Biomass CHP Plant Güssing – A Success Story

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ABSTRACT: A steam biomass gasification process has been demonstrated in Güssing, AT. 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. The plant consists of a dual fluidized bed steam gasifier, a two stage gas cleaning system , a gas engine with an electricity generator, and a heat utilization system. The start up of the plant was in January 2002 and until September 2002 2500 hours of operation with the gasifier and the gas cleaning system and 750 hours of operation with the gas engine could be reached. The overall performance of the CHP plant is very good, however, some minor problems had to be solved. The most important parts operate quite well only the cooler of the producer gas had to be improved. In Austria and also in other European countries there are currently good conditions for an economical operation of an CHP-plant based on biomass due to high prices for green electricity. Nevertheless, further efforts have to be done to reduce the investment as well as the operating costs. The producer gas has a high amount of H_2 and CO and is therefore also well suited for the production of synthesis gas.

BACKGROUND

Güssing is a small town with about 4.000 inhabitants and is located about 200 km south of Vienna near to the Hungarian border. For a long time this border was called the iron curtain and therefore nearly no industry settled there which in consequence led to a lack of jobs for the people living there. Many of them migrated to other regions for ever or at least over week for working. The region was very poor until biomass as source of energy was discovered.

40 % of the region of Güssing is covered with wood. Therefore sufficient raw material is available for the energy supply of the whole city. About ten years ago the major of Güssing and some other visionary people worked out a concept for the supply of Güssing only with energy from renewable raw material from the region. This concept included energy saving as well as energy production by building new and

innovative demo-plants. The main fields of energy demand of a city are: fuel for transportation, residential heating, and electricity. *Fig. 1* shows these three columns of energy demand and the respective plants in Güssing.

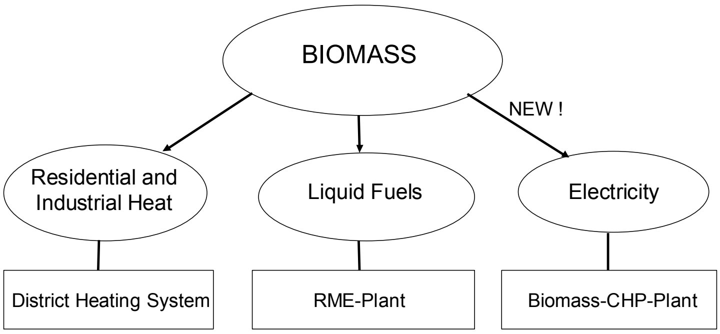

Fig. 1: Energy supply of Güssing (100 % renewable).

The RME-plant started production already in 1990. This plant is able to produce more biodiesel than necessary for the overall consumption of fuel in the city of Güssing. In 1998 the district heating system was commissioned which was the largest biomass based district heating system in Austria at that time. The grid supplies 95 % of the city of Güssing. The third column was realized in 2002 as a new 2 MWel demonstration plant for CHP production went into operation. This plant is able to produce the whole electricity which is consumed by the people living in Güssing. Nowadays Güssing is supplied by 100 % of renewable energy which is fully based on biomass.

COMBINED-HEAT AND POWER (CHP) PLANT

SHORT DESCRIPTION OF THE PROCESS

An innovative process for combined heat and power production based on steam gasification has been demonstrated in Güssing. 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*. The most important 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 (*Fig. 3*). 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.

