Global Trends in the application of Biomass Conversion Technologies for Combined Heat and Power

Regional workshop: "Opportunities and Challenges in Biomass Conversion Technology"

14-06-2016

State-of-the-art technologies for CHP application

The following technologies based on **biomass combustion and gasification** are well suited and highly developed for biomass CHP plants and are commercially available on the market:

- **Small scale**: Gas & ORC turbines
- **Large scale**: Steam turbines

RELEVANT TECHNOLOGIES

- ✓ CHP Plant with gas turbine
- ✓ CHP Plant with ORC turbine
- ✓ CHP Plant with steam turbine

Classification of Biomass CHP system scale

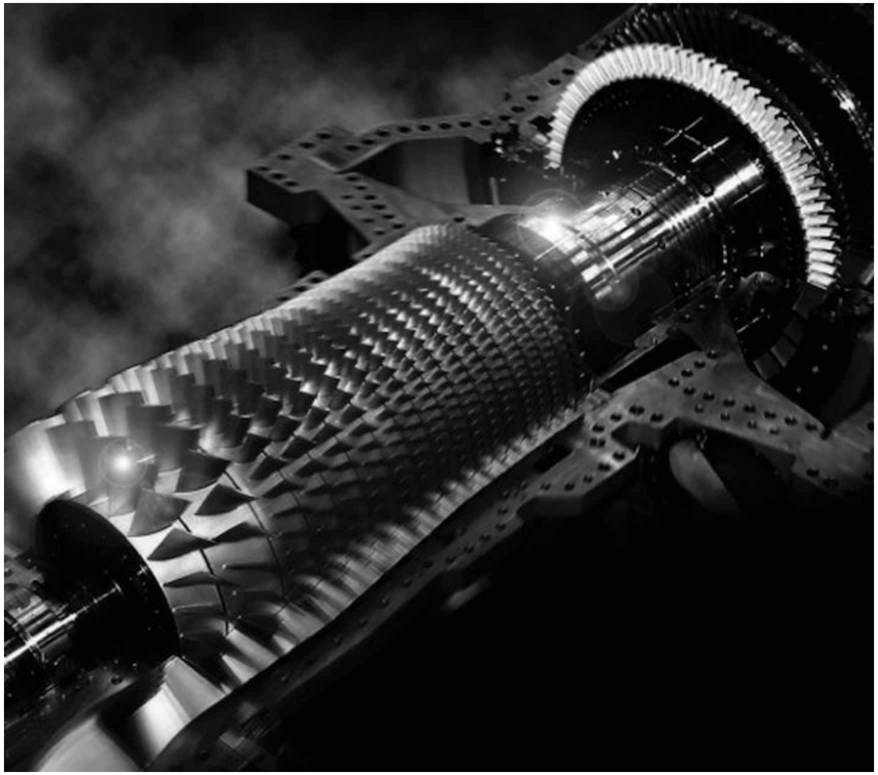
- Small-scale biomass CHP systems

  capacity range: <2000 kW
- Large-scale biomass CHP systems

  capacity range: >2000 kW

Source: IEA

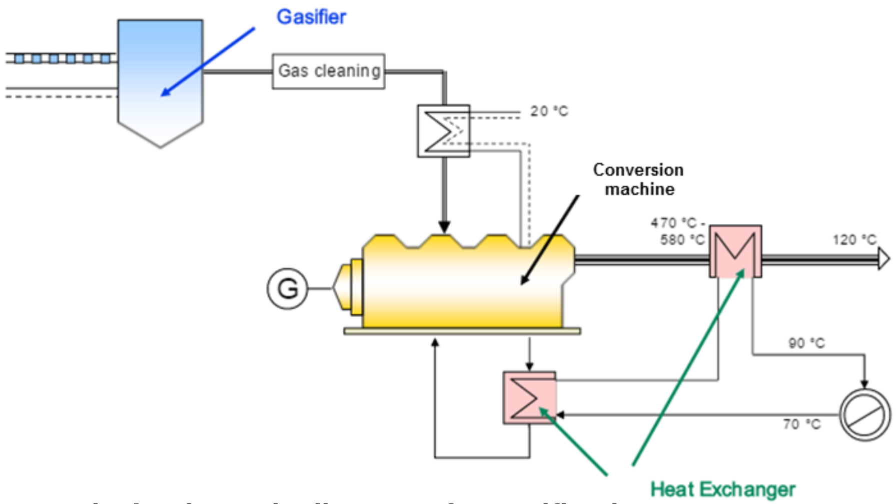
Biomass Conversion : Gasification with Gas turbine



