

Sustainable gases from biogenic residues – An experimental and simulation-based investigation of synthetic natural gas and hydrogen production

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The production of renewable gases from biogenic residues may contribute to a clean energy transition and increases the independence from natural gas imports. In Austria, the Erneuerbaren-Ausbau-Gesetz (EAG) provides the basic legislative framework for an increased share of renewable gases of 5 TWh a⁻¹ in 2030. Renewable hydrogen and methane, e.g. renewable synthetic natural gas (SNG), are the two most relevant energy carriers in this context. A possible production pathway for these energy carriers is the steam gasification of biogenic residues and the consecutive synthesis and separation of SNG and hydrogen, respectively.

Within the BIG-Green Gas project, the production of (raw-)SNG and hydrogen is experimentally investigated in pilot- and demonstration-scale and theoretically scaled-up via process simulation to industrial plant sizes. Hence, biogenic residues, such as bark, paper sludge and corn cobs, are gasified in the 1 MW_{th} dual fluidized bed (DFB) gasification plant of the Syngas Platform Vienna. The obtained product gas is then cleaned and bottled in gas cylinders for further investigation. At TU Wien, the bottled syngas is used for raw-SNG and hydrogen production at pilot-scale. For the purpose of high-purity hydrogen production, a process chain consisting of a water-gas shift (WGS) unit, gas cleaning units and a pressure swing adsorption (PSA) unit is investigated. On the other hand, a fluidized bed methanation unit is utilized for the investigation of raw-SNG production. The results are further used for the simulation of industrial-scale hydrogen and SNG production concepts with the process simulation software IPSEpro based on a fuel input of 50 MW_{th} each.

The experimental results show that the production of high-purity hydrogen and raw-SNG, utilizing syngas from the gasification of biogenic residues, is technically feasible. High-purity hydrogen, suitable for PEM-fuel cell application according to ISO 14687 (purity $\geq 99.97\%$), could be produced steadily over a time-span of 18 h without any fluctuations or signs of deterioration. Parameter variations in the WGS and PSA units revealed suitable process parameters, yielding a hydrogen recovery of 73%. Higher hydrogen recoveries were found to be possible if slightly higher threshold values of inert gases, such as nitrogen ($> 300 \text{ ppm}_v$), would be allowed according to the respective standards. Similarly, raw-SNG could be produced over a time period of 16 h with a slight decrease in the methane content of 0.5 vol.-%_{db}. However, catalyst analyses revealed no significant catalyst deactivation despite the sub-stoichiometric H₂/CO ratio of the product gas. Previous variations in reaction temperature, space velocity, water and hydrogen addition were performed to yield suitable process parameters for fluidized bed methanation.

The fully integrated and optimized industrial-scale simulations indicate that 24.3 MW_{th} of high-purity hydrogen or 30 MW_{th} of grid-ready SNG can be produced from 50 MW_{th} of bark. Additionally, about 9.6 t/h of almost pure biogenic CO₂ and 7 MW_{th} of district heat are available as secondary products in case of hydrogen production. In case of SNG production, 5.7 t/h of CO₂ and 6 MW_{th} of district heat are available. Thus, about 3.7% and 4.5% of the demanded renewable gas share in 2030 could be covered by a 50 MW_{th} bark-to-hydrogen and a 50 MW_{th} bark-to-SNG plant, respectively.