Biomass gasification in small scale energy systems

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Introduction

Coal, natural gas, oil and nu clear energy are the basic primary energy carriers that serve to pro duce electricity, heat and cold. It is estimated that in 2006 share of the above mentioned energy carriers in global electricity production was equal to 82% [1, 2]. On the other hand in recent years, when selecting new energy technology, most often a deciding influence has also ecological considerations. These are very often more important than economic indices. This has found a special emphasize in energy policies of the European Union countries, where reduction of anthropogenic emissions of greenhouse gases, including first of all carbon dioxide, constitutes a special challenge for the energy industry in the years to come. Main priorities of the European energy Policy until 2020 that were assigned by the EU Parliament cane is referred to as:

- 20% reduction of greenhouse gases emissions in relation to the level from 1990
- 20% reduction of global primary energy consumption (achieved through increase of energy efficiency in energy production, energy efficiency of equipment and generally by energy savings etc)
- reaching 20% share of renewable energy sources in total primary energy balance.

Accomplishment of these objectives can be executed among others by increasing the share of biomass utilisation as a fuel for energy systems. Biomass, as one of the basic renewable energy sources (RES) is an interesting carrier of chemical energy, which can be converted into electricity, heat or cold. In addition, in a long term perspective till 2050, biomass is regarded, in a group of organic fuels, as one of the fuels that constitute source of primary energy for gas-steam systems integrated with gasification (including also the installation of capturing of CO_2) [3]. Actually, due to specific characteristics, biomass is utilised mainly in small or medium energy systems that serve first of all as electricity or heat producers. Biomass that is an after production waste seems to be especially very attractive and can be utilised as a fuel for the cogeneration systems integrated with gasification.

There exist many possible methods of solid biomass classification. One of the accepted criteria has been division into main classification groups and sources. In figure 1 the idea is presented of biomass division into main groups and classification of origin and sources of solid biomass.

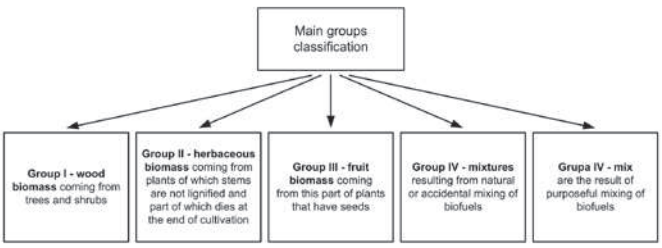

Fig. 1. Main classification groups of origin and sources of solid biomass [4]

Biomass is utilised for energy purposes mainly in processes of combustion, not so often in gasification and pyrolysis. In figure 2 are presented opportunities of using biomass to produce electricity and heat by means of thermal and thermochemical conversion.

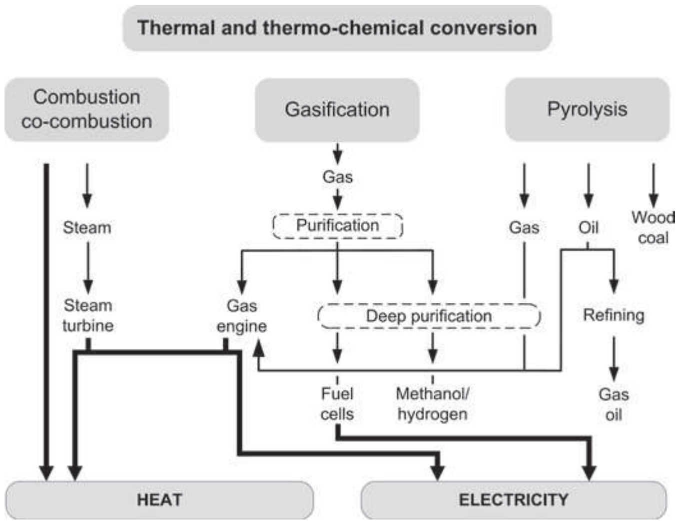

Fig. 2. Opportunities of thermal and thermochemical conversion of biomass into electricity and heat [2]

It has been estimated that world's biomass potential to be used for energy purposes in 2006 was equal to 1186 Mtoe, and in 2030 is going to Reach about 1660 Mtoe [1,2]. This means that in 2030 the biomass share in primary energy demand will constitute about 10%.