Gasifier technology offers the possibility of converting biomass into a producer gas, which can be burned in gas turbines. Fixed bed gasifiers are the preferred solution for small- to medium-scale applications. Updraft gasifiers can scale up to 40 MWth while down-draft gasifiers do not scale well beyond 1 MWth. They typically have a grate to support the gasifying biomass and maintain a stationary reaction bed. They are relatively easy to design and operate and generally experience minimum erosion of the reactor body.

Source: IRENA, MHPS

Biomass CHP Plant with Gasification



Typical Schematic diagram of a Gasification process

The downdraft gasifier is used for small scale gasification of woody biomass of uniform sizes and shapes. The gasifier can handle uniformly sized biomass fuels having moisture content and ash content less than 20 % and 5 % respectively. The producer gas from downdraft gasifier has lesser tar-oils (<1 %), higher temperature (around 700 ºC) and more particulate matter than that from an updraft gasifier.

Weak points

The downdraft gasifier has lower overall efficiency since a high amount of heat content is carried over by the hot gas. Because the product gas contains tar, oil, phenols and ammonia, the major disadvantage of gasification Biomass CHP Plants are the high cost associated with the cleaning of this gas. In effect, removal of tar is one of the biggest technical challenges facing the commercialization of gasification technology. If not removed, the tar condenses on the wall of the downstream equipment such as heat exchangers, combustion engine, reactors or fuel cells. In addition, the gasification process produces excess steam for temperature control that leads thermal losses and requires special condensate treatment

Source: Kumar et Al., Warnecke et Al., Chopra et Al., Fichtner

Biomass Conversion : ORC Turbines

Organic Rankine Cycle (ORC) power plants work on the same principle as steam turbines but use an organic fluid instead of water. Thanks to different physical properties, the use of an organic fluid leads to more reliable and higher efficiency plants for low to medium temperature heat sources and small-to-medium-size plants. ORC technology is commercially available but has been continuously improved. ORC process needs an intermediate thermal oil cycle. This cycle is operated at ambient pressure but high temperatures.

Source: IEA, Turboden

Biomass Conversion : ORC Turbines

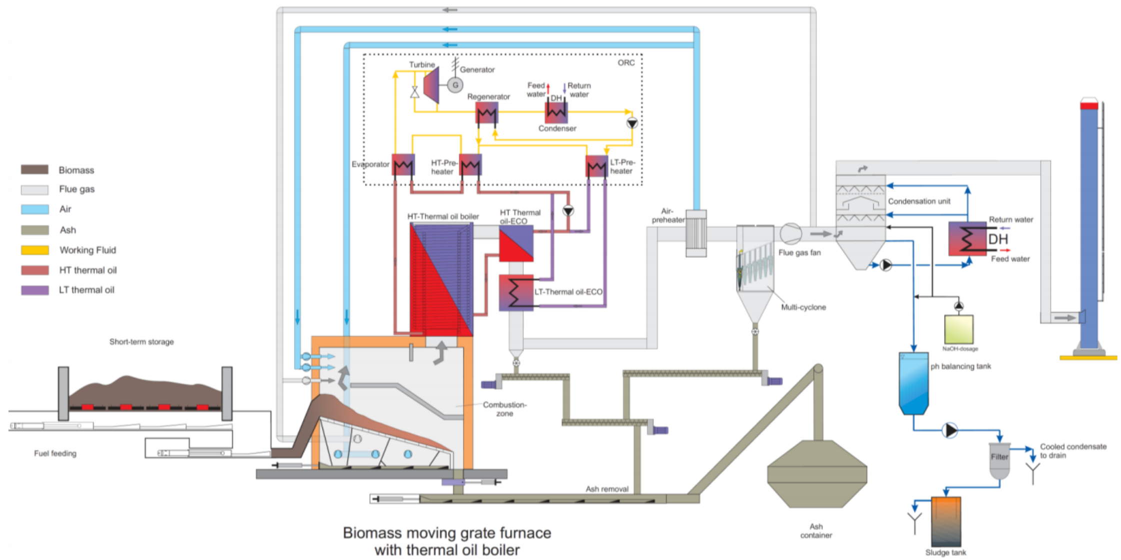
A number of ORC based systems are available for small scale biomass CHP applications. The benefits of using an organic working medium in place of water are:

