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TRIGENERATION POWER PLANTS USING BIOMASS FOR SUSTAINABLE DEVELOPMENT AND REDUCING POLLUTION

Krisztina UZUNEANU, Gelu COMAN, Marcel DRAGAN
"Dunarea de Jos" University of Galati

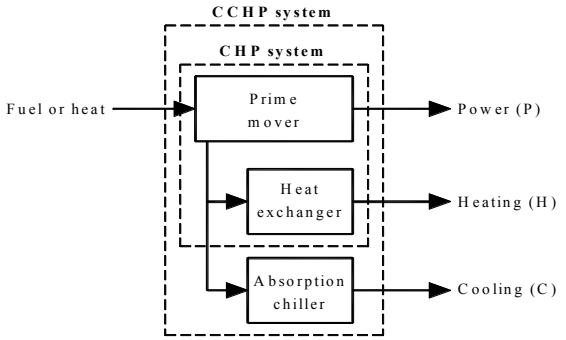
ABSTRACT: The tri-generation principle is well known and it basically consists in the simultaneous production of power, heating and cooling. One of the most significant ways of achieving the concept of sustainable development may be the use of biomass in tri-generation plants. Biomass needs to undergo several processes so that it can be widely used as a source of energy. These processes will transform its accumulated energy (carbon and hydrogen) into solid, liquid and gaseous fuels. Thus biomass is a promising alternative in using in micro tri-generation plants, especially in residential areas.
KEYWORDS: biomass, tri-generation, sustainable development, pollution

1. TRI-GENERATION CONCEPT

The tri-generation concept refers to the simultaneous production of mechanical power (usually converted to electricity), heat (at low and high temperatures) and cooling (using heat at high temperature) using only one source of primary energy [1, 7]. This source is represented by fossil fuels or by some appropriate types of renewable energy sources (biomass, biogas, solar energy, etc).

Tri-generation systems (Combined Cooling, Heating and Power Systems - CCHP) use fuels in more efficient way than if the desired products were produced separately.

The assessment of the tri-generation plants can be made according to various criteria, such as:energetic efficiency, exergetic efficiency and fuel savings.



- ***Fig. 1*** [12]

The fuel savings is determined by the difference in the consumption of fuel by separate heating, cooling and power productions, F_S and total consumption of fuel by tri-generation heat and power productions, F_{TG}.

These performance criteria show certain advantages of the tri-generation plants as compared with the separate systems of heat, cooling and power are achieved.

One objective of tri-generation systems is the diversification of energy sources, especially use of renewable ones, accordingly to the geographical location and possibilities [18].

2. A MICRO CCHP SYSTEM

At the moment, small scaled combined heating, cooling and power systems are emerging on the market and it is a very good solution especially to supply energy for individual houses, offices, hotels and small building blocks.

These micro CCHP Systems are however quite expensive and not enough diffuse in Europe.

Micro-CCHP systems represent an opportunity to address all of the following requirements at once: conservation of fossil energy resources, moderation of pollutant release into the environment and assured comfort for home-owners.
The residential consumers' energy demand is made of the following:

- the electrical demand for the home utilities
- the hot water demand
- the heating/cooling demand

The electrical demand of the residential consumer is dependent on the endowment of electrical devices in the house. The standard monthly consumption of a

Romanian residence is (100-300) kWh and can be considered constant for a residence.
The medium hot water consumption is estimated to 50/liters/day/person.
The specific heat and cooling consumptions differ from country to country (climate), but also depend on the residential consumers' comfort level.

Tri-generation system applied to residential buildings covers the usual thermal power needs < 25 kW(th) and electrical power needs < 5 kW(e) [4, 9].

The fundamental requirement for a tri-generation micro-CCHP system is to provide full services and comfort for the customers with or without external supply of power while utilizing electricity and fuel in the most efficient manner through heat recovery and other integrated system solutions.
The target customers are people with houses located outside the utility's distribution lines or in areas with unreliable electric grid service. [11, 16]

The micro-CCHP systems comprise a prime mover, which generates electricity, and the heat recovery and utilization components which use the heat rejected by the prime mover provide space heating, hot water, and cooling [10].
The prime movers to be evaluated include:
- reciprocating engines;
- micro steam and gas turbines;
- fuel cell systems;
- Stirling engines. [5, 13]

They can do a comparison between all prime movers [14] and it results the Stirling cycle engines can use different types of renewable sources of energy including biomass, solar and geothermal energy, but for small-scale CCHP systems using biomass as a renewable fuel, the Stirling engines are the best solution for plants with nominal electric capacities between 10 and 150 kW [9].

