# Experiences on fuel flexibility of small-scale biomass gasification systems

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Small-scale biomass gasification systems can clearly be considered robust enough for operation. They have seen a high and widespread diffusion in Europe in the last 15 years, in particular coupled with internal combustion engines for combined heat and power (CHP) generation[1]. However, the commercialized systems – which development have been prompt by high feed-in tariffs and incentives for clean power production – are still affected by some issues: the need for very specific feedstock properties [2], frequent maintenance operations and required operator supervision [3] to ensure a smooth and reliable prime mover operation and consequent electricity production.

Within this context, this research work focus on fuel flexibility and load modulation capability of biomass gasification systems. Fuel flexibility refers to the possibility of using different feedstocks (e.g. forest residual) or the same type of biomass but with different properties in terms of moisture and size distribution (e.g. chips and pellets). Load modulation capability refers to the control of the feeding load in order to produce energy meeting the energy demand. In both ways, the performance of the gasification system can be enhanced, producing energy when it is needed (load modulation) or using several feedstocks (fuel flexibility).

The gasifier used for the gasification tests is an open top pilot-scale gasifier placed at the Bioenergy and Biofuel Lab of the Free University of Bolzano (Figure 1). The plant is an open top downdraft system, where both gas and feedstock move downward as the reactions proceed. The gasification reactor, a gas cleaning system, a flare and a monitoring and controlling system compose the experimental set-up. In order to increase the char temperature in the reduction zone, a part of char can be burn injecting secondary air into reactor. In this way, the reactor can be used as a double stage gasifier modulating the air in two separate zone in order to control the gasification process and to adapt it to different feedstock properties.

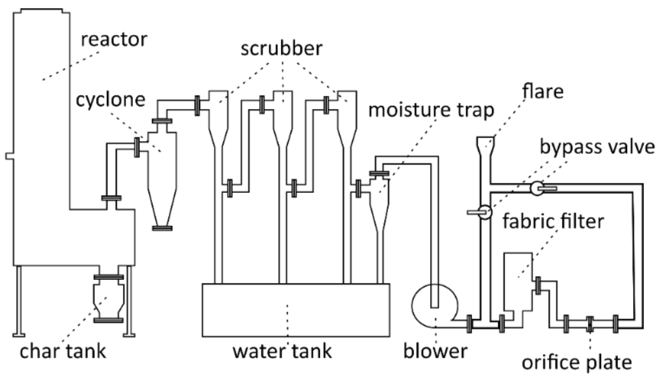


Figure 1: overall schematic of the pilot-scale open top gasifier system

Gasification experiments have been performed using several biomasses (wood chips, wood pellet, torrefied pellet and wood pellet mixed with char) at different gasification conditions (from 0.17 up to 0.35 of ER value). In particular, four different datasets have been collected during four different experimental campaigns:

- Load Modulation (LM): in this campaign, the load of the gasifier, operated with standard wood pellet, has been modulated varying the blower set point, ranging from 44% to 69% to 82% to full load [4];
- Char Recirculation (CR): in this campaign, char has been recirculated together with wood pellets, with shares ranging between about 5% to about 10% [5];
- Torrefied Pellets (TP): in this campaign, three gasification experiments have been carried out using standard pellet, torrefied pellet at 250 °C and torrefied pellet at 270 °C, also varying the secondary air from 0 NLPM to about 38 NLPM [6];
- Bark and Chips (BC): in this campaign, the gasifier has been operated with standard wood chips, also mixed with different shares of bark (ranging from 30 % to 80 %) [7].

In all the different campaigns, the feedstocks and the corresponding chars are characterized according to standard methods in order to determine:

- the moisture content of the samples (as received and after the stabilization process);
- the ash content (of the stabilized samples);
- the high and lower heating value;
- the elemental analysis in terms of C, H, N, S content.

The producer gas composition during the tests is monitored by coupling the gasifier with a gas chromatograph (3000 microGC, SRA Instruments). The producer gas is characterized in terms of H2, O2, N2, CH4, CO and CO2. Before entering into the gas chromatograph, the gas steam is cleaned by means a cleaning line composed by 6 impinger bottles filled with propanol and a filter containing silica gel to ensure the complete absence of tars and water in the gas analyzed. The instrument was calibrated before each test using a cylinder containing a mixture of certified gases.

A digital lab balance is used to calculate both char and biomass weights, and the time interval between the charging and discharging cycles is recorded. The mass flow rates (biomass and char) can be determined for each period divide the weights recorded to the time cycle. On the contrary, the air and the producer gas mass flow rates are calculated by a linear system taking into account the global mass balance, the carbon and the nitrogen balance. This methodology can be applied afterwards the characterization of biomass, air, producer gas and char composition.

The results show that the increase of the secondary air flowrate always ensured a higher LHV of the producer gas and higher CGE values and that the gas composition and process parameters are correlated with the ER value considered regardless the material used, therefore demonstrating that the gasification process can be optimized (at different load in terms of producer gas power) using secondary air in order to: control the equivalent ratio, enhance the carbon conversion (increasing CO and decreasing char production) due to the highest temperature in the char reduction zone, increase the cold gas efficiency of the gasification system.
At the same time, the control of ER due to the secondary air modulation can help on fuel flexibility achieving: producer gas LHV higher than 4.5 MJ/kg with pellets and approximately equal to 4 MJ/kg with woodchips, specific gas energy higher than 3 kWh/kg, CGE approximately equal to 70%, char production lower than 5%.

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