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Selecting the appropriate gasification technology and system design for Power and Biomass-to-Liquid concepts: A case study

F. G. Albrecht, D. H. König, R.-U. Dietrich
German Aerospace Center, Institute of Engineering Thermodynamics, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany

Abstract

Biomass based biofuels offer a significant potential to reduce greenhouse gas emissions in aviation and heavy load transportation. Though, the available biomass potential is subject to natural restrictions and further limited due to usage competition with other biomass applications. In order to maximize biofuel yield, Power and Biomass-to-liquid (PBtL) concepts gained recently in importance. The main idea is to add sustainable hydrogen from water electrolysis using renewable electricity in a reverse water-gas shift (rWGS) reactor to common biomass gasification concepts.

A great challenge is to identify the optimal system design of PBtL plants in terms of fuel yield, energy efficiency and fuel net production costs. A large number of more or less state-of-the-art biomass gasification technologies exist currently on the market each one requiring a different biomass pretreatment and raw gas cleaning. Furthermore, the design of the synthesis plant offers various optimization options regarding operation conditions, selection of Fischer-Tropsch reactor type and number and position of recycle streams.

Various PBtL system designs have been proposed at the German Aerospace Center (DLR) based on the different gasification technologies fix bed, fluidized bed and entrained flow gasification. The system performances were estimated and compared in terms of carbon conversion, energy efficiency and fuel net production costs. In addition, a detailed exergy analysis of a reference PBtL concept has been carried out in order to identify further optimizations potentials in the process chain.

It was shown that the appropriate selection of the biomass gasifier highly depends on the type and available potential of biomass. Entrained flow gasification is superior in terms of economic performance for large scale PBtL plants in the >100 MW (LHV biomass) range. Fluidized bed gasification is attractive for small and medium scale plants, though, an extensive syngas cleaning is typically required. Using pure oxygen as gasification medium reduces total investment costs significantly. By implementing several recycles and a high operation temperature in the rWGS reactor, carbon conversion efficiencies close to 98% can be achieved. The product yield of PBtL concepts was thereby nearly quadrupled compared to common Biomass-to-Liquid plants. Most exergy is lost during biomass gasification and in the rWGS reactor indicating the need for further research in these areas. Capital expenses for the gasifier and the electrolyzer are the most significant cost factors for small scale plants independent of the chosen system design, whereas expenditures on raw materials and electricity define the fuel price for large scale plants.

Korrespondierender Autor:

Titel:	Selecting the appropriate gasification technology and system design for Power and Biomass-to-Liquid concepts: A case study
Vorname:	Friedemann Georg
Name:	Albrecht
Firma/Uni:	German Aerospace Center (DLR), Institute of Engineering Thermodynamics
Straße:	Pfaffenwaldring 38-40
PLZ Ort:	70569 Stuttgart
Email:	Friedemann.albrecht@dlr.de
Telefon:	+49 711 6862 232
Beitrag als:	Vortrag [ ] Posterbeitrag [x]