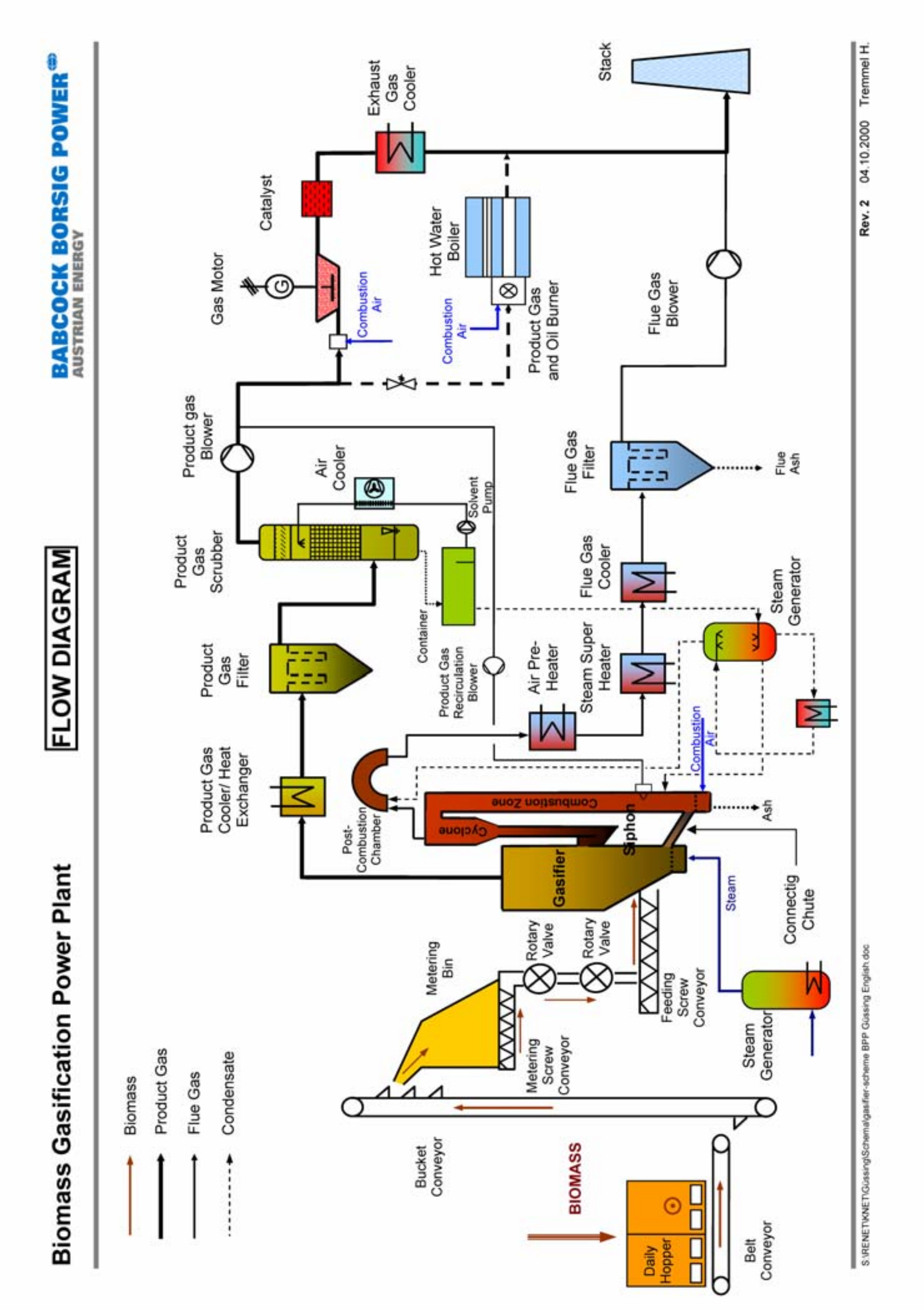

Fig. 2: Flow sheet of CHP-plant Güssing.

