# GASIFICATION DEMONSTRATION PLANTS IN AUSTRIA

Markus Bolhàr-Nordenkampf [1], Hermann. Hofbauer[1]

[1] Institute of Chemical Engineering, Getreidemarkt 9 /166, A-1060 Vienna, Austria,
Tel. +43-1-58801 159 33, Fax : +43-1-58801 159 99, bolhar@mail.zserv.tuwien.ac.at.

***ABSTRACT:*** Biomass gasification offers the possibility to produce heat and power at a high efficiency. RENET Austria, a framework of scientists, industry and operators, has set up two gasification demonstration plants in Austria. One plant uses the FICFB (Fast Internal Circulating Fluidised Bed) gasification process, an innovative process to produce a high grade synthesis gas from solid fuels. The product gas is cleaned and combusted in a gas engine. The combined heat and power (CHP) plant has a fuel capacity of 8 MW and an electrical output of about 2 $MW_{el}$ with an electrical efficiency of about 25 %.
The other plant uses a fixed bed gasifier to produce a low calorific gas, which is converted into heat and electricity in a gas engine too. This CHP-plant has a fuel capacity of 2 MW and an electrical output of about 500 $kW_{el}$ with an electrical efficiency of about 25 %.

## 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 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.
In 2000 a network of competence (Renet-Austria) was established to support the design, construction, commissioning and demonstration phase of two gasification CHP-plants in Güssing and Wr. Neustadt. The members of Renet-Austria are the manufacturers of the plant (Repotec, Jenbacher AG), the owner of the plant (Güssinger Fernwärme Ges.m.b.H.; EVN AG), 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).

## CHP-Biomass Gasification Plant Güssing

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 started in 1993.
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. Simultaneously the strongly endothermic gasification reactions (reactions with water vapour) take place (1, 2).

$$CO + H_2O \rightarrow CO_2 + H_2 \qquad (1)$$

$$C + H_2O \rightarrow CO + H_2 \qquad (2)$$

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 a cyclone and fed back into the gasification section. The heat required for the gasification reactions is produced by burning carbon brought into the combustion section along with the bed material. 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.

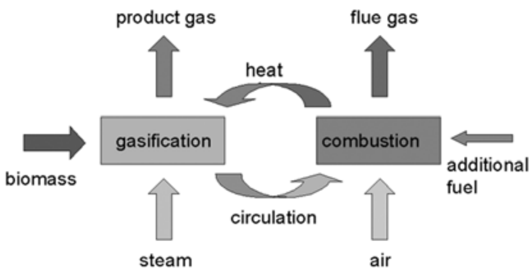


*Fig. 1:* **Principle of FICFB-gasification process**

The FICFB-gasification system, in contrast to conventional gasifiers operated with air, has 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 commercial plant is given.

## 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.

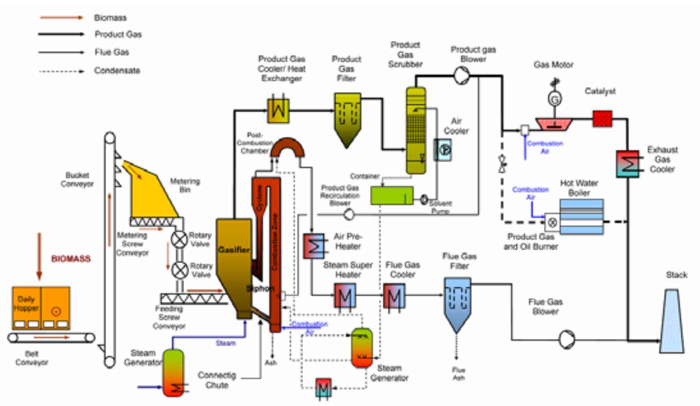


***Table 1*: Characteristic data of the plant.**

| | | |
|---|---|---|
| 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 | % |

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

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

After optimising the control system a very smooth and stable operation of the gasification and the gas cleaning could be obtained. 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 and ranges of the minor components in the raw gas as well as the clean producer gas can be found in *Table. 3*.

***Table 3*: Ranges of the main components and pollutants 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-% |

| 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 | not measured | 20 - 40 | ppm |

## 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 performed recently and the results are shown in *Table 4*. All measurements are below the emission limits which were set by the local authorities.

