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Chemical Utilization of Carbonaceous Waste and Lignite – A Case Study of Sustainable Olefin Production in Germany

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Abstract

To achieve Germany's reduction targets for greenhouse gas emissions by 2030/2050, it is essential to extend the predominant focus on the energy sector to include other carbon intensive industries such as the chemical and waste management sectors. A sector coupling of the energy, chemical and waste industries can make a significant contribution to emissions reduction through using domestic primary and secondary carbon resources (i.e. lignite and carbonaceous waste) as raw materials for chemical production instead of combusting them for electricity and heat. Gasification represents a key technology for such sector coupling of carbon intensive industries. The production of organic basic chemicals such as olefins from domestic carbon resources is of particular relevance to support the transition from a linear to circular carbon economy.

In the current linear economy, olefins are predominantly produced from crude oil and natural gas. To assess the sustainability of the transformation from a linear to circular carbon economy, a case study of olefin production via chemical utilization of domestic carbon carriers in Germany is carried out. A transformation pathway with stepwise implementation of gasification technologies for the conversion of carbonaceous waste and lignite into carbon monoxide and hydrogen for subsequent synthesis of methanol and light olefins is developed to answer the following research questions: (1) Can a circular carbon economy with lignite integration be sustainable?, (2) What are the economic perspectives of a circular carbon economy, (3) How does a circular carbon economy compare to the linear economy in terms of CO_2 emissions, employment and infrastructure?, and (4) In the long run, can a circular carbon economy achieve zero CO_2 emissions?

The time horizons for the evaluation are the reference years 2030 and 2050, with integration of regeneratively produced hydrogen assumed for 2050. Detailed mass- and energy-balances are generated by flowsheet simulation using Aspen Plus and validated process models. The overall carbon balance is presented in mass-flow diagrams to illustrate the transformation pathway towards a circular carbon economy. The carbon recycling rate into the product and CO_2-emissions serve as key performance indicators. In the base scenario without integration of renewable hydrogen, carbon recycling rates of up to 45 % and a reduction of CO_2-emissions by 35 % compared to the current linear carbon economy can be achieved. Carbon recycling rate increases with the integration of renewable hydrogen. With large-scale production of renewably hydrogen in 2050 and its integration in the gasification process, carbon recycling rates of above 90%, corresponding to a reduction of CO_2-emissions by 95%, are possible.