ECN-RX--05-183

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Published at 14th European Biomass Conference & Exhibition,

Paris, France, 17-21 October 2005

Revisions	
A	
B	
Checked/Approved/Issued by: H.J. Veringa	ECN Biomass

November 2005

MILENA GASIFICATION TECHNOLOGY FOR HIGH EFFICIENT SNG PRODUCTION FROM BIOMASS

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ABSTRACT: MILENA is the name of an indirectly heated (allothermal) air-blown gasification concept, developed and patented by ECN. It is designed to efficiently produce a N_2-free product gas with high amounts of hydrocarbons. It is developed to be the first step of a high efficient biomass-to-SNG concept. Tests with a 30 kW_{th} lab-scale facility revealed MILENA to be a stable process producing a product gas, which contains very high amounts of hydrocarbons on energy basis. Cold gas efficiencies of 80% are possible for large-scale systems. With MILENA technology, biomass-to-SNG plants should be able to reach 70% efficiency. Early 2006, a complete lab-scale biomass-to-SNG system will be ready for tests.
Keywords: allothermal conversion, gasification, methane

1 INTRODUCTION

Biomass is recognized in most countries as the renewable energy source with the largest potential. Since generally biomass will be relatively expensive, high efficient conversion processes are needed to obtain economically attractive systems. This especially is true for countries like the Netherlands, where biomass energy must rely on imported biomass.

Gasification is broadly recognized as an attractive conversion process. The reasons most often mentioned are the high efficiency and the back-end flexibility. The produced gas can be burned to produce electricity, but it can also be used to synthesize chemicals and transportation fuels. There is however, not such thing as a best gasification technology. The optimum system very much depends on the type of downstream processing and gas application as well as the type of fuel.

Recently, a renewed interest has grown in SNG (synthetic natural gas) as an energy carrier. In the early 70s, much work has been initiated in the US on coal-to-SNG. Although most has been cancelled in the 80s because of the changing energy picture, one multi-GW plant has actually been realized in North Dakota [1,2]. Now, SNG seems an attractive energy carrier for green biomass energy. Compared to biomass, SNG can be transported efficiently and cheap, can use existing infrastructure, can be converted easily, and can count on a high social acceptance. The production of SNG can take place at large-scale with corresponding advantages of economy of scale. Furthermore, SNG can be stored underground in some places (*i.e.* buffering), enabling efficient operation throughout the year independent of a fluctuating demand.

For the conversion of biomass into SNG, biomass must be gasified first. The produced gas is then upgraded by methanation to natural gas specifications. Different biomass gasification technologies are available. These can be divided into two categories: high-temperature and low-temperature gasification. High-temperature gasification (typically above 1200°C) results in a gas, which merely contains H_2 and CO as combustible components. At low-temperature however (typically below 1000°C), also hydrocarbons are present in the gas. A circulating fluidised bed (CFB) gasifier operated on biomass at 900°C typically produces a gas containing 50% hydrocarbons (mainly methane, ethylene, and benzene) on energy basis. A high initial yield of CH_4 ("instant SNG") is attractive, since the conversion of H_2 and CO to CH_4 (methanation) involves approximately 20% efficiency loss (heat production).

Figure 1 schematically shows possible cases for overall biomass-to-SNG processes with typical efficiencies for three different gasification technologies: high-temperature entrained flow (EF, typically 1400°C), circulating fluidised bed (CFB, typically 900°C), and indirectly heated (also referred to as allothermal) gasifier. The envisaged high overall efficiency of biomass to SNG of the latter option has been the reason for ECN to start the development of an indirect gasification process. This paper focuses on the indirect gasification process called MILENA. In reference [3] the methanation process is described in more detail.

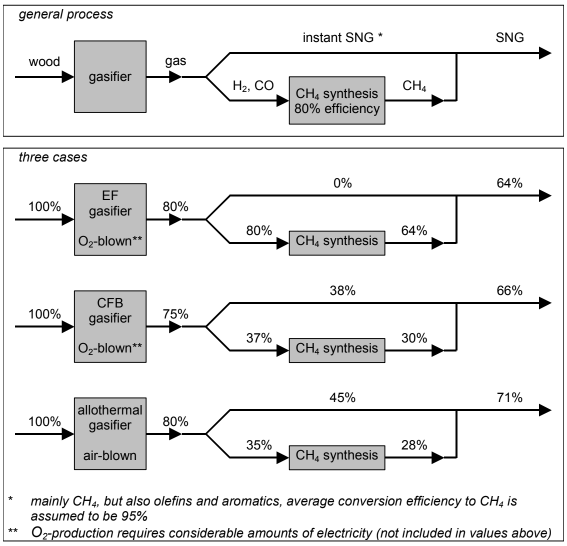

Figure 1. *Green Gas production efficiencies for different gasification technologies, EF: entrained flow, CFB: circulating fluidised bed*

