to a lower extent than heat. Applications for cogeneration vary according to heat demand, the temperature of the heat required, and its variation over time.

Two typical application domains for cogeneration have emerged: the combined heat & power (CHP) plant in industry, and the heat and power sector in the electricity supply ('municipal heat and power supply'). The latter produces mainly low-temperature heat for heating and hot water supply in buildings. In addition, block heat and power plants with ratings of a few kW to a few MW are becoming relatively important.

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<sup>4</sup>A technical guide in the German language available from the Working Group 'CHP Economics' of VDEW, the German utility association.

## **Cost of cogeneration compared to separate production**

Large cogeneration plants in the range of a few 100 Megawatt (MW) using coal or natural gas are capable to produce electricity at lower costs, despite their higher investment costs, if they can lower their fuel costs through realising their energy efficiency advantage.

This advantage needs to be weighed against the cost of heat transport, which has a strong impact in the case of district heating. This applies particularly for the construction of new district heating networks. In large areas, this can lead to high start-up losses, due to protracted development of new connections. These effects can reduce, or even eliminate the economic advantage of lower heat production cost.

## **Decentralised heat supply**

The critical issue of heat transport costs applies only to a limited extent for decentralised cogeneration facilities, with a limited number of users. For regions where there is no meaningful application of district heating, such facilities raise high expectations. But because of the high specific investment cost for decentralised cogeneration units, economic exploitation will only be possible under certain conditions.

For example, the heat demand needs to be sufficiently large, in order to be able to use a facility with the lowest possible specific investment costs. In addition, the profile of this heat demand needs to be such, that it enables a good utilisation of the facility. A rule of thumb is to guarantee 5000 hours full-load equivalent operation for heat production. This is easier to realise for heat processes in industry and commerce, than for supplying heat to homes, with a requirement of around 1600 hours per year. When making investment calculations, the tariffs for cogeneration electricity supplied to the grid and the fiscal treatment of the electricity generated in the cogeneration unit make a large difference.

## **Development of cogeneration for space heating**

The technical possibility exists to fully cover the demand for low temperature heat (up to 100 degrees) by cogeneration. The extent to which this theoretical potential can be exploited depends on whether the combined production of heat and electricity, compared to separate production, results in economic, energy or ecological advantages.

Stringent constraints apply to the further development of district heating:

- Population decreases in the medium term
- With better standards for buildings and production processes, the specific heat demand has a tendency to decrease, resulting in a lower utilisation of production facilities.
- Economic conditions of exploitation will be seldom achieved for the development of new district heating networks

As a result, we're limited to the consolidation of existing district heating networks. Nevertheless, we can expect a significant increase in the production of electricity from cogeneration, since technical development results in cogeneration facilities with a larger electricity production in relation to the installed heat capacity (higher CHP coefficient, i.e. more electricity, less heat).

## **Development of cogeneration in industry**

More promising are the conditions for the development of cogeneration in industry. The reducing heat demand in this sector is compensated by 2 factors: by the higher technical potential of cogeneration compared to the heat demand in industry, related to higher fuel prices, and by the high utilisation related to a heat demand all year round. Higher CHP coefficients provide an additional driving force.

## **Development decentralised cogeneration systems**

A lot is expected from decentralised cogeneration in smaller facilities, such as block heat and power plants, and fuel cells, for use in industry as well as small applications (households, commerce, public facilities). The advantage here is the elimination, or strong reduction of costs for heat transport, as well as avoided costs for using the grid.

Disadvantages are the significantly higher investment costs, as well as fuel, operating and maintenance costs, and the lower efficiency for electricity production in relatively small units.

## Cogeneration in Germany

Cogeneration heat (space heat, hot water and process heat), with a market share of 6% takes the 4<sup>th</sup> position in Germany, after natural gas (47%), oil (25%) and electricity 11.5%. For space heating alone, its position is third.

In the past, overestimated figures have been given for cogeneration electricity, i.e. around 80 TWh<sup>5</sup>. The error resulted from adding electricity produced from condensing heat to cogeneration electricity. This applied particularly to the cogeneration facilities in industry. Today, rule FW 308 is obligatory for the calculation of cogeneration electricity. Based on this, the annual production amounts to 55 TWh. This is almost 10% of the combined electricity production in Germany for 2004 (around 554 TWh).

## Cogeneration in Europe

German cogeneration plants operate more frequently in the combined regime and less often in condensation regime compared to other European countries. With a market share of 10%, Germany is behind Denmark (40%), the Netherlands (39%) and Finland (34%) for cogeneration electricity, but ahead of Italy (9%), Sweden (8%), UK (5%) and France (5%).

When using the calculation rule of FW 308, the position of Germany improves significantly, since leading countries such as Denmark generate a higher portion of electricity from condensing heat in cogeneration facilities. While Denmark is often cited as example, it should be noted that development of space heating using natural gas has been inhibited by regulation over a long period of time, while fuel oil prices have been kept artificially high by taxation.

## Prospects for cogeneration

Many communications consider the development of cogeneration, next to more use of renewable energy as one of the most important instrument for CO<sub>2</sub> reduction. Decentralised cogeneration is considered of paramount importance. When approaching the matter from a business perspective, some skepticism is usually applied to such 'grand schemes'.

Considering the reducing demand for heat, due to increasing energy performance in buildings, the reduction in population, the expected dismantling of existing heat production systems based on natural gas and the considerable costs for new district heating networks,

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<sup>5</sup>A TWh is a billion kWh

the prospects for developing large municipal cogeneration facilities are slim. In this segment, we can expect consolidation within existing networks. This may not suffice though to compensate for the reducing heat demand.

Production of electricity from these facilities might very well increase, through the modernisation of old cogeneration facilities, especially when also switching fuel from coal to natural gas, leading to a sizeable increase of the CHP coefficient, and therefore to a larger electricity yield per unit of heat produced.

The prospects are clearly better for cogeneration in industry, while we should be careful as well not to overestimate the potential. This depends strongly on the increase in electricity and fuel prices.

The strongest growth can be expected for decentralised facilities, not least because of the very low starting base. But here, economic performance needs to be improved significantly, and technical breakthroughs (fuel cells) need to be realised.

Considering the developments that can be expected, decentralised cogeneration facilities are unlikely to play the role attributed to them by 2020 in many studies. Additional barriers have been caused by the rising oil prices (and therefore higher gas prices), since smaller facilities, and especially the block heat and power plants operate on gas. This assessment applies as well for fuel cells, especially since the economic production of hydrogen lies in the distant future. In the long run, small cogeneration units may succumb to the increasing competition from separate heat production systems using electricity (increasingly from renewable sources), such as for example in heat pump systems.

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