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Comparative simulation study of fuel production pathways from biomass-derived syngas

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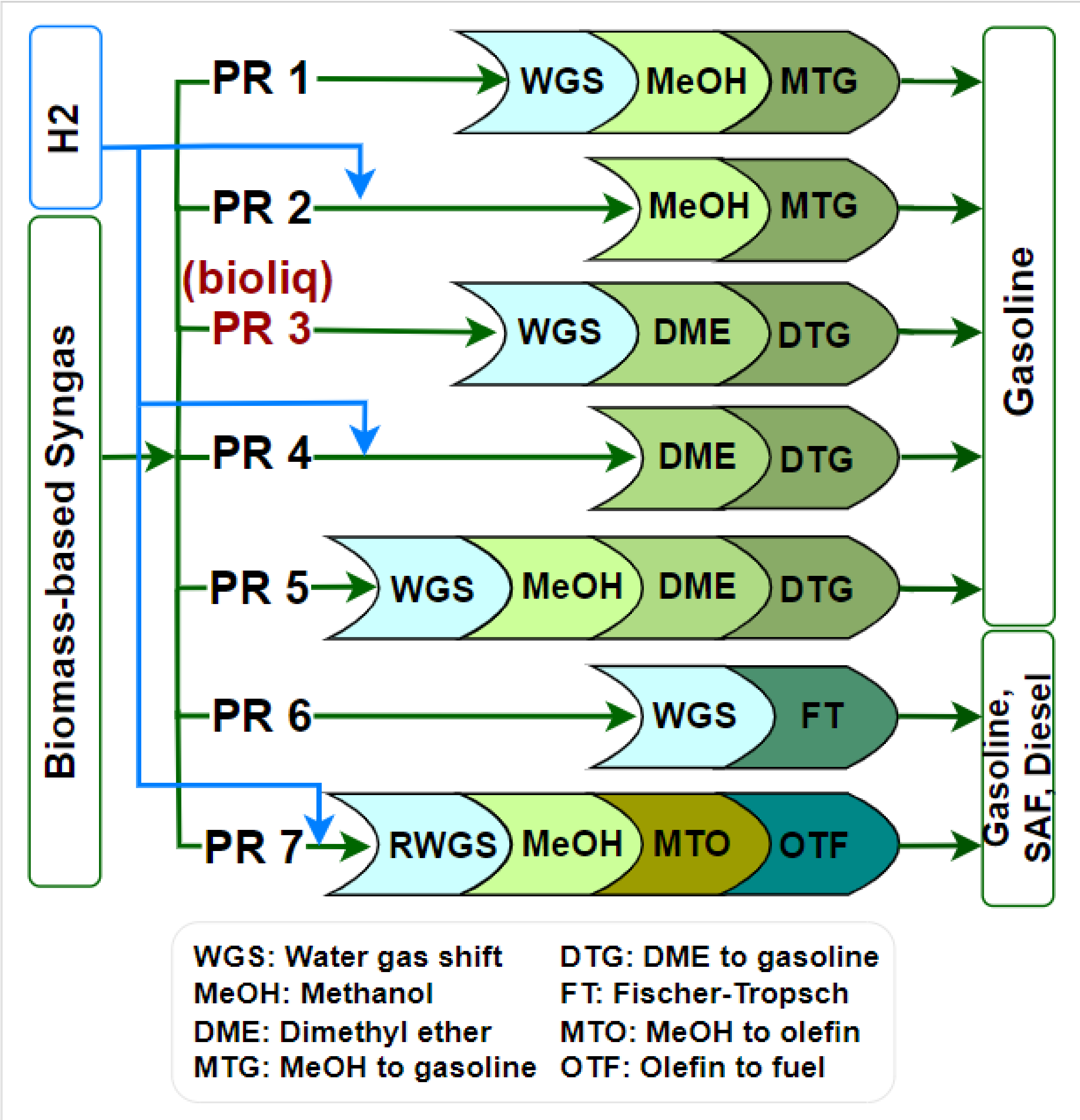
The bioliq® pilot plant located at the KIT in Germany is a successful example of conversion of lignocellulosic biomass into gasoline. The process includes four steps: fast pyrolysis, entrained flow gasification, syngas cleaning, and fuel synthesis, where biomass-derived syngas is converted into gasoline via dimethyl ether (DME) synthesis.[1] During the bioliq project, several tons of fuel were produced over the last years operational campaigns; the produced gasoline fraction was blended with fossil-based fuels and successfully applied to test engines and cars. The focus of the present work is on the “fuel synthesis unit” of this pilot plant for converting biomass-derived syngas into fuels. The optimization of the current plant configuration is conducted first, followed by the investigation of alternative process pathways for production of gasoline [2], sustainable aviation fuel (SAF), and diesel fractions.

This study is performed by developing reliable simulations in Aspen Plus® to evaluate different processes beyond experimental investigation. For this purpose, process pathways of DME synthesis followed by DME to gasoline (DTG), MeOH synthesis followed by MeOH-to-gasoline (MTG) and MeOH-to-olefin (MTO) to fuels, as well as Fischer-Tropsch (FT) synthesis to fuels are selected, as represented by Figure 1. The precision of simulations is ensured through detailed technical considerations by employing kinetic models, experimental data from lab or industrial plants, and validation with real plant data when available. The process pathways are compared based on feed conversion rate, fuel mass and energetic efficiencies and also hydrogen and carbon balances.

Technical studies comparing these process pathways for biofuel synthesis from biomass-derived syngas are limited in existing literature, and most of the recent works focus on fuel synthesis via power-to-liquid technology using renewable CO_2 and H_2 as feedstock. This work follows the bioliq process concept and uses a biobased syngas-feed derived from an operational test.

The process pathways are compared in terms of feed conversion rate, fuel mass and chemical energetic efficiencies, as well as H_2 consumption and CO_2 formation. The simulation results indicate that for gasoline production the current bioliq process constellation, i.e. direct conversion of biomass-derived syngas to DME followed by DTG process, is more advantageous than other process routes. For SAF production the MTO-to-fuels pathway is promising, for which data obtained from an innovatively developed laboratory-scale reactor at the KIT have been used in modeling. The findings of this detailed technical study provide insights for approximating achievable fuels efficiency, and facilitate the identification of the most optimal process configurations concerning different optimization objectives. Besides, this technical work will support the basis for subsequent TEA and LCA studies.



Comparison of process routes (PR) for fuel synthesis from biomass-derived syngas

References:

[1] Dahmen, N. et al., (2017), The Bioliq Process for Producing Synthetic Transportation Fuels, WIREs Energy & Environment, https://wires.onlinelibrary.wiley.com/doi/10.1002/wene.236

[2] E-Moghaddam, M. et al., (2024), Gasoline Synthesis from Biomass-Derived Syngas Comparing Different Methanol and Dimethyl Ether Pathways by Process Simulation, Based on the Bioliq Process, Energy Fuels, https://pubs.acs.org/doi/10.1021/acs.energyfuels.3c04524