WBA fact sheet

BIOMASS COMBINED HEAT AND POWER (CHP)

SUMMARY

Combined heat and power (CHP) means the simultaneous production and utilization of heat and electricity. Combined heat and power production uses a series of proven, reliable and cost-effective technologies that are already making an important contribution to meeting global heat and electricity demand.

CHP, particularly together with district heating and cooling (DHC), is an important part of greenhouse gas (GHG) emission reduction strategies, due to higher efficiency and whence, a reduced need for fuels. The construction of new DHC grids is a prerequisite for an increased CHP application.

The public authorities have an important role to play in the initiation of DHC-grids. They must be interested in connecting their buildings to the grid to serve as a good example for the other building owners. When you achieve this boost it is normally not necessary to finance DHC-grids from public authorities.

This fact sheet has been prepared by the WBA to provide information regarding the latest developments surrounding the use of biofuels in CHP applications.

INTRODUCTION

Buildings account for almost a third of final energy consumption globally and thus are considered a major contributor to global CO_2 emissions. Currently, both space heating and cooling, as well as hot water, are estimated to account for roughly half of the global energy consumption in buildings.

Energy-efficient and low/zero-carbon heating and cooling technologies for buildings have the potential to reduce CO_2 emissions by up to 2 gigatonnes (Gt) and save 710 million tonnes oil equivalent (Mtoe) of energy by 2050. Most of these technologies, such as combined heat and power (CHP) and heat pumps are commercially available today.[1]

Stand-alone power plants

Stand-alone power plants, also named condensation plants, deliver only electricity meaning that any heat generated during the process is simply not used. The combustion technology transforms the chemical energy in the fuel into electricity and heat. However, in these plants the heat energy is lost with the flue gases and the cooling water.

In the most efficient designs of stand-alone power plants these losses have been reduced. At the very high steam temperature and pressure used in these plants, it is possible to reach over 40% electricity efficiency. The energy loss is around 60%. With an advanced (and expensive) gas combined cycle process, it is possible to increase the electricity efficiency up to 50-55%.

The city of Sundsvall in middle Sweden is located between two mountain ranges. Before district heating was introduced, smoke from hundreds of chimneys and smoke stacks caused serious air pollution, particularly on cold winter days. Today almost all of the houses are connected to the district heating grid, supplying 80,000 people with heat. And the air quality has improved accordingly.
Pictures supplied by Sundsvall Energi. Photo: Torbjörn Berhkvist