The Stirling engine is an external combustion engine which uses an external source of heat obtained in a separate combustion chamber [11, 13, 14, 17].
In order to use Stirling engines in tri-generation plants we have to take into account the advantages and disadvantages of these engines.
Some advantages are:

- The Stirling engines use on a large variety of fuels, including all fossil fuels, but also renewable fuels like: biomass, solar, geothermal and nuclear energy.
- The emissions released are very low, since the combustion can be controlled and monitored.
- The noise produced by a Stirling engine is lower than that of an internal combustion engine.
- The Stirling engine has a long driving time, (about 10000 hours between overhauls) and the requirements for maintenance are low.
- The efficiency when converting heat to electricity is 15-30%
- The cost of 1 kWh of power from a tri-generation system is 3 – 4 times less than for centralized power systems, and the heat generated is essentially free [12]

The major disadvantages of the Stirling engines include [6]:

- The high cost;
- The engine needs a few minutes to warm up;
- Low durability of some parts.

3. BIOMASS IN TRI-GENERATION PLANTS

Global warming due to carbon dioxide (CO_2) emission has become a serious environmental issue in recent years. The current living and economical standards depend strongly on all energy sources, it is necessary to realize a new technology that utilizes biomass as a source of energy. Climate change and limited fossil resources call for a reduction of non - renewable primary energy input and greenhouse gas (GHG) emissions by 50 to 80 % by 2050.

Tri-generation plants using biomass are used in order to achieve a sustainable development in energetic area, especially for reducing the impact of greenhouse gas emissions. Burning of biomass in cogeneration plants leads to obtain carbon dioxide which is further consumed by plants.
For this reason biomass is included in the category of renewables. Biomass is the only carbon-based renewable fuel so this is the reason its application becomes more and more important for climate protection [8].

The advantages of using energy from biomass and from anaerobic digestion processes:

- It is a way for companies to use wastes in order to generate energy while reducing their storage costs.
- The biomass is a renewable source. Fuel can be obtained from different grains and plant waste that may otherwise be thrown away.

Organic waste such as dried trees, leaves, hay, animal carcasses or other debris resulting from food processing are abundant and can be used to produce energy.
Residues generated by human activity, such as paper or garbage, can be collected and used as biomass to produce energy

- It can be used in combination with other energy sources in installations that generate both current and heat.
- Burning biomass releases a smaller amount of carbon dioxide emissions than coal or gas.