Most of the “instant SNG” as mentioned in Figure 1 is methane. It however also contains unsaturated hydrocarbons, like ethylene and benzene that will react with hydrogen into methane. This reaction is slightly exothermal. The “instant SNG” is assumed to be converted to methane with 95% efficiency.

2 INDIRECT GASIFICATION

2.1 General

Indirect (allothermal) gasification is characterized by the separation of the processes of heat production and heat consumption. It therefore generally consists of two reactors, connected by an energy flow. One important category of allothermal gasification is formed by the processes where biomass is gasified/pyrolysed and the remaining solid residue (char) is combusted to produce the heat for the first process. Examples of this kind are the FERCO/SilvaGas-process developed by Battelle and the FICFB-process developed by the University of Vienna. An overview is given in reference [4].

These types of reactor theoretically are operated at an equilibrium based on the temperature dependence of the char yield in the gasifier: char yield increases with temperature. Since this char is combusted to produce the heat, this leads to an equilibrium where char yield matches the energy demand of the gasification.

Allothermal gasifiers generally produce two gases: a medium calorific gas with little or no nitrogen and a flue gas. The production of a N_2-free gas without the need of air-separation is one of the advantages over direct gasification processes like a CFB. Another important advantage is the complete conversion. The ashes that remain, contain little or no residual carbon since this is the product of a combustion process. Indirect gasifiers also have the option to deal with residues from e.g. gas cleaning such as tars. These can be added to the combustor and contribute to the overall efficiency rather than impose a waste problem.

2.2 Milena technology

Milena is the name of a technology developed by ECN to fulfill the demands of a biomass-to-SNG process with a high efficiency. Milena is an indirect gasifier operating similarly to the FERCO/Silvagas-concept: biomass is heated and gasified in a circulating flow of hot sand and the less reactive remaining solid char is directed to the combustor where the circulating sand is heated. However, Milena is simpler, more compact, and better suited for operation at elevated pressure. The gasification takes place in a riser, whereas a bubbling fluidised bed serves as combustor. The two reactors are integrated as schematically shown in Figure 2.

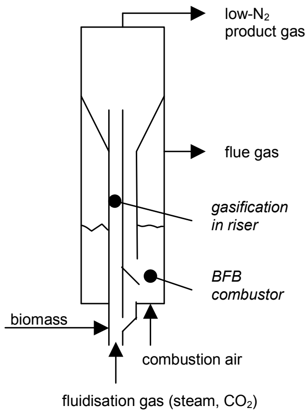

Figure 2. *Schematic drawing of the Milena indirect gasification technology*

2.3 Milena lab-scale facility

ECN realized a lab-scale Milena gasifier in 2004, see Figure 3. It has a capacity of approximately 5 kg/h of biomass. The Milena facility is integrated in the lab-scale test park at ECN. It therefore can be connected with one or more of the following units: TREC-reactor for high-temperature tar removal and filtering, high temperature ceramic filter, gas cooler, OLGA tar removal, water scrubber, dry gas cleaning, compressor, SOFC, Fischer-Tropsch synthesis reactor, or gas engine.

Figure 3. *Lab-scale 5 kg/h Milena indirect gasification reactor at ECN*

3 EXPERIMENTAL RESULTS

The lab-scale Milena test facility has been operated during dozens of tests under different conditions. Parameters that have been varied are: biomass fuel mass flow, bed material, bed material size, supplementary fuel to combustor (simulating tar recycle), and fluidisation gas flow.

Typical test results are summarized in Table 1. Most N_2 leaves the gasifier in the flue gas. The N_2 in the product gas mainly is the result of a small N_2-purge of the biomass feeding system. The average gasification temperature was approximately 800°C, the combustor was operated at 870°C.

