Techno-economic Assessment of Water-conscious Green Methanol Production

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Abstract

Methanol is an important commodity in today's economy employed extensively as a feedstock in the chemical industry and as an energy carrier. Its importance is reflected by a current demand of more than 100 Mt/a and it is projected to increase significantly in the future. While green methanol production has already attracted some attention, water-conscious production is becoming increasingly important due to worsening water stress in many regions.

In this study, a comprehensive techno-economic assessment is conducted to quantify the future expected cost of water-conscious green methanol production in arid regions. Therefore, two process chains, one based on direct CO_2 hydrogenation and one based on synthesis gas, are modeled and compared.

Both process chains utilize adsorption-based direct air capture (DAC) to provide CO_2 and H_2O directly from the ambient air. The employed DAC model incorporates the impact of the climatic conditions and is combined with hourly resolved weather data to derive the specific energy demand and co-adsorption ratio for each considered region on a high temporal resolution. In the first process chain, polymer electrolyte membrane electrolysis is considered to produce hydrogen from the adsorbed H_2O. Subsequently, CO_2 hydrogenation is employed for methanol production. The alternative process chain utilizes a solid oxide electrolyzer for synthesis gas provision combined with conventional CO hydrogenation for methanol production. Both process chains are combined with hourly resolved renewable energy generation profiles of onshore wind turbines and open-field photovoltaic (PV) systems. The ETHOS.FINE framework is utilized to perform techno-economic optimization of the systems. First, the maximum technical potential is derived, which is constrained by the available renewable energy potential and by the energy demand of DAC in the corresponding regions. Second, cost optimization is performed to minimize the total annual system cost and determine the levelized cost of methanol (LCOM).

The results indicate LCOM in a range of 700 to 2000 €/t dependent on the region and process chain. Generally, high wind full load hours lead to the lowest LCOM. In the regions with the lowest LCOM, the cost of the process chain contributes about 60% of the total cost. The largest cost driver

is electrolysis (20-40%) followed by the DAC plant (10-25%) while the cost of the methanol synthesis only contributes about 6-12% of the total cost. The amount of co-adsorbed water varies greatly between regions (0.7-2.3 t_{H2O}/t_{CO2}) potentially leading to operational constraints.

Finally, we show that water-conscious green methanol production can be competitive and highlight the need of a regional perspective in techno-economic assessments.