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DEEP DEFOSSILIZATION IN GERMAN INDUSTRY – A TECHNO-ECONOMIC ANALYSIS OF LOW-CARBON OPTIONS

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Overview

Carbon-neutral hydrogen is widely considered a key part of the ongoing renewable energy transition as a substitute for fossil fuels. However, switching from fossil fuel to carbon-neutral hydrogen is not always the most sensible choice. Instead, other low-carbon options, especially the direct use of electricity, are a preferable alternative for many applications. The presentation at this conference will show an approach to derive future hydrogen demands by identifying the least-cost low-carbon option for various industrial production systems and scenarios in Germany. Preparing such a transition roadmap requires detailed knowledge of the techno-economic data of the currently installed conventional production systems and the suitable low-carbon options. Therefore, a bottom-up approach on the industrial process level is applied. According to the literature, using carbon-neutral hydrogen could be a promising low-carbon option especially for industries requiring high-temperature heat, i.e., for industries that rely on temperature windows for which heat pumps are not technically feasible. The analysis also considers the usage of carbon-neutral hydrogen as feedstock and as a reducing agent.

Method

The complexities and interdependencies of industrial production systems require the application of cut-off criteria, ensuring that only the relevant production systems become part of the analysis. To this end, the first step is to identify and analyze production systems applying a bottom-up approach, deriving greenhouse gas (GHG) emissions and heat demands on a process level. Later in the analysis, the disaggregation of production systems allows using the same processes in different production systems. The selection of fossil fuel-based production systems depends on four criteria: the absolute GHG emissions from the conventional processes included in the production system (I), the type of the GHG emissions (II), the temperature ranges in which the underlying processes operate (III), and the requirement of hydrogen, carbon, or carbon compounds as feedstock or as a reducing agent (IV). The second step is to define reference production systems and their low-carbon options to be compared. The definition of the reference conventional and low-carbon production systems is based on a literature review. To compare the different low-carbon options with each other, a reference unit of measure, which forms a common basis for all calculations performed, is defined. For this analysis, the quantitative reference is 1 ton of final product per year. The third step of the analysis is to derive the inputs, outputs, and operation and maintenance costs of the underlying processes according to the literature in at least one of the conventional or low-carbon production systems considered, to set all the values adopted in relation to the production systems' quantitative reference defined, and to monetarize the inputs and by-product outputs. Also, the analysis includes the annuities of the investments required to implement the low-carbon options. These normalized data allow, in the fourth step, to determine the least-cost low-carbon option for each conventional production system for given scenario assumptions, and to derive potential future hydrogen demands from the industries considered in the last step.

Results

The results of the analysis include a description of the defined reference conventional and low-carbon production systems, the determination of the least-cost low-carbon option for a variety of hydrogen prices, and the hydrogen demand resulting from achieving climate neutrality, assuming that the most cost-efficient low-carbon option would be implemented. In total, the analysis covers 25 conventional production systems and 61 low-carbon options. Preliminary results show that break-even hydrogen prices, i.e., the specific hydrogen costs below which the hydrogen-based low-carbon option would be the most cost-efficient, varies across the different industries in a range of 50 € per MWh to 140 € per MWh with most break-even points falling between 70 € per MWh and 105 € per MWh. While the complete fuel transition of all industries considered to hydrogen would result in a hydrogen demand of 350 TWh, hydrogen prices above 140 € per MWh would cause only production systems with unavoidable hydrogen necessity to switch to carbon-neutral hydrogen, yielding a total demand of 25 TWh. More details will be provided at the conference.

Conclusions

The results show that making generalized statements about whether to defossilize an energy-intensive process by either switching to carbon-neutral hydrogen or direct electrification are not sensible, as the break-even hydrogen prices of the industries show a broad range, and the resulting hydrogen demand is very susceptible to variations of the assumed hydrogen price. Hence, decisions on how to defossilize the energy-intensive industrial sector should be based on a detailed analysis of the particular production systems. Due to several simplifications, this analysis can only serve as an initial assessment for decision-makers of concrete industrial plants. However, from an energy system perspective, it may support, e.g., energy system modelers with either exogenous hydrogen and additional power demands of energy-intensive industries when transformed to climate neutrality or the underlying techno-economic data as model input.