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Simulation-based Design and Implementation of a Laboratory-scale Power-to-Liquid plant

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Abstract

The continuously increasing emission of greenhouse gases has been widely recognized as a major challenge of the 21st century. While the share of renewable energy is increasing, the progress in other sectors such as mobility and industry was rather limited. Especially the industrial sector is hard to defossilize due to the scale of the current industrial processes.
Carbon direct avoidance (CDA) is being discussed as a pathway to limit emissions i.e. in the steel industry [] and the substitution of coke by hydrogen as a reducing agent is widely considered as the most attractive pathway to low-carbon steel production.
For other branches such as the lime and cement industry CDA is not an option due to CO_2 being an integral part of the process chain. In these cases, a carbon capture and utilization (CCU) process is a possibility to avoid emissions. Especially Power-to-Liquid processes have received increasing attention due to the possibility to provide hydrocarbons to a defossilized economy.
Currently, market entry for such technologies is impeded by a strong competition of crude oil based products. Therefore, the process proposed in this work relies on a high degree of heat integration and by-product utilization in order to reach a high efficiency. Also the product synthesis was modified in order to obtain a higher-value product spectrum, such as waxes and higher alcohols in order to achieve a high revenue level.
Taking into account the possibility of internally reforming of short chained hydrocarbons in an SOEC, the electrolysis was experimentally investigated and a model was derived. Based on a process model incorporating the SOEC model as well as experimentally derived data of a modified Fischer-Tropsch synthesis, a laboratory scale plant was designed and implemented. The lab plant allows for the investigation of phenomena associated with utilization of by-products by internal reforming via a tail-gas recirculation as well as of approaches for the utilization of a purge gas stream for educt pre-heating.