Biomass CHP Plant Güssing – Using Gasification for Power Generation

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ABSTRACT: The combined heat and power (CHP) plant has a fuel capacity of 8 MW and an electrical output of about 2 MWel with an electrical efficiency of about 25 %. Wood chips with a water content of 20 - 30 % are used as fuel for the FICFB (Fast Internal Circulating Fluidised Bed) gasification process, which is an innovative process to produce a high grade synthesis gas from solid fuels. The gasification zone is separated from the combustion zone using two fluidised bed reactors. The bed material circulates between these two zones to serve as a heat carrier for the gasification process. The necessary heat is obtained by burning remaining charcoal or additional fuel in the combustion zone. Steam is used as a gasification agent, to yield a nearly nitrogen free product gas with high calorific value of 12 MJ/Nm³ dry gas. The start up of the plant was in January 2002, until December 2002 the gasifier and the gas cleaning system reached 3000 hours of operation, together with the gas engine 1050 hours of operation could be reached.
Key words: gasification, fluidised bed, power generation, demonstration

INTRODUCTION

The use of biomass as a source of energy in Austria amounts to approx. 11 % of the entire primary energy demand. For the last 10 years this proportion has remained unchanged, although high priority is being given to renewable forms of energy. A decline can be found in some fields, like wood stoves, whereas an increase can be seen in the fields like woodchip burning and district heat supply systems.
Climatic conventions (Kyoto, Buenos Aires) and the European Union White paper demand a substantial increase in the use of biomass, which can be achieved only if new applications for the use of biomass are developed, like electric power generation from biomass. Gasification seems to have the greatest potential in this area, offering great flexibility and high electrical as well as high overall efficiencies.
These conditions led to the development of the FICFB-gasification system (**F**ast **I**nternal **C**irculating **F**luidised **B**ed) [1, 2, 3, 4] by the Institute of Chemical Engineering together with AE Energietechnik.
The fundamental idea of this gasification system is to physically separate the gasification reaction and the combustion reaction (*Fig. 1*) in order to gain a largely nitrogen-free product gas. Biomass entering the stationary fluidised bed gasification reactor is heated up, dried, devolatilised and converted to CO; CO_2; CH_4; H_2; H_2O_g as well as char (C). Simultaneously the strongly endothermic gasification reactions (reactions with water vapour) take place (1, 2).

$$CO + H_2O \rightarrow CO_2 + H_2 \tag{1}$$

$$C + H_2O \rightarrow CO + H_2 \tag{2}$$

A chute connects the gasification with the combustion section, operating as a circulating fluidised bed. Bed material together with any non-gasified carbon is transported through this chute into the combustion section, where the remaining carbon is fully combusted. The heated bed material is separated by e.g. a cyclone and fed back into the gasification section. The necessary heat required for the gasification reactions is produced by burning carbon brought along with the bed material into the combustion section. Additionally, the temperature in the combustion section is controlled by supplementary fuel, like recirculated product gas or wood. The gasification section is fluidised with steam, the combustion section with air, resulting in two different gas streams, a nearly nitrogen-free product gas with a calorific value of 12 MJ/Nm^3 (dry) and a flue gas from the combustion section.

The FICFB-gasification system has, in contrast to conventional gasifiers operated with air, the advantage that it produces a nitrogen-free gas, which after appropriate cleaning and treatment is usable as a synthesis gas in the chemical industry or as a source of energy. In this paper the development of this process from a pilot plant to the commercial plant in is given.

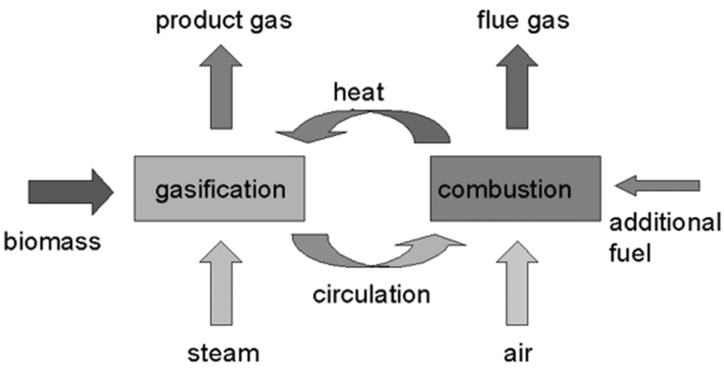

Fig. 1: Principle of FICFB-gasification process

DESCRIPTION OF THE COMBINED-HEAT AND POWER (CHP) PLANT

In Güssing this innovative process for combined heat and power production based on steam gasification has been demonstrated. Biomass is gasified in a dual fluidised bed reactor. The producer gas is cooled, cleaned and used in a gas engine. A detailed flow sheet is shown in Fig. 2. , characteristic data of the demonstration plant are summarized in Table 1.
Biomass chips are transported from a daily hopper to a metering bin and fed into the fluidised bed reactor via a rotary valve system and a screw feeder. The fluidised bed gasifier consists of two zones, a gasification zone and a combustion zone. The gasification zone is fluidised with steam which is generated by waste heat of the process to produce a nitrogen free producer gas. The combustion zone is fluidised with air and delivers the heat for the gasification process via the circulating bed material.

