Solar E-Methanol Production Based on CSP/PV Hybrid Power Plants

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Abstract: Global trade of renewable hydrogen derivatives could become a key factor in reducing global greenhouse gas emissions. Methanol, a versatile chemical building block, is one of the most promising hydrogen carriers in this context. If produced with hydrogen and CO_2 from a sustainable source, methanol could not only replace current fuels, but also help the chemical industry move away from fossil feedstocks. The hydrogen with a low CO_2 footprint required for the methanol synthesis can be produced by water electrolysis powered by renewable electricity. Due to the enormous potential of solar energy and the availability of unused land, the Earth's sunbelt could become a major producer of green hydrogen and thus an exporter of renewable e-methanol.

However, producing hydrogen derivatives such as e-methanol cost-efficiently using solar energy is challenging. Low electricity costs can be achieved by using photovoltaics (PV), but the availability of the electricity source is limited to daytime, and depending on the solar irradiation the supply can fluctuate. To reach more electrolyzer full-load hours and to ensure the required minimum electricity demand of the plant, a stand-alone system without grid connection needs some kind of storage solution. Storing electricity in large quantities with batteries is too expensive to be an option. In addition, further synthesis processes require a relatively continuous supply of hydrogen, electricity and also often thermal energy. Combining PV with concentrated solar power (CSP) and thermal energy storage (TES) seems to be a good way to meet these requirements at sites with high solar irradiation. In the absence of solar radiation, stored thermal energy can be used to generate electricity in a steam cycle, allowing very continuous operation of the electrolyzer and the overall plant. These hybrid solar energy systems for synthetic fuel production offer a wide range of operating modes and plant configurations. In addition to thermal energy storage, electrical energy storage and physical storage of process components, e.g. hydrogen, can be included. Due to this variety, finding the best system design with the lowest levelized product costs is a complex optimization problem.

Therefore, this work introduces an energy system model for e-methanol production powered by CSP/PV hybrid power plants. Based on included techno-economic data, the model is able to determine cost-optimal designs of such solar e-methanol production plants based on a global optimization algorithm. The optimized plant designs are presented and compared to plant configurations without hybridization of CSP and PV. Furthermore, the influence of the solar resource on methanol production cost, plant design and plant operation is analysed by performing optimizations for different plant locations.

Acknowledgements:

The authors of this work gratefully acknowledge the funding of the projects SolareKraftstoffe (Grant agreement Nr. 03EIV221), MENA-Fuels (Grant agreement Nr. 03EIV181A-C), TUNol (Grant agreement Nr. 03EE5123E) by the Federal Ministry for Economic Affairs and Energy, on the basis of a decision by the German Bundestag and financial support from DLR's basic funding for the project Neofuels.