Rising electricity and heat prices delivered from power plants to the enterprises-consumers are the reason that companies aiming to reduce costs of purchasing energy media undertake their own efforts to produce energy on site. In recent years it has been observed rising interest in small and medium size systems that produce electricity and heat in cogeneration. Cogeneration systems called also in English CHP (Combined Heat and Power) systems are characterised first of all by high overall energy efficiency, low emission of pollutants and possibility to burn low calorific gases, high availability, short construction periods and attractive economic indices of investment. Management (i.e. utilisation) of own enterprise's residues and after production wastes from wood industry, agricultural production and from specially dedicated energy crops in order to produce electricity and heat through the application of the cogeneration system can bring about measurable benefits. These benefits are referred to as indigenous and cheaper electricity and heat, open opportunity to get receiving additional revenues from selling certificates of green (renewable energy) and yellow (cogenerated energy).

Basic solutions for energy systems fed with process gases from biomass gasification can be referred to as [5]:

- piston gas engines or micro-turbines
- stirling engines

- condensing power plants with the organic energy carrier the so called Organic Rankine Cycle power plants
- systems with steam boilers fired with biomass.

Selected exemplary energy systems of small capacity integrated with biomass gasification

Among small units producing energy and heat in cogeneration, first of all, the systems with gas piston engines have been developed. This is connected mainly with lower investment in relation to other types of equipment and with lower requirements to the purity of process gas. Below in figure 3 the general flow diagram of biomass gasification with piston gas engine is presented. Installation comprises: system for fuel preparation, objective of which is to chop/comminute of biomass and pre-drying of the fuel, gas generator, system of gas cleaning to comply with the requirements of low dust and organic pollution in the raw gas to engine, and gas piston engine geared with electricity generator and finally, system of heat recovery from the flue gases.

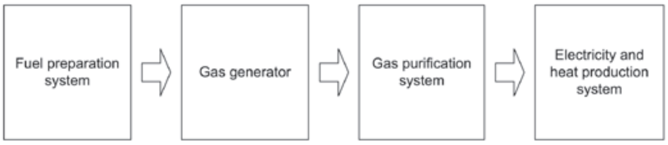

Fig. 3. General flow diagram of biomass gasification installation with internal combustion gas engine

Biomass gasification installation in Güssing (Austria)

One of the exemplary of small capacity installations using biomass gasification technology has been installation located at Güssing in Austria. Construction started in September 2000 and commissioning took place in November 2001 [6,7]. Figure 4 presents simplified flow diagram of the installation in question for wood gasification. The installation comprises six basic blocks. First block of the installation is the system of fuel preparation, the objective of it is first of all to pre-dry wet biomass by means of hot air, which is produced from low grade waste heat from the gasification installation, the overall efficiency of the system is thus increased. Second block constitutes gas generator with the circulated fluidised bed, gas generator uses steam as the gasifying agent. Gas produced in reactor (i.e. in second block) prior to its combustion in engine is directed to the third block, objective of which is to clean it. First, gas with temperature of about 850°C is being cooled down in a heat exchanger to the temperature of about 150°C. In bag filter the particulate pollutants are captured, and afterwards they are recirculated back to combustion chamber (i.e. to gasifier) due to high

C content in particulates. Preliminary cleaned process gas is directed to scrubber, the purpose of the scrubber is to remove organic impurities, ammonia and other chemical compounds. In the consecutive block chemical energy contained in gas is transformed into heat and electricity is means of the specially adopted for this purpose IC engine that is geared with electricity generator. Into this system the ORC system was also added, the ORC system play a role of extracting additional electricity from the waste heat from the separate elements of the installation. The energy carrier in the ORC system has been low boiling liquid, which makes it possible to generate organic vapour from low grade heat. The last block of this installation has been system of flue gases recovery from the combustion zone of the gas generator. The flue gases created in the combustion zone at temperature of about 900°C are cooled down and dust is precipitated at the bag filter, then they are exported to atmosphere by means of a stack. Heat of flue gas cooling is being utilized in the ORC system.

Application of steam as the gasifying agent significantly increases net calorific value of the resulting gas. Gas produced in gas generator has its NCV (net calorific value) at the level of about 12 MJ/m^3_n and with the following shares of the main constituents of process gas:

- hydrogen - about 40%
- carbon oxide - about 26%
- carbon dioxide - about 19%
- methane and hydrocarbons C_2-C_6 - about 12%.

The balance (makeup to 100%) goes to nitrogen and impurities. Availability of gas generator as well as of gas engine has risen significantly from since the beginning of operation of the installation, and in 2005 was equal to over 90% for gas generator and for the gas engine supplied by GE Jenbacher was over 80%. Investment costs were equal to 9 million euro, and cost of optimisation of the installation addend to this figure 1 million euro.