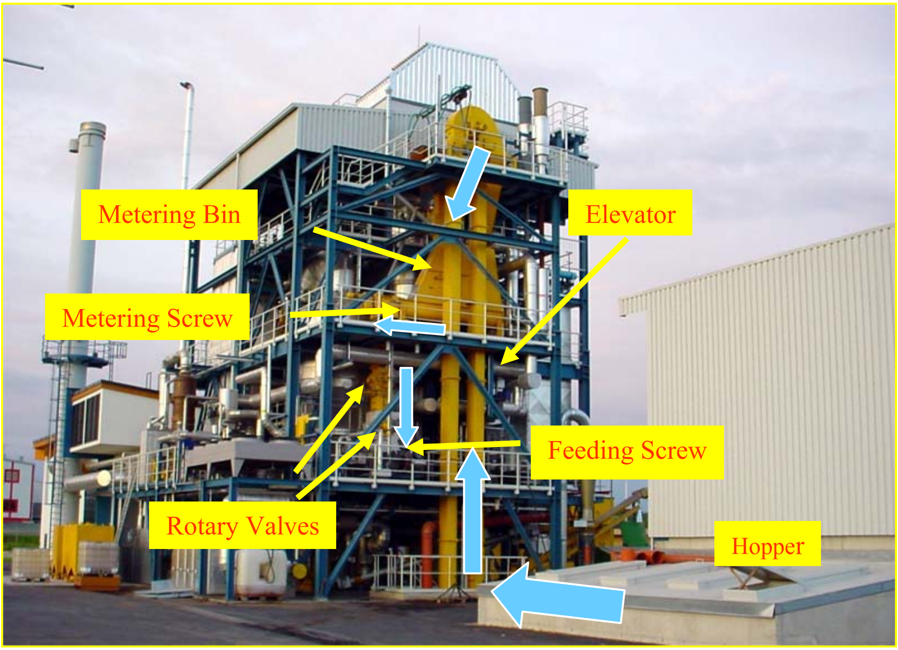

Fig. 3: Biomass conveying .

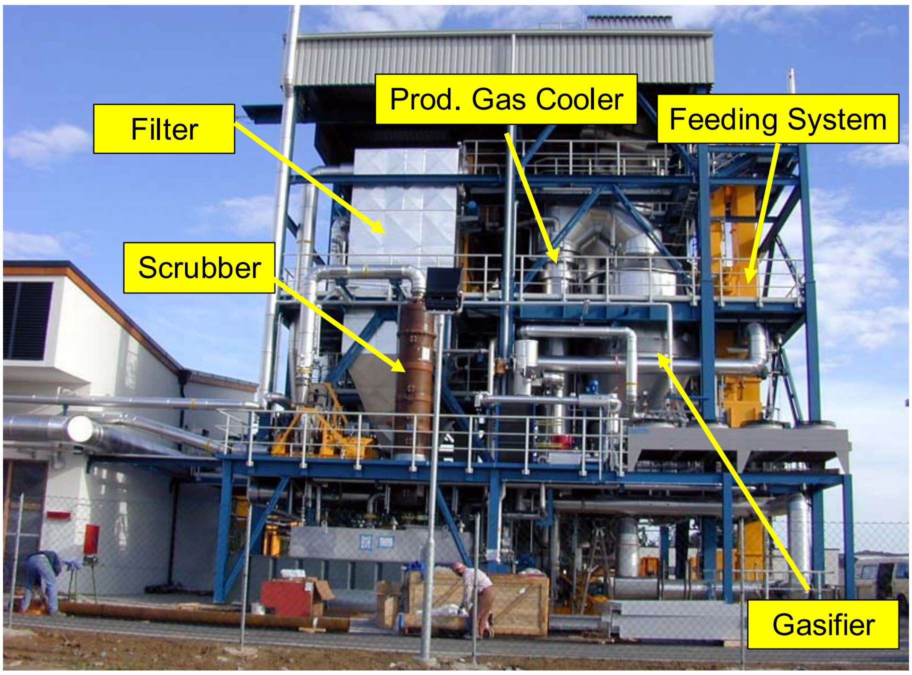

Fig. 4: Producer gas line.

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 (*Fig. 4*). 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 back into 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 introduced 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 heat of the engine´s flue gas is used to product district heat.

The sensible heat of the flue gas for the combustion zone is used for preheating of the air, superheating the steam and also to deliver heat to the district heating system. A gas filter separates the particles before the flue gas is released via a stack to the environment.

DESIGN PHASE

The basic idea of the gasification process originates from the Vienna University of Technology and was published first in 1982 for coal gasification [1]. The gasification process was adapted for biomass during the last ten years. *Table 2* shows the main stages of this research and development process.