***Table 4:* 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 most other gasifiers.

# CHP-Biomass Gasification Plant Wr. Neustadt

The plant consists of a twin-fire downdraft fixed bed gasifier with a fuel power of 2 MW. Air is supplied after the drying zone of the biomass at the bottom of the gasifier. The bottom air accounts for the post gasification of the remaining char. The product gas is first cooled by the air preheater of the gasifier and then quenched with water to 50°C. For gas cleaning a wet electrostatic precipitator is used. The gas flow through the reactor is maintained by the compressor situated behind the electrostatic precipitator. The cleaned gas is combusted in a Jenbacher gas engine to yield 500 kW of electrical power and 700 kW of district heat.

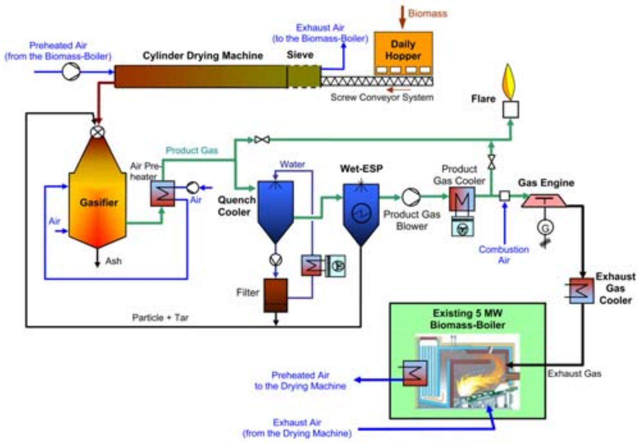


***Fig 3:* Flow sheet of CHP-plant Wr. Neustadt**

Fixed bed gasifiers require quite stringent fuel specifications in terms of particle size and water content. In order to obtain a specific particle size distribution and water content, a rotary sieve dryer is used. Preheated air from the district heating boiler is used for the drying of the fuel; the exiting air is feed back to the boiler and burned. The separated small fuel particles are used as additional fuel for the boiler as well as the remaining char loaded ash from the gasifier. Particles and tar filtered off from the quench water are fed together with the drain of the wet electrostatic precipitator into the boiler for combustion. Furthermore, the exhaust gases from the gas engine is blown into the biomass boiler. Thereby the remaining CO and other combustible components are destroyed to meet the emission limits. The additional district heating power is delivered into the grid using the existing pumps. However when the gasifier is in operation the load of the district heating boiler is reduced (Figure 3).

## Operation Experience

Very stable gas compositions with an average heating value of 4.5–5.0 MJ/Nm³ are achieved operating the gasifier, with the main components and pollutants given in Table 5.

***Table 5*: Ranges of the main components and pollutants in the producer gas (dry gas)**

| | |
|---|---|
| hydrogen | 16-18 vol% |
| carbon monoxide | 17-20 vol% |
| carbon dioxide | 9-11 vol% |
| methane | 2-4 vol% |
| nitrogen | remaining vol% |

<table>
<tr><th></th><th>raw gas</th><th>clean gas</th></tr>
<tr><td>tar</td><td>400 – 450 mg/Nm³</td><td rowspan="2">< 15 - 35 mg/Nm³</td></tr>
<tr><td>particles</td><td>30 - 40 mg/Nm³</td></tr>
<tr><td>ammonia</td><td>-</td><td>< 20 ppm</td></tr>
</table>

The gas cleaning performed excellent, yielding very low dust and tar loadings of 15–35 mg/Nm³ in total. The stable gas conditions as well as the low pollutant loadings resulted in excellent operation behaviour of the gas engine. An electric efficiency of 25% could be achieved. The drying as well as the sieving performed excellent, as the post combustion of the gas engine exhaust gas did. For evaluation purposes the plant was modelled in IPSEpro, a flowcharting program, in order to evaluate the influence of different parameters like ambient temperature or air preheating temperature on the efficiency of the plant. These simulations prove to be a valuable help for further optimisation of the plant. Further on influences of parameters can be evaluated before they are tested in reality on the demonstration plant.

# Conclusions

The framework Renet has been able to install two gasification demonstration plants in Austria successfully. The small (500 $kW_{el}$) plant aims at small regional district heating grids, which want to extend their heat production onto power production, the large (2000 $kW_{el}$) plant aims at large regional district heating grids as a stand alone CHP-plant

Both plants provide the possibility to convert biomass with a high efficiency into heat and power and can help to fulfil the goal to increase the share of electrical power from renewable energy technologies in Austria.

After the conclusion of the demonstration phase further implementations of these plant types are planned in Austria and the European Union.

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