Technological parameters of the installation:

- fuel's chemical energy input - 8 MW_{th}
- thermal output - 4.5 MW_{th}
- power output - 2 MW_{el}
- electric efficiency - 25%
- total system efficiency - 80%.

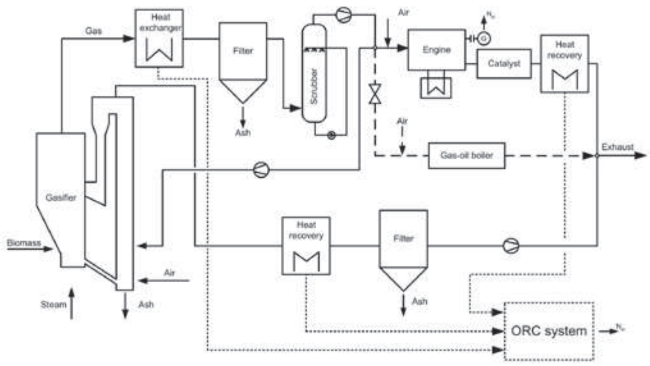

Fig. 4. Flow diagram of biomass gasification installation in Güssing [6, 7]

Biomass gasification installation in Louka (Czech Republic)

In Louka south of Czech Republic was built installation for gasification of wood waste that is recovered from the nearby sawmill. Installation comprises gas generator Imbert type with fixed bed, which has a specific narrowing (choke point) in lower part of the reactor. The generator is supplied with the flue stream of 190 kg/h and net calorific value of 14 MJ/kg. Gas produce in the generator has average net calorific value of 5.2 MJ/m^3_n and exhibits following composition:

- hydrogen - about 16%
- carbon oxide - about 20%
- carbon dioxide - about 10%
- methane - about 1%.

Biomass is proportioned in batches by opening upper cover of the reactor. Wood from the fuel tank is transported first by the conveyor and then by means of trolley (or fork lift) is loaded to gas generator). Ambient air heated up to temperature of 200÷250°C constitutes the gasifying agent. Temperature in the gasification zone is equal to about 850°C. Gas temperature at the outlet of generator reaches about 400°C. First element of gas cleaning is cyclone, which role is to remove coarse dust and then gas is directed to the bag filter where minute particles are removed. The consecutive element of the gas cleaning system is cooler, which cools the gas down to about 70°C and then gas is directed to water scrubber. Gas cleaned in this way is forced to the cogeneration unit to produce electricity and heat. The installation applied gas engine of TEDOM Company, gas engine exhibits electricity production efficiency of 35%. Presented installation is able to produce 200kW_{el} of electricity and 350 kW_{th} of heat.

Biomass gasification installation in Zabrze, Poland

At the Institute for Chemical Processing of Coal in Zabrze, Poland it was developed and constructed experimental installation for gasification of different types of biomass. System of biomass gasification is presented in figure 6, it comprises three zone gas generator, dry system of gas cleaning and double-fuel IC engine coupled with electricity generator in order to be able to produce electricity and heat in cogeneration. Gas generator (it goes by name GazEla) GazEla has been three zone reactor with the fixe bed. Ambient air constitutes the gasifying agent and is delivered by means of the radial fan to three areas (zones) of the reactor: under grate, to middle part of the reactor and above the bed of the fuel. Fuel stacked outside of the hall is delivered by means of bucket conveyor first to the biomass tank, then by means the screw proportionate feeder to the upper part of the generator. Biomass in the reactor undergoes in sequence the following thermal processes:: drying, pyrolysis, partial combustion, gasification and final combustion of the carbonizate in order to deliver heat for the endothermic gasification process. Gas generator constitutes a vertical cylindrical reactor.. One of the main advantages of gas generator GazEla is the possibility to change the point of process gas evacuation by means of the up comer pipe that exists inside of it. Proper selection of the point of gas evacuation makes it possible to minimize amounts of the organic substances that are created during gasification process and to optimise composition of the process gas from the point of view of its further utilisation. [9, 10, 11].