In 1983 a 10 kW test rig was built to study the fundamental behaviour of a Fast Internal Circulating Fluidised Bed (FICFB) gasifier. The design at that time was a fluidised bed with a daft tube. The basic behaviour of such a system was successfully studied which was the base for the further development. The name FICFB remained the same until now although the design changed to an external circulating fluidised bed system.

A 100 kW pilot plant was used to gasify different fuels (biomass, sewage sludge, coal, etc.) and to carry out a comprehensive parameter study. This pilot plant consists not only of the gasifier but also of the same gas cooling and gas cleaning system which was later realized at the demonstration plant in Güssing. From this pilot plant a lot of design parameters for the demonstration plant could be achieved. A detailed description of the 100 kW pilot plant and the respective results can be found elsewhere [2, 3].

Table 2: Development of the FICFB-Gasification Process.

Stage	Institution	Installation	Period
1	TU Vienna	10 kW test rig	1993 - 1996
2	TU Vienna + AE Energietechnik	100 kW pilot plant + gas cleaning	1997 - 2002
3	Renet Austria	8 MW demonstration plant Güssing	2000 - 2004

In 2000 a network of competence (Renet-Austria) was established to support the design, construction, commissioning and demonstration phase of the CHP-plant in Güssing. The members of Renet-Austria are the manufacturers of the plant (AE-Energietechnik, Jenbacher AG), the owner of the plant, and a research organisation (TU Vienna). The work of the competence network is funded by the government and two federal states of Austria (Burgenland, Niederösterreich). Due to this support from Renet-Austria many questions during the design phase could be clarified by experiments at the 100 kW pilot plant or by mathematical simulation work [4].

CONSTRUCTION PHASE OF THE DEMONSTRATION PLANT

The construction of the demonstration plant started in September 2000 and was finished again in September 2001. This very short time was possible as no serious problems during this phase occurred. The official opening ceremony was hold on 20. September 2001.

COMMISSIONING AND DEMONSTRATION PHASE

The autumn of the year 2001 was very warm in Austria. Therefore the first test runs of the demonstration plant could be carried out November 2001. First the control system of the plant has to be adjusted. This was necessary because no experience was available for such a type of gasification process. Within the time of two month no constant and stable operation was possible. This unsteady operation lead to some deposits in the producer gas cooler due to bad gasification conditions. After this first period a good performance could be reached. From 21. February 2002 to 22. March 2002 the gasification and gas cleaning system was in continuous operation without any problems and also the gas composition was as expected from the results of the pilot plant.

After more than 1500 hours of successful operation with the gasification and the gas cleaning system the gas engine was coupled. Till the end of September 2002 more than 2500 h of operation with the gasifier and gas cleaning and more than 750 h of operation with the gas engine could be reached. Currently a two years demonstration period is carried out to optimise the operation and especially to reduce the operation costs.

OPERATION EXPERIENCE

FUEL SUPPLY

The biomass supply is secured by long term contracts. The fuel for the heat and power production are wood chips 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 this 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 dry fuel which are residues of local wood working industries.

HEAT AND POWER UTILIZATION

Heat is delivered to a district heating system 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 over the whole year. The heating station itself operates drying chambers 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 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. In this first period of operation olivine is used as bed material. The composition of the producer gas at the demonstration plant was very similar to that measured at the pilot plant. 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-%