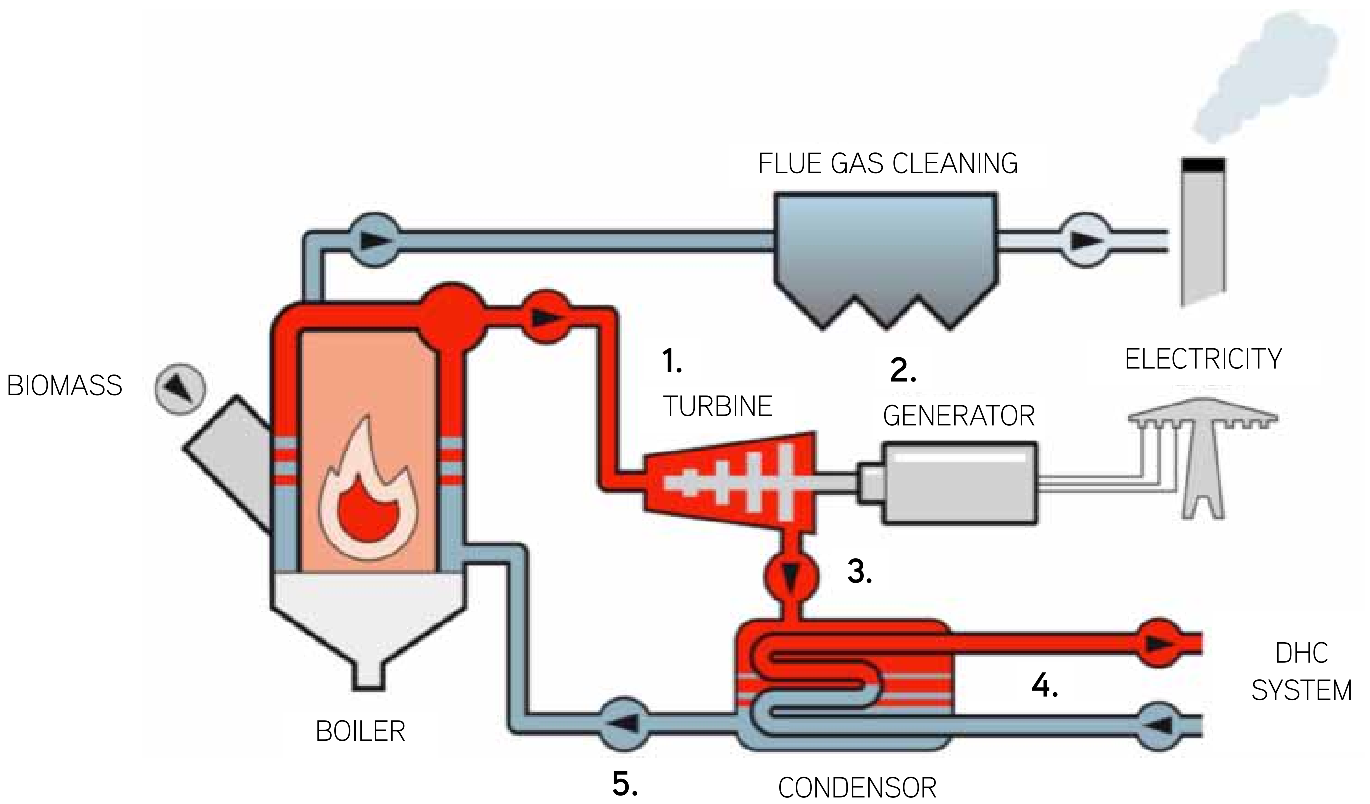


Figure 1: Schematic diagram of a CHP plant Source: [4]

1. The high-pressure steam produced in the boiler spins the turbine.
2. The turbine drives a generator to produce electricity.
3. The steam that leaves the turbine has relatively high thermal energy.
4. The captured heat is distributed to customers by insulated pipes in DHC systems.
5. After the heat energy is drawn off via a heat exchanger the water returns to the boiler.

Combined Heat and Power plants

Unlike a stand-alone power plant, CHP plants deliver electricity and usable heat and are therefore much more efficient in terms of usable energy output. When planning for a CHP plant the investigation of the demand of heating and cooling in the surrounding area is crucial, whether this be for industry or residential use.

The heat energy that is supplied from a CHP plant is provided by excess heat that is released subsequent to the process of condensing and cooling steam produced as a result of the combustion of the fuel.

This production of heat, distributed to industry or for district heating and cooling (DHC), results in some reduction in the possible electricity output if the plant had been run in condensing mode – i.e., producing only electricity. Using the CHP mode with a modern combustion steam cycle and a relatively large CHP unit (>50 MWe) could produce approximately 35% electricity and 55% useful heating and/or cooling energy. The energy loss within this unit is only 10%.

With different advanced technologies like Integrated Gasification Combined-Cycle (IGCC) it is possible to increase the electricity output to about 50%, based on a fixed heating demand. Smaller (under 10 MWe) biomass-fuelled CHP plants using steam turbines, depending on the fuel and the technology implemented, can achieve an overall efficiency of 85 to 90%, and electricity efficiency of 12-25%, or in the case of biogas fuelling a gas motor, up to 38% as electricity.

District Heating and Cooling (DHC) – infrastructure

DHC systems distribute hot water, steam or chilled water generated at a central plant (either DHC or CHP plant) through separate systems of insulated pipes to residential and commercial buildings connected to the DHC system. Once the heat or the chilliness in the water is used in customer buildings, it is returned to the central plant to be reheated or rechilled and then circulated through the closed-loop DHC piping system.

In regions where there is no adequate present demand for heat, there may be an opportunity to have cooling provided for houses and offices, institutions and industries. In this case an absorption heat pump can utilize the heat from the CHP plant. Heat pumps in general use electricity to move heat from a cool space into a warm, making the cool space warmer and the warm space cooler. Absorption heat pumps use a small amount of electricity but get most of their energy from a heat source.