Table 1. *Typical product gas and flue gas composition in lab-scale Milena gasification facility operated with dry beech wood (10% moisture)*

		product gas	flue gas
CO	vol% dry	44	
H_2	vol% dry	18	
CO_2	vol% dry	11	15
N_2 + Ar	vol% dry	4	71
CH_4	vol% dry	15	
C_{2-5}	vol% dry	6	
C_{6-7}	vol% dry	1	
tar (C_{8+})	g/m_n^3 dry	45	
H_2O	vol% wet	25	2
O_2	vol% dry		4

Based on the lab-scale experimental results and the experience of ECN concerning scale-up effects for CFB-gasifiers, the gas composition of a large-scale system is calculated. For the calculations, wood with 25% moisture has been assumed as fuel. Furthermore, tar is assumed to be removed completely by the OLGA tar removal unit [5]. Benzene and toluene are assumed to be removed for 50% and 75%, respectively. The separated tars, benzene, and toluene are recycled to the combustor reactor of the Milena plant. Table 2 shows the calculated composition of the raw gas directly downstream the gasifier. The resulting cold gas efficiency after gas cleaning is approximately 80%.

Table 2. *Calculated product gas and flue gas composition in large-scale (100 MW_{th}) Milena gasification plant operated with wood (25% moisture)*

		product gas	flue gas
CO	vol% dry	29	
H_2	vol% dry	31	
CO_2	vol% dry	20	18
N_2 + Ar	vol% dry	0	80
CH_4	vol% dry	14	
C_{2-5}	vol% dry	5	
C_{6-7}	vol% dry	1	
tar (C_{8+})	g/m_n^3 dry	45	
H_2O	vol% wet	35	4
O_2	vol% dry		2

4 BIOMASS TO SNG

The system envisaged to produce SNG from biomass with a high efficiency is shown in Figure 4. Efficiency numbers are based on calculations for a large-scale system. Approximately 70% biomass-to-SNG efficiency can be obtained. Additionally, a few percent net electricity may be produced by a steam cycle.

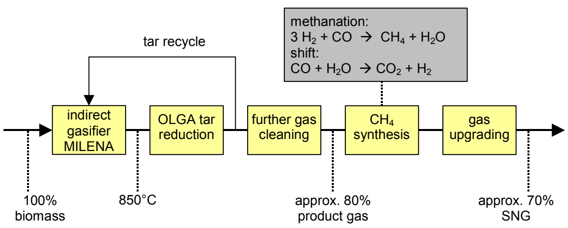

Figure 4. *Biomass-to-SNG system based on Milena technology*

Early 2006, ECN will complete an integrated lab-scale system as shown in the figure above. The gas cleaning will rely on OLGA tar removal followed by different adsorption processes to remove e.g. sulphur and chlorine compounds. At the same time, ECN is involved in the realization of a pilot-scale facility in the North of the Netherlands.

5 CONCLUSIONS

Indirect (allothermal) gasification is an attractive option to convert biomass into a combustible gas. MILENA is the name of an allothermal gasification technology developed by ECN. It is a compact and easy design, which can produce a medium calorific (essentially N_2-free) gas already high in methane without the use of pure oxygen. The efficiency is high and the fuel conversion is complete. The product gas contains high amounts of hydrocarbons, which makes the MILENA-concept very suitable for a biomass-to-SNG plant. Currently, ECN is finalizing the construction of a complete lab-scale test unit with MILENA-gasifier, OLGA tar removal, further gas cleaning and methanation.

6 REFERENCES

1. S. Stelter: The new synfuels energy pioneers; a history of Dakota gasification company and the Great Plains Synfuels Plant, Dakota Gasification Company (2001).
2. *www.dakotagas.com*. (2004).
3. E. Deurwaarder, H. Boerrigter, H. Mozaffarian, L. P. L. M. Rabou and A. van der Drift: *Methanation of MILENA product gas for the production of bio-SNG*, 14th European Biomass Conference & Exhibition, 17-21 October 2005, Paris, France (2005).
4. A. van der Drift: *An overview of innovative biomass gasification concepts*. In: 12th European Conference on Biomass for Energy, 17-21 June 2002, Amsterdam, the Netherlands, pp. 381-384 (2002).
5. H. Boerrigter, S. V. B. van Paasen, P. C. A. Bergman, J. W. Könemann, R. Emmen and A. Wijnands: *OLGA tar removal technology*, ECN, Petten, The Netherlands, ECN-report ECN-C--05-009, 55 p. (2005).