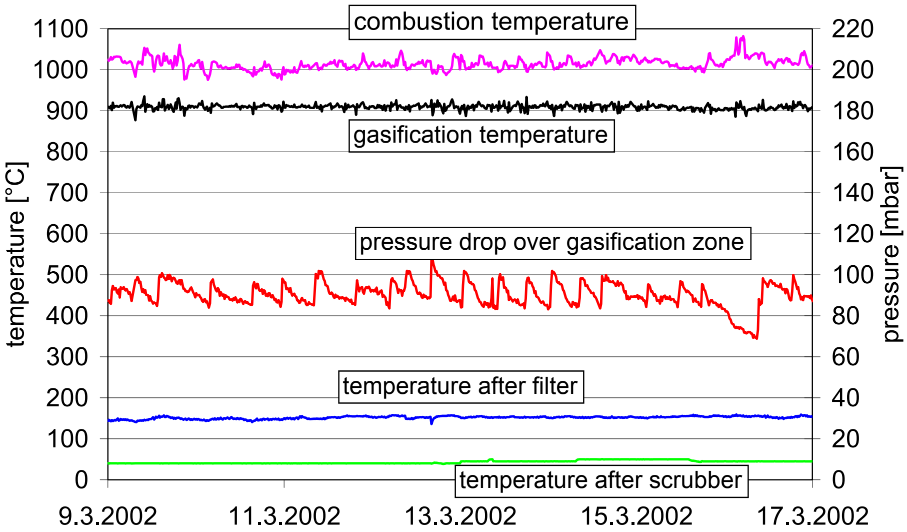

Fig. 5: Online measurements of temperatures und the pressure of the gasification bed.

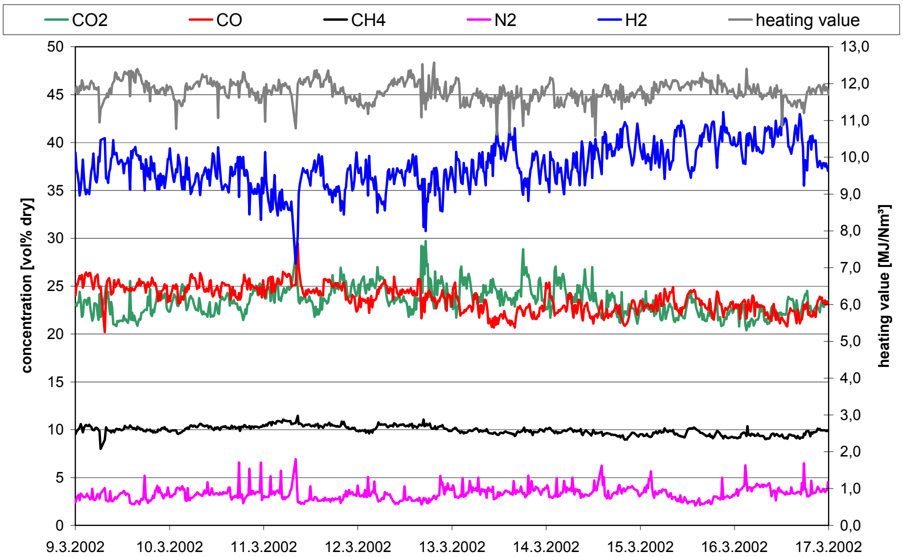

Fig. 6: Online measurements of the gas composition and calculation of the heating value.

The producer gas leaves the gasifier at the top and enters into the gas cooling and cleaning section. The influence of the tar content on the bed material and gasification agent is shown in *Fig. 7*. Steam as gasification agent leads to a lower tar content compared with air blown gasifiers. Further on, the bed material can act as catalyst for tar cracking. One essential feature of any bed material is a sufficient resistance against attrition. Olivine is a suitable bed material although there are big differences in various olivines. By using a special designed catalyst for tar cracking the primary tar reduction can even improved. In case of Güssing olivine as bed material and steam as gasification agent is used.

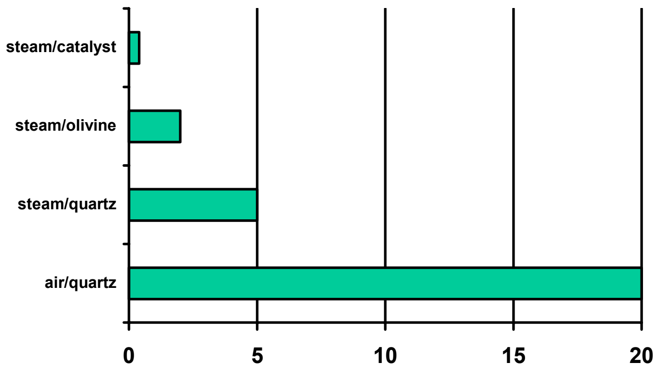

Fig. 7: Influence of bed material and gasification agent on tar content (g/Nm^3 dry gas).