In the case of a CHP plant, the absorption heat pump is driven by the heat from the condensed steam having passed by the turbine. The cool water is then distributed in a district cooling pipe system to provide cooling in warmer months to many of the same buildings as the DHC grid services heat in colder months. [2]

In DHC grids, sustainable energy sources and new types of production technologies are adopted, and existing ones significantly extended. Various biofuels and waste resources are increasingly replacing fossil fuels in existing and new CHP facilities. Other renewables like (deep) geothermal and solar from large thermal plants are also being increasingly integrated. [3]

Biomass for electricity – Fuels and technologies

Electricity production can be fuelled by solid, liquid or gaseous biofuels, with the biggest fraction of biopower today being produced using solid biofuel.

The main technologies in use to transform solid biomass to electricity are steam production to spin a turbine (the steam

TABLE 1:
BIOENERGY POWER PLANT FUEL CONVERSION EFFICIENCIES AND COST COMPONENTS

Capacity	Typical Power Generation Efficiency	Capital Costs (USD/kW)	Operating Costs (% of Capital Cost)
10 MW	14 – 18	6 000 – 9 800	5.5 – 6.5
10-50 MW	18 – 33	3 900 – 5 800	5.0 – 6.0
50 MW	28 – 40	2 400 – 4 200	3.0 – 5.0
Co-firing*	35 – 39	300 – 700	2.5 – 3.5

*Co-firing costs relate only to the investment in additional systems needed for handling the biomass fuels, with no contribution to the costs of the coal-fired plant itself. Efficiencies refer to a plant without Carbon Capture and Storage (CCS). Source: [5]

CHP APPLICATIONS

CHP technology exists in a wide variety of energy-intensive types and sizes of facility, including:

Municipal: DHC systems, wastewater treatment plants

Residential: multi-family housing, planned communities

Industrial manufacturers: chemical production, refining, ethanol production, pulp and paper, food processing, glass manufacturing

Institutions: schools and universities, hospitals, prisons, military bases, nursing homes

Commercial buildings: hotels and casinos, airports, large office buildings

Rankine Cycle), the Organic Rankine Cycle (ORC) and gasification.

For small-scale applications, Stirling engines may be utilised. Biogas from anaerobic digesters can produce electricity by fuelling a gas engine driving a generator and these Biogas operated fuel cells are currently in the early stages of commercialization.

AN EXAMPLE DEMONSTRATING BIOMASS FOR CHP

A modern 5 MW electrical capacity biomass-fuelled combined heat and power (CHP) plant generates around 30,000 MWh_e of electricity and 50,000 MWh of heat energy annually. This plant would require about 40,000 green tons (35% moisture) woody biomass (roughly 120 thousand MWh fuel energy value).

The steam produced in the biomass-fuelled boiler is under high pressure and spins the steam turbine which in turn drives a generator to produce electricity. When steam passes through a turbine it only loses a portion of its thermal energy, so when it exits the turbine it still has relatively high thermal energy. In stand-alone power stations this heat is absorbed by cooling water (possibly drawn from adjacent sea, lake or river, but it may be by using an evaporative cooling tower). CHP is designed to capture this heat and use it for productive purposes. The heat is distributed to the customers by insulated pipes. After the heat energy is drawn off via a heat exchanger the water returns in another pipe to the boiler. By using a far higher percentage of the energy in the fuel CHP technology should result in energy cost savings, waste heat reduction and lower CO_2 emissions.

Industries that require high amounts of heat and electricity are ideal for this application. The typical industries need heat for drying, evaporation, water and space heating. To locate a CHP near an ethanol factory, painting industry, food processing plant, cold store or pellets factory is attractive. The key to an economically viable CHP plant is that there must be a demand for the heat that is captured from the electricity generating process. In Europe, small and large-scale district heating plants are using CHP technology increasingly, and these plants have proven to be very efficient.

Using biomass solely for electricity generation is seen as an inefficient use of biomass. Modern commercially viable heating, cooling and cogeneration technologies can reach efficiency levels of up to 80-90%, whereas production of electricity alone from biomass may only have an efficiency of around 25-30%.

DIFFERENT ASPECTS ON BIOMASS-FUELLED CHP

Finance

The IEA's Technology Roadmap "Bioenergy for Heat and Power" 2012 shows an overview of biomass-fuelled plant fuel conversion efficiencies and cost breakdowns. See table 1 above.