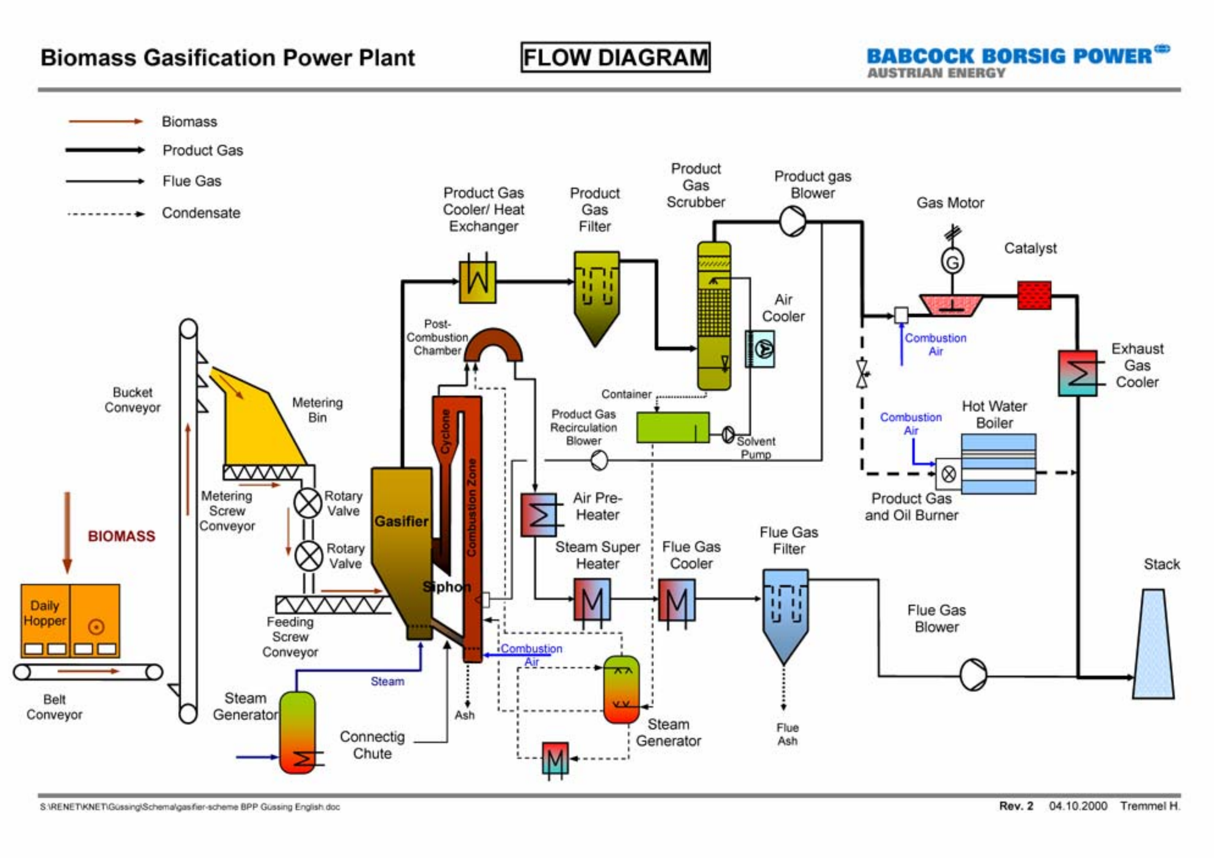

Fig. 2: Flow sheet of CHP-plant Güssing.

Table 1: Characteristic data of the plant.

Type of plant	Demonstration plant	
Fuel Power	8000	kW
Electrical output	2000	kW
Thermal output	4500	kW
Electrical efficiency	25,0	%
Thermal efficiency	56,3	%
Electrical/thermal output	0,44	-
Total efficiency	81,3	%

The producer gas is cooled and cleaned by a two stage cleaning system. A water cooled heat exchanger reduces the temperature from 850°C – 900°C to about 160°C – 180°C. The first stage of the cleaning system is a fabric filter to separate the particles and some of the tar from the producer gas. These particles are returned to the combustion zone of the gasifier. In a second stage the gas is liberated from tar by a scrubber.