- It is less corrosive
- The necessity for superheating to ensure there is no droplet formation during the pressure drop in the turbine is removed
- The turbine can operate at a lower speed, reducing stress on components and allowing direct drive of the generator without reduction gearing.

Source: Biomass Energy Centre, Enertime

Biomass CHP Plant with ORC process

Technology suppliers provide the ORC technology in complete and compact modules which only have to be connected to the thermal oil cycle, the water cycle and the electricity interfaces. The biomass-fired thermal oil boiler, the thermal oil economisers and the air pre-heater are equipped with an automatic cleaning system based on pressurized air. This system has already proved its efficiency due to the fact that manual boiler cleaning is necessary only once a year and boiler operation takes place without rising flue gas temperatures at boiler outlet. This aspect is of great relevance for a high availability and overall efficiency of the CHP plant.



Schematic diagram of the overall biomass CHP plant based on ORC turbine

Weak points

Due to the limited operation (feed) temperature of thermal oil and silicone oil, the electric efficiency is limited. Furthermore, the thermal oil is flammable and therefore needs different safety equipment and precautions to enable a safe operation

Source: IEA

Biomass Conversion : Steam Turbines

Steam turbine CHP systems generate electricity as a by product of heat (steam) generation. A steam turbine requires a separate heat source and does not directly convert fuel to electric energy. The energy is transferred from the boiler to the turbine through high-pressure steam, which in turn powers the turbine and generator.

In CHP applications, steam at lower pressure is extracted from the steam turbine and used directly or is converted to other forms of thermal energy.

Source: SEAI, Siemens

Biomass Conversion : Steam Turbines

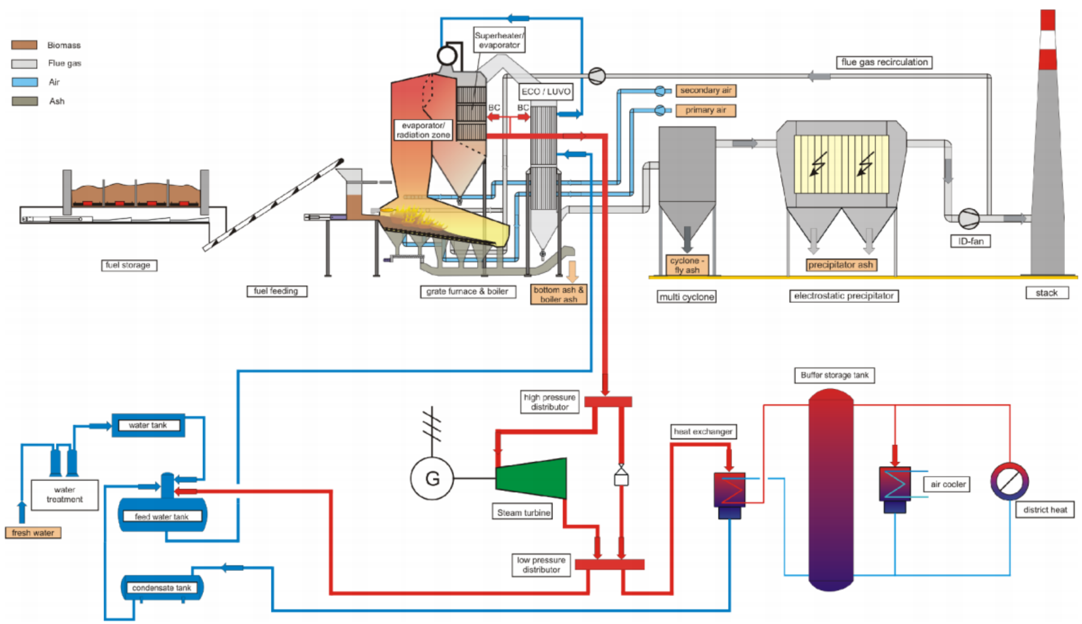
The attainable electric annual use efficiency (= annual electricity production / annual fuel input based on its net caloric value) depends on the live steam parameters (temperature, pressure) and on the other hand on the necessary temperature level for the process and/or district heat consumers.