According to Table 1, the bigger the

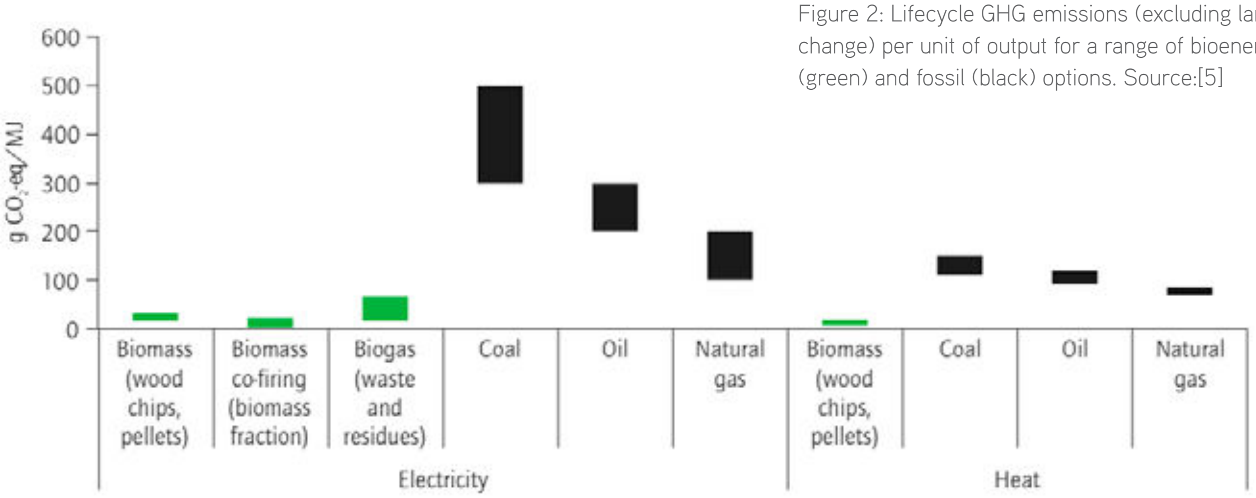


Figure 2: Lifecycle GHG emissions (excluding land use change) per unit of output for a range of bioenergy (green) and fossil (black) options. Source:[5]

plant, the lower the specific cost of investment per MW capacity. Yet, this relationship is only one part of the picture. Normally, the bigger the plant the more difficult it is to find a heat demand big enough to use the heat by-product of the electricity production, and also the longer the distances to haul the biomass to the plant. Efficient CHP plants can only be built if the plants thermal output matches the local demand for heat.

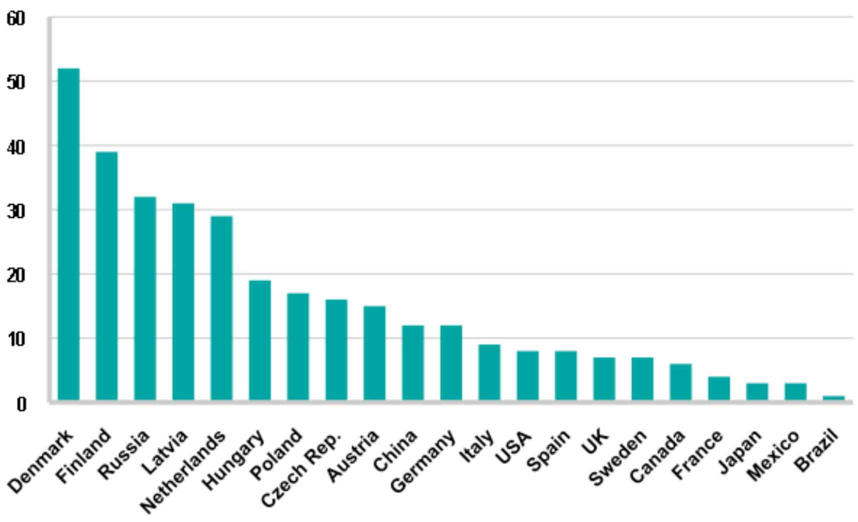
In many cases a necessary scale of heat demand might depend on the existence of a DHC system. A district heating grid is part of the infrastructure of a town or city. Energy utilities specializing in producing electricity (there are some exceptions like Scandinavian countries) are normally not interested in building DHC systems. Therefore public policy at municipal, state or federal level may have to require the construction of DHC systems as a prerequisite for the development of CHP plants in those places where there is no industrial heat consumer.