Spent scrubber liquid saturated with tar and condensate is vaporized and fed for thermal disposal into the combustion zone of the gasifier. The scrubber is used to reduce the temperature of the clean producer gas to about 40 °C which is necessary for the gas engine. The clean gas is finally fed into a gas engine to produce electricity and heat. If the gas engine is not in operation the whole amount of producer gas can be burned in the boiler to produce heat. The flue gas of the gas engine is catalytically oxidised to reduce the CO emissions. The sensible heat of the engine´s flue gas is used to produce district heat, the one of the flue gas from the combustion zone is used for preheating air, superheating steam as well as to deliver heat to the district heating grid. A gas filter separates the particles before the flue gas is released via a stack to the environment.

OPERATION EXPERIENCE

FUEL SUPPLY

The biomass supply is secured by long term contracts. As fuel wood chips are used, delivered by local wood farmers who have established a wood farmers association. The price is fixed for a duration of ten years (within index adaptation) which is currently about 1.6 Cents/kWh. The water content of the wood chips is about 25 %. In future it is intended that 40 % of this fuel should be replaced by a cheaper (0.7 cents/kWh) and dryer fuel consisting of residues from the local wood working industries.

HEAT AND POWER UTILIZATION

Heat is delivered to a district heating grid which has a length of more than 20 km. The consumers are mainly private houses (300), public offices, schools, and hospital (50). Furthermore, there is a growing demand of industrial heat which is needed the whole year around. Also wood drying chambers have been installed in the vicinity which are additional heat consumers. Currently, first experience could be made with cooling using district heat. Electricity is sold to the electrical grid operator with a feed-in-rate of 12.3 Cents/kWh.

PLANT PERFORMANCE

After optimising the control system a very smooth and stable operation of the gasification and the gas cleaning could be obtained. *Fig.* 5 and *Fig. 6* show online measurements of the temperatures, pressures and the gas composition.

The small temperature difference between the combustion and gasification zone indicates that there is sufficient circulation of bed material between the two zones. The calorific value of the dry producer gas is constant at about 12 MJ/Nm^3. The nitrogen content originates mainly from the purge gas in the rotary valves and particle filter. Typical ranges of the gas composition can be seen from *Table. 3*.

Table 3: Ranges of the main components in the producer gas (dry gas)

Component	Range	Dimension
hydrogen	35 - 45	Vol-%
carbon monoxide	20 - 30	Vol-%
carbon dioxide	15 - 25	Vol-%
methane	8 - 12	Vol-%
nitrogen	3 - 5	Vol-%

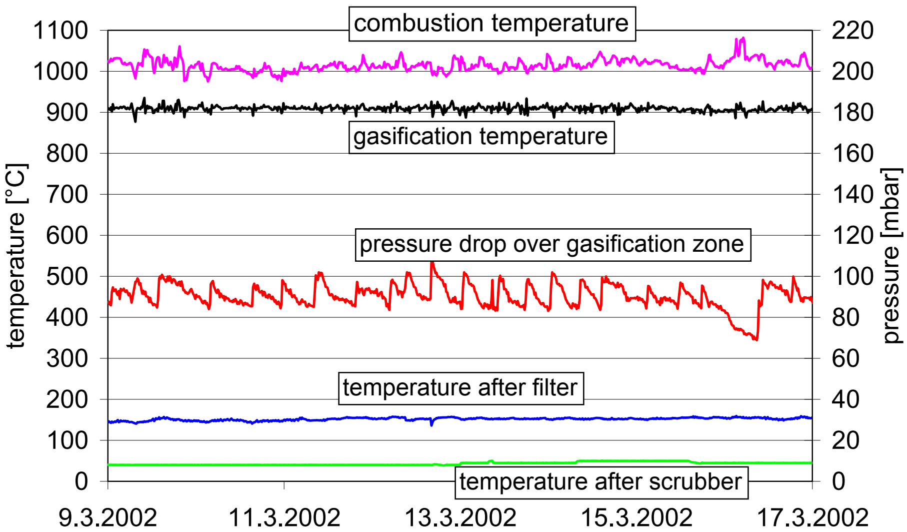

Fig. 5: Online measurements of temperatures und the pressure of the gasification bed.