The producer gas is cooled by a heat exchanger from a temperature of 850 – 900 °C to 150 – 180 °C. At the beginning of the testing period some fouling problems were observed. This was mainly due to a bad operation of the gasifier. After optimising the operation of the gasifier (temperature >800 °C, steam to biomass ratio >0,6) the fouling disappeared. Corrosion at the entrance of the heat exchanger was observed after 1500 h. It was tried to solve this problem by dividing the heat exchanger into two parts. The first part (hotter part) was manufactured from an higher quality steel better suited to resist the conditions at the entrance.

The particles and some tar is remove from the gas by a precoated fabric filter. This part of the gas cleaning section worked up to now without any problems. After 2500 h of operation no cleaning or exchange of the filter cloths were necessary. The spent precoat material and the separated particles are returned back into the combustion chamber to burn out the carbon and hydrocarbons.

Most of the tar and some ammoina is removed by a scrubber . This scrubber uses a solvent which gives excellent results for tar removal. The spent solvent together with tar components is fed into the combustion zone und combusted. The temperature of the gas is further reduced to about 40 – 50 °C in the scrubber which is necessary for the gas engine. Therefore most of the steam condenses there. This condensate is evaporated and fed into the after burning chamber of the combustion zone. This is a main advantage of the process as no waste water problem arises. Typical values of the tar content along the gas cleaning line can be seen in *Fig. 8*. The measurements at the demonstration plant were similar to those at the 100 kW pilot plant. The clean producer gas has a very low tar content (10-40 mg/Nm^3 dry gas) which is no problem for the operation of the gas engine.

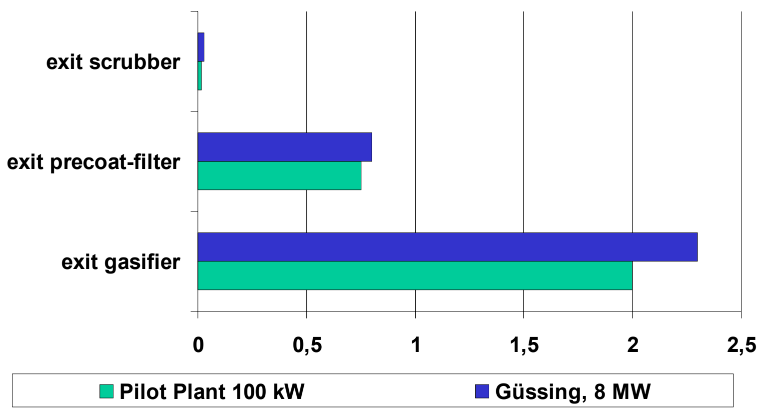

Fig. 8: Tar content (mg/Nm^3 dry gas) over the gas cleaning line.

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.

The CHP plant Güssing is characterised by an excellent environmental performance:

(1) low gaseous emissions
(2) no liquid emissions
(3) ash only from the combustion zone (very low carbon content)

ECOMNOMY 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. EURO
Funding (EU, National)	6	Mio. EURO
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 an reduction and optimisation of operation means (bed material, precoat material, scrubber liquid).

ACCEPTANCE OF THE CHP-PLANT IN GÜSSING

The acceptance of the CHP-plant by the people of Güssing as well as the local authorities is excellent. The reasons for this acceptance are manifold:

(1) CHP-plant was the missing link for the complete energy supply by biomass for the city of Güssing
(2) The production of heat and electricity only from local raw material end a higher price is paid
(3) Sufficient local biomass is available
(4) Energy supply is now independent from oil price
(5) Local job creation not only by the CHP power plant but also by the settlement of wood working industry

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. 2500 h of operation of the gasifier and the gas cleaning part of the plant could be reach until September 2002. 750 hours of operation of a Jenbacher gas engine with an electrical output of 2000 kWel showed that the 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:

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

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