UNLOCKING INDUSTRIAL DEMAND-SIDE FLEXIBILITY FOR THE POWER SYSTEM TROUGH LOCAL GREEN HYDROGEN PRODUCTION: A CASE STUDY IN GERMANY

Marius Tillmanns, Jan Priesmann, Aaron Praktiknjo
RWTH Aachen University, Institute for Future Energy Consumer Needs and Behavior (FCN), Chair for Energy System Economics
+49 241 80 [49873; 49897; 49691]
[marius.tillmanns; jan.priesmann; apraktiknjo]@eonerc.rwth-aachen.de

Overview

Reducing greenhouse gas emissions in the industry sector is a major challenge for the success of the energy transition. Fossil energy sources for the provision of process heat and for non-energy use are particularly difficult to substitute with renewable energy sources. At the same time, the rising share of fluctuating renewable energies leads to an increasing demand for flexibility in the power system in order to ensure security of electricity supply and grid stability as well as to create incentives for the further development of renewable energies while limiting curtailment and the costs for grid expansion. Renewably produced hydrogen is set to play a key role in completing the energy transition and essential for the decarbonised energy supply in the industrial sector [1], [2]. Moreover, electrolysers represent a new source of flexibility for power systems with a high share of renewable energies [3], [4]. Thus, green hydrogen yields the potential of addressing both challenges, the decarbonisation of industry and integrating new flexibilities into the energy system. To tap this potential, it is fundamental to bring together the perspective of the overall energy system at the macro level on the one hand and the business perspective of the companies at the micro level on the other. In order to safeguard existing economic sectors and to create incentives for industry to invest in carbon-neutral technologies and provide demand flexibility for the grid, strategies for decarbonisation and demand-side management in the industrial sector must be evaluated together with the economic viability of business models.

In this paper, we perform a techno-economic analysis of the integration of hydrogen in the German industry sector. We evaluate the technical, economic and regulatory potentials and limitations of electrolytically generated hydrogen utilisation (power-to-gas, P2G) in an exemplary case study at an industrial site. Our analysis uses production data covering demands for electricity and process heat as well as material consumption at the site. We consider different regulatory frameworks for grid charges and distinguish three scenarios for the targeted level of decarbonisation. We analyse in which scenarios the integration of hydrogen into the local process chain is economically viable and in which scenarios subsidies are required. In particular, we assess the current regulatory framework and examine to what extent it has an impact on the profitability of business models at the micro level. In addition, we analyse how regulations for grid charges have to be designed to incentivise decarbonisation and system-serving behaviour. Our results suggest that regulations concerning grid fees currently have a major effect on the profitability of integrating green hydrogen in the industry sector.

Methods

For the analysis of potentials and limitations of green hydrogen integration in the German industry we develop a techno-economic optimisation model for the local energy system at an industry site that minimises costs for the procurement, generation, storage and utilisation of energy carriers such as electricity, natural gas and hydrogen also considering investment costs. The exogenously given demand for electricity and process heat has to be covered at all times. In order to be able to consider the specific characteristics of the individual process chains in the optimisation, a high temporal resolution is required.

The optimisation model calculates an overall concept for green hydrogen production and utilisation at an industry site, taking into account technical, economic and regulatory criteria. The focus is on the analysis of the implications of the regulatory framework, especially regarding grid charges, the technical design of hydrogen production and use, as well as the evaluation of the integration of further system components such as large hydrogen or battery storage that add flexibility potential for the smoothing of peak loads and load shifting. In addition to potentials from local hydrogen production at the site (onsite), the technical concepts considered also include the option of possible external hydrogen production at a nearby wind farm (offsite) as well as the option of a connection to a national or European hydrogen backbone.

Different scenarios are designed representing different targets for the decarbonisation of the industrial site. While no exogenous targets for emission reduction are set in the baseline scenario, a 30% reduction of carbon emissions is assumed in the emission reduction scenario and a fully decarbonised production in the green production scenario. Since investments in electrolysers and in the adaptation of processes and production technologies are long-term investments and the parameters of our model, such as energy prices, are subject to uncertainty, we perform a sensitivity analysis to determine the sensitivity of our optimisation results to price changes. We apply and test the model in a case study at a steel mill site. For this, we use production data on the energy and material demand of the processes at the site.

Results

Our results indicate that the regulatory framework, in particular the regulation of grid charges, is a decisive factor for the profitability of the production and use of green hydrogen in German industry. In the baseline scenario green hydrogen use is not cost-efficient for the industry site as prices for green hydrogen are relatively high in comparison to natural gas prices. In the emission reduction scenario and in the green production scenario with a exogenously given emission reduction target of 30%, respectively 100%, the local production and use of green hydrogen is cost-efficient due to potential savings regarding grid charges.

However, the current regulatory design for grid charges does not incentivise the provision of flexibility to the power system. Rather, the regulations promote uniform electricity demand instead of flexible demand depending on the feed-in from renewables or on system-wide peak loud hours.

Conclusions

Sector coupling in industry will play an important role in decarbonising the industrial sector. In addition to the electrification of industrial processes, the integration of hydrogen offers the potential to decarbonise processes that cannot be electrified and, at the same time, to make the electricity demand of an industrial site more flexible by decoupling the electricity drawn from the power grid and the electricity demand from the process chain at the site. Especially in industry sectors where industrial demand-side management is difficult to implement due to specific process characteristics, electrolysers can increase the flexibility of industrial electricity demand.

However, our case study suggests that the investment is not cost-efficient for the exemplary industry site under the current regulatory framework. Subsidies or an adjustment of levies, fees and taxes are needed to support companies in the decarbonisation of industrial processes. With regard to the flexibility potential of electrolysers and local green hydrogen production, this case study indicates that the current regulation of grid charges sets the wrong incentives and rewards steady rather than flexible electricity demand. Thus, the current regulatory design in Germany creates incentives for peak-shaving of peak demand at the site, but does not incentivise adjusting demand to the availability of intermittent renewables or system-wide peak load hours. In order to tap the potentials of the production and use of green hydrogen in industry, it is therefore necessary to adapt the regulatory design with a view to the requirements of a future decarbonised energy system.

Our modelling approach can be transferred to other energy-intensive industries such as the chemical industry. As the different industry sectors and sites are characterised by individual process designs and energy demand patterns, they may offer different potentials of providing flexibility, leading to different implications regarding the economic viability of integrating green hydrogen.

References

[1] Federal Ministry for Economic Affairs and Energy (2020). The National Hydrogen Strategy. Retrieved from https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.html. 18.04.2022.
[2] European Commission (2020). Hydrogen Strategy for a Climate-neutral Europe. Retrieved from https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf. 18.04.2022.
[3] Ruhnau, O. (2022). How flexible electricity demand stabilizes wind and solar market values: The case of hydrogen electrolyzers. Applied Energy, 307, 118194.
[4] Rabiee, A., Keane, A., Soroudi, A. (2021). Green hydrogen: A new flexibility source for security constrained scheduling of power systems with renewable energies. International Journal of Hydrogen Energy, 46(37), 19270.