May 2004 ECN-RX--04-048

BIO-SYNGAS: KEY INTERMEDIATE FOR LARGE SCALE PRODUCTION OF GREEN FUELS AND CHEMICALS

Presented at "The 2nd World Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection" in Rome, Italy, 10-14 May 2004

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ABSTRACT: Biomass will play a major role in future as a renewable energy source. Present study focuses on the production of fuels and chemicals from biomass. It is expected that biosyngas will play a key role and the biosyngas market volume will be huge. Plants mostly will be large-scale. Slagging entrained flow gasification is identified as the most suitable technology, since it is robust, commercially available and capable of converting a wide range of biomasses. With woody biomass, pre-treatment can probably be limited to size reduction to approximately 1 mm. Total efficiency can reach 84%. Torrefaction can be considered as a back-up option. If grassy biomass is considered, flash pyrolysis to produce an oil/char-slurry might be the cheapest way, despite the fact that the total efficiency drops to 76%.

1 INTRODUCTION

Biomass is heading for a great future as renewable energy source. It not only is available in large quantities, it also is the only renewable energy source that is suitable for the sustainable production of (generally carbon containing) transportation fuels and chemicals. A promising option to do so is to convert biomass into a biosyngas by gasification and subsequently synthesize the required products.

2 CONSIDERATIONS

Generally, syngas plants are large. The typical scales for the different applications are:

- transportation fuel sector: > 1000 MW
- chemical sector: ~100 MW

The world market for transportation fuels and chemicals is huge: approximately 30% of the world energy consumption [1]. The transition to green alternatives therefore requires biomass, which should be available in large quantities. Since wood and grass-like material make up 70-90% of the total technically available amount of biomass worldwide [2], it is reasonable to focus on these biomass fuels as main renewable energy sources for chemicals and fuels.

3 SYNGAS MARKET

In total about 6000 PJ/year of syngas is produced worldwide, corresponding to almost 2% of the present total worldwide energy consumption. Figure 1 shows the present syngas market distribution. The world market for syngas (mainly from fossil energy sources like coal, natural gas and oil/residues) is dominated by the ammonia industry. Also the H_2 in oil refineries represent a significant share in present syngas applications.

Since even a total substitution of the present syngas market by biosyngas will not be enough to meet the various targets for renewable energy and CO_2-emission reduction, new markets have to come forward. This is considered to be the transportation fuels and chemicals market. This coincides with different goals of local authorities to decrease the dependency of oil producing countries.

In Europe, 5.75% of the fuels must be renewable by 2010. It is expected that this will be increased to 10% by 2020. In the Netherlands, long-term biomass transition visions have been developed lately by the Ministry of Economic Affairs. As a reference it is stated that biomass will play a major role and biomass will mainly be used for high quality products like transportation fuels and chemicals. In the Dutch concept vision for 2040 is mentioned that 20-45% of fossil energy used in industry will be replaced by biomass. Assuming 30% as an average value and translating this to world scale, the total syngas market will be increased to approximately 50 000 PJ/year and will be dominated by biosyngas. The world syngas market will look as shown in Figure 2.

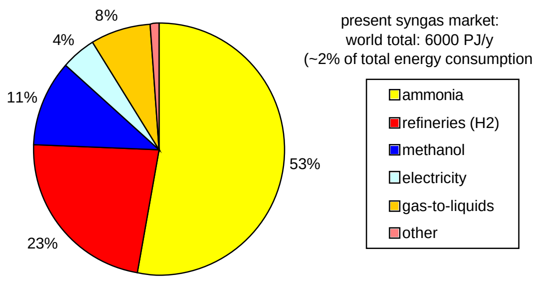

Figure 1: Present world syngas market

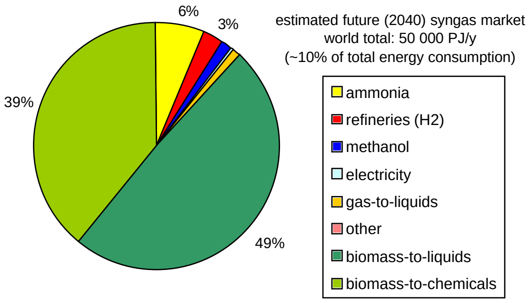

Figure 2: Predicted world syngas market in 2040

4 BIOSYNGAS PRODUCTION

In a joint study of ECN and Shell, a gasification technology has been selected for the production of biosyngas [3]. Important starting points were: large-scale plants and suitability for both wood and grassy material as biomass fuels. Pressurised slagging entrained flow gasification has been identified as it is a robust technology, commercially available and capable of converting a wide range of different fuels. Depending on the type of biomass, flux materials should be added and slag and/or fly ashes should be recycled. If clean wood is applied, silica or clay should be added to ensure sufficient melt at typical gasifier temperatures of 1300°C. Figure 3 shows a typical result from thermodynamic modeling using clean beech wood as fuel. These results were confirmed by lab-scale experiments with an entrained flow simulator at ECN [4].

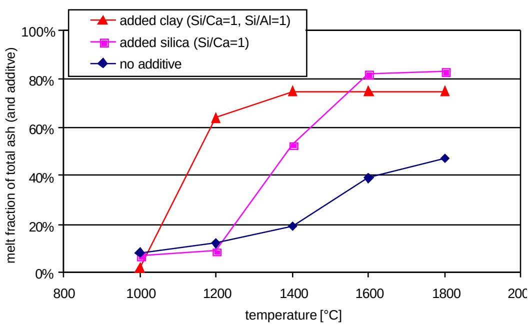

Figure 3: Calculated melting behaviour of clean wood (beech) with two realistic additives

5 PRE-TREATMENT

The upstream processes of a biosyngas plant probably are the most challenging. In order to convert biomass into a biosyngas at typically 1300°C within several seconds in an entrained flow gasifier, biomass particles should be relatively small. Present applications mostly are operated on either a solid/liquid-slurry or solid particles of 100 µm or smaller. Fuel feeding takes place by slurry pump or pneumatically respectively.

