HYDROGEN IN THE EUROPEAN POWER SECTER – A CASE STUDY ON THE IMPACTS OF REGULATORY FRAMEWORKS FOR GREEN HYDROGEN

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Overview

The ambitious decarbonization goals call for a quick transformation of the energy system. Focusing on the power sector, rapid and targeted efforts are required to meet the goals at international and national level. So far, the expansion of renewables like wind and solar energy plays a major role in the German power sector. Despite the commitment to phase out coal, fossil fuels like coal and gas continue to contribute significantly to electricity supply. In order to decarbonize this sector as soon as possible and to foster sustainable concepts such as sector coupling, green hydrogen (H_2) is seen as an important part in the German power sector transformation. Until now, domestic production as well as imports usually served only specific processes at industrial scale. Due to increasing generation from fluctuating renewables as well as the possibility of converting industrial processes and mobility applications to use green H_2 instead of other resources, the integration and scale-up of a hydrogen industry is crucial for the energy transition.With the Renewable Energy Directive (RED) (and especially the Delegated Act on Renewable Hydrogen), the European Union provides a framework that defines criteria for green H_2 for the transport sector. Stakeholders assume that the rules, if applied to H_2 production in general, could impede the ramp-up of the European hydrogen economy. These criteria include temporal correlation, geographical correlation and additionality. In this context we analyze the effect of different restrictions on the production of green hydrogen from a system perspective. The focus lies on the role of domestic electrolyzers, hydrogen-fired power plants as subtitutes for natural gas-fired ones and influences of varying hydrogen import prices as well as possible decarbonization paths until 2045 (Germany) and 2050 (Europe).

Methods

We start with a comparative review of existing studies regarding power sector decarbonisation and the integration of power-to-hydrogen or H_2-Imports. From these findings, we create scenarios which are then analysed using the optimization-based energy system model E2M2s. This model is a planning tool for the long-term development of the European electricity and heat market and allows in particular the endogeneous determination of the expansion of conventional and renewable plant capacities as well as flexibilities like battery storages and power-to-gas capacities. It is based on minimizing system costs and results thus correspond to the expected market outcomes under full competition. Existing capacities earn at least their variable costs and fixed operating costs. Revenues of endogenously added capacities correspond at least to their full costs. A particular strength of the model is the stochastic representation of the renewable feed-in by means of recombining trees. Uncertainties regarding different renewable feed-ins are therefore taken into account. To keep the problem solvable in a reasonable amount of time, a 'typical day' method is applied. Policy measures can be taken into account through additional restrictions. The model calculates, among other things, the optimal power plant portfolio, electricity prices, power plant operations, trade balances and the CO_2 price under a given CO_2 cap. Applications of the model include Swider and Weber (2007), Spiecker et al. (2013), Spiecker and Weber (2014), Bucksteeg et al. (2019) and Blumberg et al. (2022).

In this paper, the model is extended to take the future hydrogen system into account in a simplified way. That is, a hydrogen demand equation is implemented as well as European H_2 transport and third-country imports with an exogenously set world market price level. Demand is partly defined exogenously but it is increased endogenously by the demand from H_2 power plants and H_2 heatboilers. The demand can be served by electrolyzers, imports from neighboring countries or third countries. To analyze the effects of restrictions on green hydrogen production, a restrictive case is compared to the base case. To model the restrictions of the RED directive in a stylized way, electrolyzers can only be operated with electricity from wind onshore plants, that are built in the same year (additionality), are located in the same bidding zone (geographical correlation) and the electricity has to be produced in the same time segment (temporal correlation). Additionally, the influences of different H_2 import price levels and restrictions on maximum imports from third countries on the results are analyzed.

Results

Preliminary results show that by imposing strict restrictions on the domestic European hydrogen production, the endogenous investments in electrolyzers decrease compared to a case without restrictions. Taking Germany as an example, the restriction on the hydrogen production yields an electrolyzer capacity of only 27 GW in 2045 compared to 47 GW without restriction. In a setting with lower H_2 import prices, the capacities decrease even further. Also the EU becomes more dependent on third country imports, especially when assuming rather low import prices. Further results will be presented at the conference.

Conclusions

Based on the preliminary results, it can be concluded that strict criteria for the definition of green hydrogen impede the domestic production of green hydrogen and increase the EUs dependency on hydrogen imports. The investment in and use of domestic electrolyzer capacities is moreover strongly dependent on the development of global hydrogen prices.

References

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