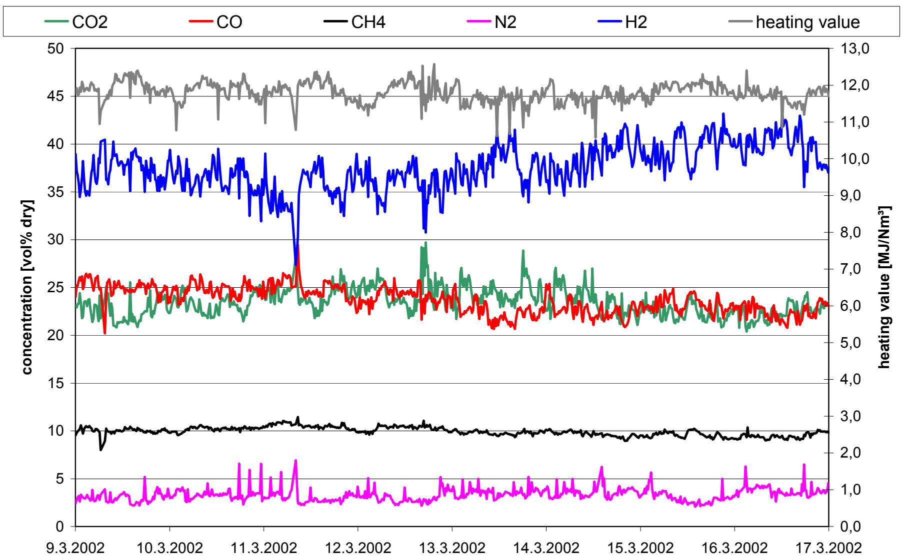

Fig. 6: Online measurements of the gas composition and calculation of the heating value.

Table 4 contains typical ranges of the minor components in the raw gas as well as the clean producer gas. Hydrogen sulfide was only measured in the clean gas therefore no values are available for the raw gas.

Table 4: Producer gas quality (minor components)

Component	Raw gas	Clean gas	Dimension
tar	1,500 - 4,500	10 - 40	mg/Nm^3
particles	5,000 – 10,000	<5	mg/Nm^3
ammonia	1000 - 2000	<400	ppm
hydrogen sulfide	n.m.	20 - 40	ppm

n.m. not measured

ENVIRONMENTAL ASPECTS

The flue gas from the gas engine and the flue gas from the combustion zone are mixed together and released via the stack to the environment. Measurements of the emissions were measured recently and the results are shown in *Table 5*. All measurements are below the emission limits which were set by the local authorities.

Table 5: Emissions from CHP-plant Güssing (dry gas, ref. 5 % oxygen).

Component	Range	Dimension
CO	900 - 1500[1]	mg/Nm^3
	100 - 150[2]	mg/Nm^3
NOx	300 - 350	mg/Nm^3
dust	< 20	mg/Nm^3

1 without catalyst
2 with catalyst

As already discussed in the previous chapter there are no liquid emissions from the CHP plant. The condensate from the scrubber is evaporated and fed into the combustion zone where the organic matter is combusted.
The only solid residue is the fly ash from the combustion zone. Therefore the carbon content in this fly ash is very low (<0.5 w-%) and can be handled similar to an ash from biomass combustion. This is an essential advantage compared to the most other gasifiers.

ECONOMY OF THE DEMONSTRATION PLANT

The CHP-plant in Güssing can be operated economically under the Austrian conditions. The conditions are currently quite well and are characterized on the one hand by high fuel costs and on the other hand by high feed in tariffs for electricity. Some economic data for the demonstration plant are summarized in *Table 6.*

Table 6: Economic data of the demonstration plant.

Cost category	Amount	
Investment cost	10	Mio. €
Funding (EU, National)	6	Mio. €
Operation cost / year	10 - 15	% of investment costs
Price for heat (into grid)	2,0	Cents/kWh
Price for heat (consumer	3,9	Cents/kWh
Price for electricity	12,3	Cents/kWh

For the next plant 25 % reduction of investment cost can be expected due to the experience and learning at the demonstration plant. Furthermore, the operation costs will be reduced essentially. This will be done by aiming at an unmanned operation and a reduction and optimisation of operation means (bed material, precoat material, scrubber liquid).

CONCLUSIONS

A CHP-plant based on a steam blown dual fluidised bed biomass gasifier with a capacity of 8 MW has been demonstrated successfully in Güssing. Until December 2002 the gasifier and the gas cleaning system reached 3000 hours of operation, together with the gas engine 1050 hours of operation could be achieved. The smooth operation of the Jenbacher gas engine with an electrical output of 2000 kWel showed that gasification and gas cleaning is working with an excellent performance. All expectations as well as the emission limits could be met. Some minor improvements were necessary especially concerning the producer gas cooler. Compared to other CHP-plants based on gasification of biomass the Güssing plant can be designated as real success story.
The FICFB-gasification process has a large potential for the future as it leads to a high grade producer gas which can be used for various applications:

- Combined heat and power production (CHP) with gas engines, gas turbines or fuel cells
- Hydrogen production
- Synthesis gas for production of substitute natural gas (SNG), methanol, Fischer-Tropsch-diesel

ACKNOWLEDGEMENT

The work described in this paper was funded by the competence centre programme Knet. The financial support of the Ministry of Economy and Labour and of the Federal States of Niederösterreich and Burgenland is gratefully acknowledged.

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