Electric annual use efficiencies are usually between 18 and 30 % for biomass CHP plants in the capacity range between 2 and 25 MWel.

Source: SEAI, Siemens

IRENA
International Renewable Energy Agency

Biomass CHP Plant with Steam process



Schematic diagram of the overall biomass CHP plant based on steam turbine

Since the steam turbine requires a very constant operation, the <u>steam parameters</u> must be <u>kept as constant as possible</u>. In order to fulfil these requirements, the <u>fuel mixture</u> must be <u>kept as homogeneous as possible</u> (as different biomass fuel fractions with different water contents are used).

The main focus on further investigations is based on steam parameters to increase the plant efficiency.

Weak points

<u>Changing fuel composition and quality have an impact on the steam quality and in consequence on the performance of the steam turbine.</u> The performance of the plant is limited by the steam parameters. Further rising of temperature leads to the need of special materials and increases the high temperature corrosion risk and the specific investment costs.

Source: IEA

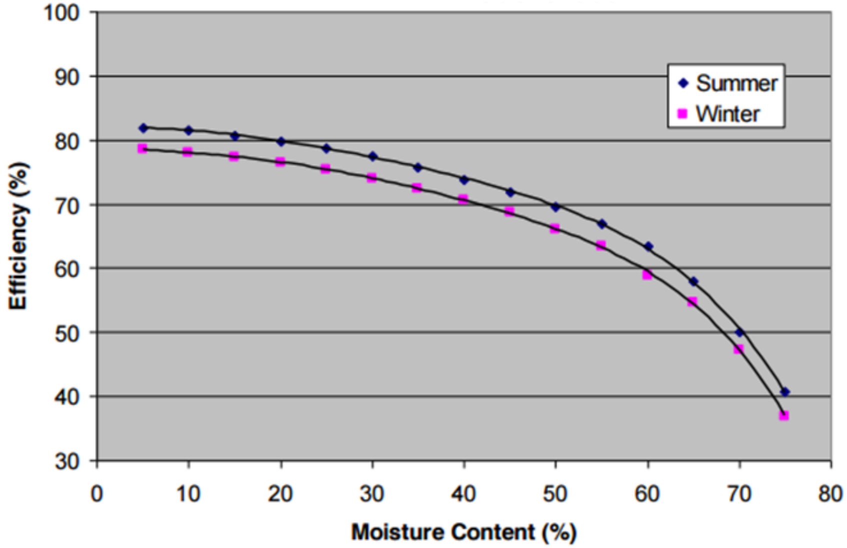
Cost and performance for Biomass CHP Plants

	Typical unit cost ($/kW)	Nominal total gross efficiency (% thermal)
CHP plant based on **combustion** with Steam Turbine	1500-2500	~80%
CHP plant based on **combustion** with ORC Turbine	3000-4000	~85%
CHP plant based on **gasification** with Gas turbine	3000-3500	~70%

Source: IRENA, IEA, Bios Bioenergiesysteme

Moisture content efficiency impact

A high share of moisture content reduces the efficiency of Biomass CHP plants



Typical Biomass CHP Plant efficiency (with Gas Turbine)

One way to address this issue is to include a Biomass drying unit to increase efficiency. It also provides additional operational advantages such as prevention of auto-ignitions in wet bark piles, reduction of drymatter losses due to microbiological degradation processes during storage, and reduction of storage volume at the plant facility.

However, adding biomass drying unit to increase plant efficiency must be balanced against additional investment & operating costs (machine costs, electricity consumption, man & machine hours).

Source: FPInnovations, UNDP

Alternative technologies for Biomass CHP plants

Small Scale	Large Scale
• Internal combustion engine, • Reciprocating steam engine, • Stirling engine,	• Integrated gasification combined cycle (IGCC), • Steam injected gas turbine (STIG)

Source: IRENA, IEA, Biomass Energy Centre

IRENA Innovation and Technology Centre
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