Environment

The IEA's Technology Roadmap "Bioenergy for Heat and Power", 2012, indicates: "Bioenergy for heat and power can provide considerable emission reductions compared to coal, oil, and natural gas-generated heat and power, when no additional GHG emissions from changes in land use occur. See figure 2.

The lowest life-cycle GHG emissions can be achieved through use of residues and wastes on site, for instance in pulp and paper mills. When using waste and residues, methane (CH_4) emissions that occur through decay of organic waste is avoided. Emission savings of more than 100% compared to fossil fuels can be achieved."

Figure 3: CHP share of total national power production. Source: [6]



GLOBAL STATUS AND POTENTIAL

The International Energy Agency (IEA) released a report in 2008 titled "Combined Heat and Power - evaluating the benefits of greater global investment". This report could be seen as a response to the call by the G8 leaders at their Summit in Heiligendamm 2007 to all countries to "adopt instruments and measures to significantly increase the share of CHP in the generation of electricity".

According to the IEA report, almost 40 countries already have CHP systems installed. The share of electricity generation by CHP plants in the G8+5 countries was 11% in 2005.

The above IEA report indicates that the share of CHP in electricity generation in G8+5 countries is expected to rise from 11% in 2005 to 15% in 2015 and 24% in 2030.

Biomass to electricity on a global scale

Global installed biomass-fuelled electricity generating capacity in 2010 was estimated at 62 GW [7], corresponding to 280 TWh [5] of electricity produced and requiring about 106 million tons of oil-equivalent (Mtoe) of biomass. The electricity is mostly generated in stand-alone power plants. An important task is to convert them to CHPs.

This figure of 280 TWh corresponds to 1.5% of the global power production. Power generation from biomass is still concentrated in OECD countries, but China and Brazil are also becoming increasingly important producers thanks to support programmes for biomass electricity generation, in particular from agricultural residues. [5]

Solid biomass (by-products of the forest industry, straw, bagasse, pellets) is the main material for bioelectricity production. It is used in CHP plants, in dedicated electricity plants, or for co-firing (biomass is used together with coal, for example) in coal-fired power stations. Co-firing is the source of about 10% of total biopower. The share of CHP plants using biomass is relatively low but detailed figures are not available. A remarkable increase in production of biopower can be expected in many countries, increasingly based on pellets, and this will be strongly dependent on government policies. ■

"Bioenergy for heat and power can provide considerable emission reductions compared to coal, oil, and natural gas-generated heat and power, when no additional GHG emissions from changes in land use occur."

Ekenäs Energi in Finland is a bioenergy CHP with the capacity of 17 MW thermal and 3,4 MW electricity. Photo: KMW Energi

POSITION OF WBA

WBA favors the sustainable, cost-competitive and efficient use of biomass for energy. The production of electricity from biomass without utilization of the heat is not efficient. Therefore WBA supports the adoption of CHP technology in using biomass for electricity production.

It is recommended that governments create economic frameworks and conditions favouring CHP development. For example: feed-in tariffs or green electricity certificates for biomass to electricity applications only if the overall efficiency of the plant is higher than 60%. Other examples of the frameworks are planning authorization of biomass co-firing installation only if the efficiency is above 60%, support programs for the construction of DHC grids and a CO_2 tax on coal, heating oil and natural gas to make heat from CHP-plants more competitive.

Exemptions in the sense of electricity production without the use of heat are justified if the biomass to electricity plant uses residues or by-products that are not easily transported over long distances and that are produced in regions without a big demand for heat; for example, straw in the vast rural regions of the world. It is better to use straw in an electricity-only plant than to just burn it on the field.

Some companies are interested to continue the operation of fossil-fuelled electricity production plants without heat use but to reduce the plants CO_2 emissions by co-firing with biomass. This is not the solution for the future because it means the continuation of an inefficient energy system and a waste of the limited biomass resource. The long term solution is in utilizing the heat, by conversion of the current plant or construction of a new CHP plant. ■

SOURCES

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