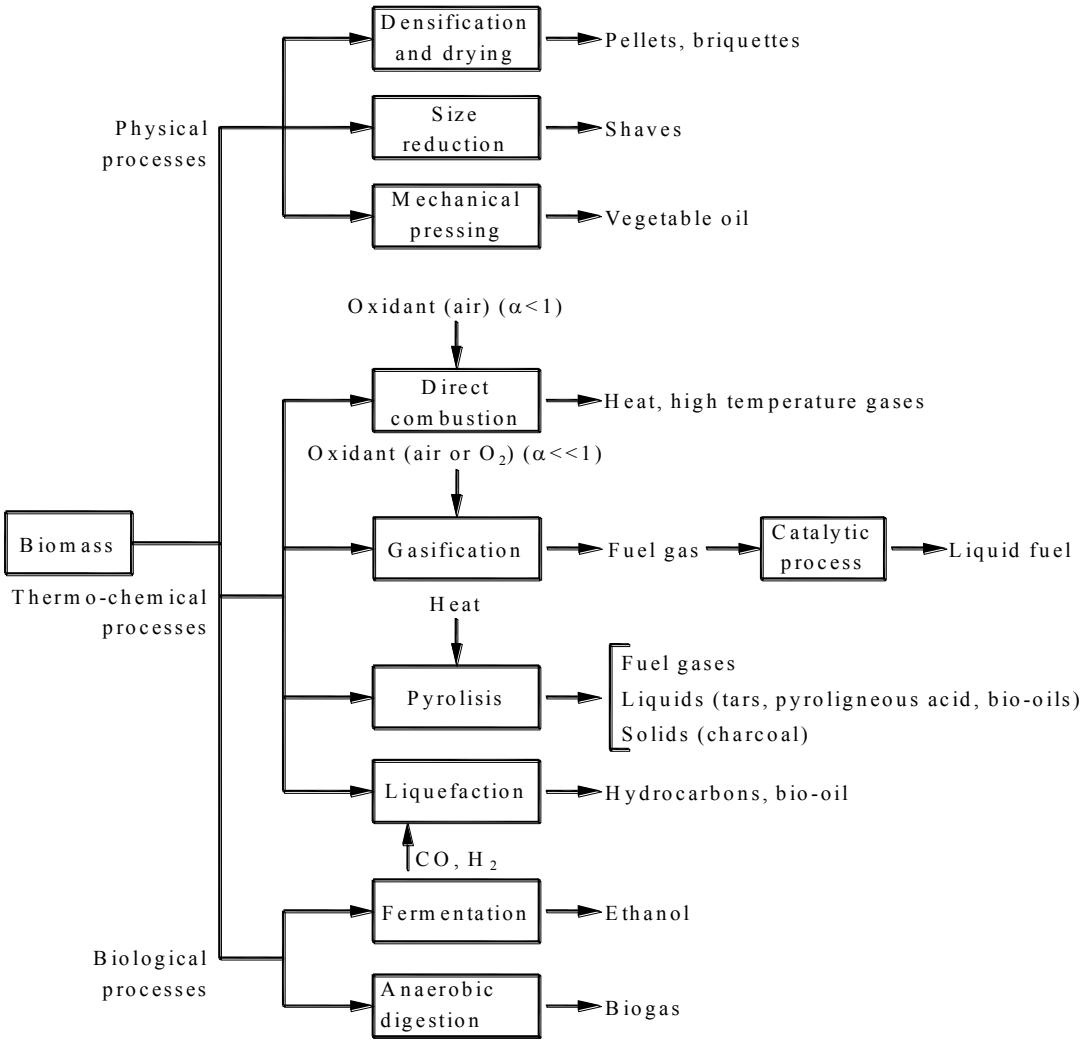


Fig. 2 Biomass energy conversion routes [15].

- The use of energy from biomass can greatly reduce transportation costs because it can be used in the same area where it is produced without the need for pipeline networks or transmission lines laid out over long distances.

The disadvantages of using energy from biomass and from anaerobic digestion processes:

- To avoid carbon dioxide emissions, biomass needs to be transformed into another type of fuel such as alcohol or methane.

In order to use biomass as a source of energy, this needs to undergo several biological, chemical and physical processes [2, 3, 15]. These processes will transform biomass accumulated energy (carbon and hydrogen) into solid, liquid and gaseous fuels.

Biological processes lead to obtain biogas and ethanol, thermochemical processes lead to obtain This conversion process requires energy thus making biomass-based energy too expensive to use on a small scale.

- Extended spaces are needed to store biomass fuels.
- Ensuring sufficient fuel supply can be difficult. If there is the intention to use waste generated by own business, they have to make sure there are enough quantities.
- Another problem is water because waste recycling processes require a large amount of water . liquid fuels by means of combustion, gasification, pyrolysis and liquefaction and physical processes lead to obtain vegetable oils, shaves, pallets and briquettes by mechanical pressing, size reduction and drying.

Fig. 2 displays the details of three kinds of conversion processes: physical, thermo-chemical and biological.

The problems that can apear when using biomass in Stirling engines are related with transforming the heat

which results from combustion process into ta working gas (fuel).

The own characteristics of biomass can raise few energetic problems. The high content of carbon (48 - 53%), oxygen (39 - 44%) and hydrogen (6 – 10%) lead to an inferior heating value of biomass and therefore a bigger amount of biomass is needed to obtain the required power [15].

However, the biomass as pallets can be successfully used as renewable fuels in Stirling engines as prime movers of co- and tri- generation plants [19].

4. CONCLUSIONS

Stirling engines as prime movers in micro-CCHP systems have a high thermal and electrical efficiency when they use renewable fuels as biomass pallets.

All the evaluation made show that Stirling engines are appropriate to be used in a micro-CCHP system, especially for residential houses in isolated areas, small buildings, hotels.

Besides the economy of fossil fuels, using biomass leads to low level of pollution because a small amount of CO_2 is obtain in combustion process.

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