Biomass can be pre-treated in order to meet requirements of present (mostly fossil fuel based) entrained flow gasifiers:

- Slurry: Fast pyrolysis can be applied to produce a oil/char-slurry from biomass [5,6]. This mainly seems attractive for low-density grassy fuels like straw, since transportation costs can significantly be reduced. The process of producing slurry however involves an efficiency penalty of approximately 15%.
- Powder: Biomass can be pulverized to particles of 100 µm or less. This however consumes huge amounts of electric energy. For the calculations, it is assumed that the powder is pressurized by lock hopper and fed by pneumatic feeder. From tests at ECN however, it appears that the resulting fiber-like material seems not suitable for pneumatic transport.
- Torrefaction: By pre-treating the biomass by torrefaction, the material gets brittle and electricity consumption upon milling to 100 µm powder reduces

from 0.08 to 0.01 kW_e/kW_{th} [7]. The process of torrefaction involves an efficiency penalty of approximately 5%. For the calculation it is assumed that the fuel is pressurized by piston and fed by pneumatic transport.

Two other pre-treatment processes should be mentioned. Both options exist because of the typical properties of biomass:

- Pre-gasification: Biomass is first converted at relatively low temperature in an oxygen-blown fluidised bed reactor. The resulting producer gas (including small solid particles consisting of unconverted fuel and ash) is introduced in the entrained flow gasifier. The energy efficiency penalty is limited to a few % at most, but two reactors must be coupled. This will make this system relatively vulnerable for malfunctioning.
- 1 mm fuel: Biomass is milled to 1 mm particles. Because of the relatively high reactivity, it is assumed that this will be small enough to get (almost) complete conversion at 1300°C. Several tests by both ECN and others confirm the validity of the assumption. Since pneumatic feeding no longer can be applied, screw feeders must be used. Compared to pneumatic feeding, this has the advantage that only little inert gas is necessary and gasifier efficiency is high. For the calculation it is assumed that the fuel is pressurized by piston.

6 EFFICIENCY

The efficiencies have been calculated assuming wood with 35% moisture as fuel and biosyngas at 40 bar with $H_2/CO=2$ as final product. Figure 4 shows the result for above mentioned five pre-treatment options. Both cold gas efficiencies and total efficiencies are given. The total efficiency includes electricity production and consumption (for pulverization, inert gas compression, O_2-compression, O_2-production) calculated to primary energy with 40% efficiency.

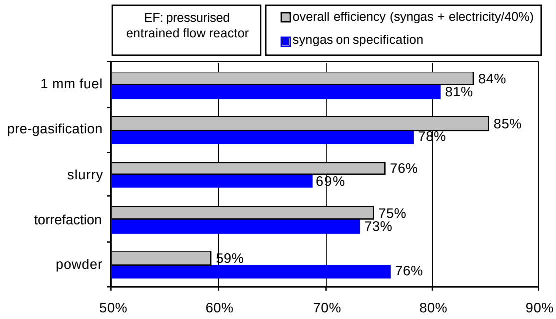

Figure 4: Efficiencies of different options (see text) from biomass to biosyngas

From Figure 5 it is clear that milling biomass to powder, similar to coal, results in a very low efficiency, mainly due to the high electricity consumption upon milling. Pre-treatment by torrefaction or pyrolysis result in much higher efficiencies. Pre-treatment by low-temperature gasification is even better. The system with 1 mm biomass directly fed into a pressurized entrained flow gasifier has the highest biomass-to-biosyngas efficiency. Moreover, this system is the simplest and therefore probably the cheapest option to produce biosyngas from woody material. Figure 5 shows this option schematically Torrefaction as pre-treatment is considered as a back-up option for solid woody biomass, but might also be useful to treat grassy material at the source (followed by pelletising) in order to increase the energy density.

It should be mentioned that the efficiency greatly depends on the way the fuel is pressurized. Lock hoppers consume enormous amounts of inert gas, whereas piston feeders do not.

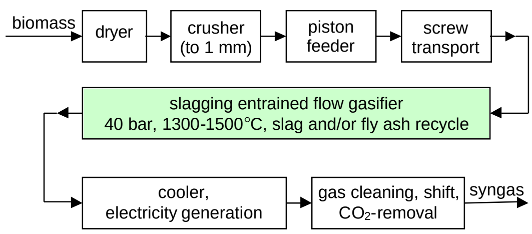

Figure 5: Preferred option for biomass to biosyngas for woody material

Grassy material may better be pre-treated by pyrolysis to produce a slurry, which can be transported relatively cheaply compared to the original low-energy density material.

7 CONCLUSIONS

Biosyngas will play a major role in future. Slagging entrained flow gasification is the preferred technology. With woody biomass, pre-treatment can probably be limited to size reduction to approximately 1 mm. Total efficiency (starting with wood with 35% moisture) can reach 84%. If grassy biomass is considered, flash pyrolysis to produce an oil/char-slurry might be the cheapest way, despite the fact that the total efficiency drops to 76%.

8 FUTURE

The following technical issues need further development in order to come to a full-scale biosyngas plant: verify conversion of 1 mm biomass particles, suitability of screw feeders in combination with entrained flow reactors, pneumatic feeding of torrefied wood, soot formation, cooling, and piston feeding in general. Furthermore, practical information is needed in the field of ash behaviour and flux requirements. Experiments with pilot-scale systems and relevant parts are foreseen in order to be ready to start the construction of a large-scale biosyngas plant within 5 years.

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