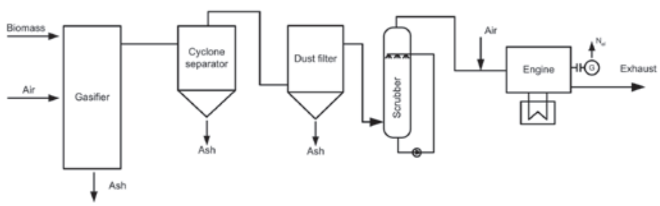

Fig. 5. Flow diagram of biomass gasification installation in Louka [8]

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Generator GazEla fed with the fuel stream e.g. woodchips at the level of about 14÷15 kg/h and with NCV of 14,5 MJ/kg produces gas with NCV in the range of 4,5÷5 MJ/m^3_n and with the following average constituents' concentrations:

- hydrogen - about 7,5%
- carbon oxide - about 25%
- carbon dioxide - about 9.5%
- methane - about 2.1%.

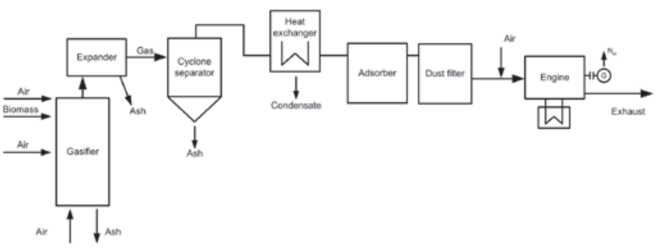

Fig. 6. Flow diagram of biomass gasification installation developer at the Institute for

Cold efficiency of the gas generator is equal to 63%

Gas produced in a gas generator prior to being directed to piston gas engine is subjected to cleaning from organic pollutants and from particulates. First element of the cleaning system is the inertial expander, its role is to take higher size particulates that are carried over by the process gas as well as to take moisture in the beginning startup phase of the installation. The consecutive element of the cleaning systems is cyclone that removes minute dust particles. Process gas that underwent preliminary cleaning is then directed to the process gas cooler, where it is cooled down to about 30÷40°C in order to condensate organic pollutants. The next element of the gas cleaning system is coke filter and bag filter, which are to remove the smallest dust particles. During gas cleaning the organic pollutants are reduced by 50% reaching at the system outlet 1900 mg/m^3_n of tars, but the efficiency of particulates (dust) removal is as high as 95%. The final (experience) dust load at the outlet from the gasification-cleaning system is equal to 50 mg/m^3_n. Clean gas is then directed to the double-fuel IC

(internal combustion) engine. Basic fuels of this engine has been diesel oil. Gradual increase of the process gas supplied to the engine automatically reduces amount of oil consumed by the engine. For the minimum parameters of the engine electricity production was equal to 15.5 kWel, the process gas stream delivered to the engine was about 40 m^3_n/h, and diesel oil delivery to the engine was equal to 2.4 l/h.

Summary

Application of biomass gasification technology in small and medium sized cogeneration units seems to be an interesting method of increasing the share of RES

(renewable energy sources) in the overall fuels balance in Polish energy sector. Distributed energy systems supplied with the fuel that is the after production waste from the wood industry and from agriculture can be especially attractive. This fuel can be processed on site in place of its creation, other fuels can come from the biomass from specialty dedicated energy crops.

Presented in this paper three exemplary installations for biomass gasification confirm technological feasibility of the CHP systems supplied with this type of fuel. Installation of wood gasification in Güssing, exhibits the highest level of system development, steam constitutes the gasifying agent, which allows to increase the net calorific value of the gas from 4÷5 MJ/m^3_n to 12 MJ/m^3_n, as compared to systems in Louka and Zabrze. The consecutive advantage of the Austrian installation is application of the fluidised bed and the ORC system that allows to increase amount of electricity and heat being produced. On the other hand systems installed in Poland and in Czech Republic exhibit significantly lower investment expenditures, which is especially of great importance in case of small systems installed in small production enterprises. In addition, simplicity of the gas generators with fixed bed, lack of the complicated elements in the system and lack of additional media (carriers) in the system of gas cleaning (like in case of the IChPW installation) allow to reduce significantly operating costs, which in turn improves the bottom line of the measure (investment).

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Translation into English by the Author

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18-22 September 2011 Villa de Leyva, Columbia North America

Official Information

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26-28 September 2011 Schaffhausen, Switzerland Europe

Official Information

The 25th conference of spectrometry (25. Spektrometertagung) will take place in Schaffhausen (Switzerland) between 26th and 28th of septembre. The conference is organzied by SASP (Schweizerische Arbeitsgemeinschaft für Spektrometrie und Elementanalytik, http://www.sasp.ch). Subjects of the conference are: New methods of spectrometry, metal analysis, environmental analysis and more.

Traditionally the language of the conference of spectrometry is German. Nevertheless participants of non German speaking countries are invited for English presentations and discussions.

Contact: www.spektrometertagung.ch