SUBJECT 3: 3.2 Pyrolysis and other biomass liquefaction technologies

Alternative fuels from Biomass and Power (PBtL) – A case study on process options, technical potentials, fuel costs and ecological performance

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Summary

Greenhouse gas emissions in the transport sector can significantly be reduced by replacing fossil based fuels with biomass-based alternatives. Several promising fuel production paths of the second generation made from residues and waste wood had already been developed in recent years. These fuel concepts typically suffer from the axiomatically limited technical potential of biomass resources in central Europe. Furthermore, fuel costs are currently not competitive on the market. In order to change this state, the German Aerospace Center has refined existing Biomass-to-Liquid (BtL) and Power-to-Liquid (PtL) concepts to the so-called Power&Biomass-to-Liquid concept. The main idea is to utilize the large technical exploitation potential of renewable electricity in modified BtL plants. The case study presents detailed results on promising process configurations of Fischer-Tropsch PBtL concepts based on different gasifier and electrolyzer technologies, the expectable technical fuel potential, fuel production costs and CO_2 footprint.
As a result, the fuel output of BtL plants can be nearly quadrupled at the same biomass input. Hence, fuel costs can significantly be reduced due to economy of scale effects. Furthermore, the specific CO_2 footprint of the fuel is reduced as well.

Method

A very simplified block-flow diagram of the PBtL process is given in Figure 1. The main process steps are biomass gasification, water electrolysis, reverse watergas-shift reaction and Fischer-Tropsch synthesis. Four process concepts have been developed and implemented in the flowsheeting software Aspen Plus. The concepts differ in the used electrolyzer (Proton exchange membrane (PEM) versus high-temperature electrolysis with a solid oxide electrolyzer cell (SOEC)) and biomass gasification technology (fluidized bed gasification versus entrained flow gasification). The Fischer-Tropsch synthesis section is the same for all concepts. All models were optimized in terms of heat integration and production costs in the course of an extensive techno-economic evaluation with the software-tool TEPET (Techno-Economic Process Evaluation Tool). In addition, an exergy analysis was carried out to identify the most significant thermodynamic optimization potentials in the concepts. Finally, the CO2 footprint was estimated by Life-Cycle assessment.

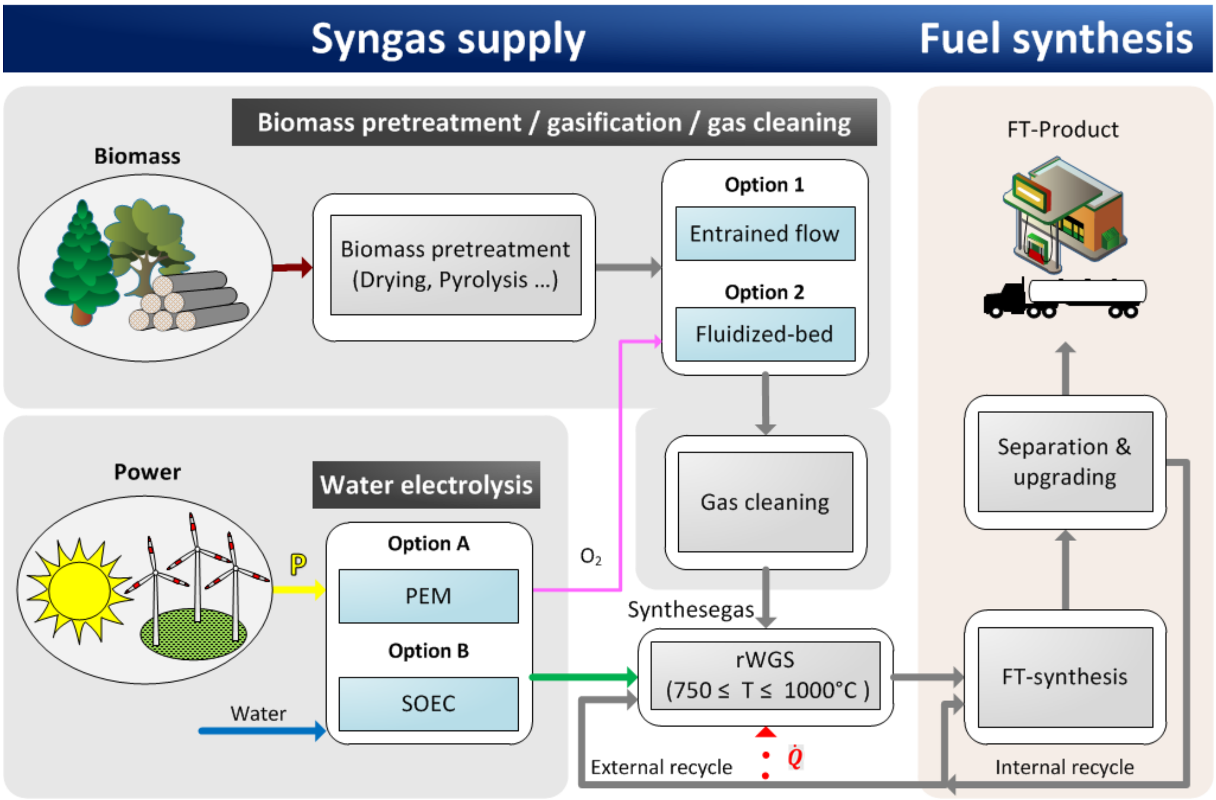

Figure 1: Block flow diagram and system boundary of PBtL concept

Results and Conclusion

Results from the study indicate that the unused biomass potential in Germany is not sufficient to replace a large share of fossil fuels with BtL-fuels. Though, fuel output can be quadrupled when utilizing green electricity in the form of hydrogen in the PBtL process. The increased fuel output results in lower fuel production costs due to the effects of the economy of scale. Regardless of the investigated concept, expenses on electricity are by far the most sensible cost factor, followed by capital costs for the electrolyzer and gasification. Fuel production costs below 1.3 €/l were estimated for large PBtL plant assuming an electricity price of 31.4 €/MWh (average EEX- Phelix index of the year 2015). The exergy analysis reveals that the electrolysis and the gasification processes are the most thermodynamic inefficient production steps. The high-temperature electrolysis with SOEC is superior to the PEM electrolysis in terms of exergetic performance, since waste heat accrues at high temperature offering the potential to generate electricity. The exergetic efficiency of gasifier systems can be increased by applying hot gas cleaning followed by heat integration. The PBtL concept is characterized by a lower CO_2 footprint, as high carbon conversion rates close to 100 % are achieved by recycling CO_2 within the system. Largest CO_2 emissions arise from the harvesting and transportation of the biomass feedstock.