A good duet for the climate:   
Why high shares in RES and H2 need each other

Sector coupling & hydrogen in electricity markets

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Motivation und zentrale Fragestellung

Research question: What is the relationship between electricity pricing, electrolysis, and the cost of electrolyzed hydrogen?

This paper explores the above research question with a focus on Germany as a case study. A deeper understanding of this relationship is important for two main reasons. One, assuming that electrolysis must be competitive with other types of hydrogen production to scale, it is valuable to understand how it may become more competitive as sector coupling takes place. Two, said sector coupling holds potential stabilizing and electricity price-altering properties. Political, research-oriented, and private domains hence hold to gain from this research.

Methodische Vorgangsweise

This paper is based on two sets of analysis. One, we work with the Green-X model (see source [6]) to generate scenarios for electricity market developments up to 2050. Two, we integrate results from the model optimization into an analysis on implications for competitiveness of H2, electricity price formation, and needs for capacities. Therefore, we first obtain continuous internally coherent results for Germany’s electricity pricing and production (capacities) through the Green X model. We then use these results to derive implications and perform analysis of practical nature, such as fluctuations in H2 production or required flexibilities in demand and storage, or of theoretical nature, such as feedback loops between H2 prices and electricity prices.

The Green X model is a techno-economic, partial equilibrium model of European wholesale electricity markets. It models the development of 20 European markets by minimizing costs for the investment in and dispatch of power plants under production, trade, and technical constraints.

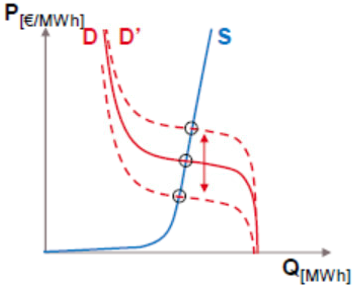
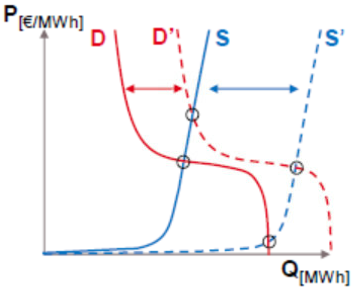
Importantly, the results from the model-run inform the level at which electrolysis may be competitive in different years. We integrate this additional electricity demand into the model to create a feedback loop between additional demand and market development. We performed the two-step analysis multiple times.

Ergebnisse und Schlussfolgerungen

We divide our findings into three levels. On the first level, we find that electrolyzed hydrogen can be competitive with other low-carbon sources, specifically blue hydrogen, at up to 6250 yearly full load hours (FLH) in 2050 or 5200 FLH in 2030. In both years this implies a levelized cost of hydrogen (LCOH) of 70 EUR/MWh (LHV).

On the second level, we look at feedback loops between electrolysis and electricity markets. Generally, we find that electrolysis leads to less electricity price volatility and reduces cannibalization for renewable energy sources. Higher flexibility in hydrogen production enhances this effect while allowing for lower electrolysis based LCOH.

On the third level, we draw generalized conclusions for how this sector coupling changes electricity supply and demand curves in highly decarbonized systems (see Figure 1). Electrolyzers allow for a “price plateau” to form in the demand curve, At this plateau, electrolyzers are price-setting. The curve continues to shift vertically depending on weather, time, and season. Secondly, supply from storage, such as hydrogen, decreases seasonal price fluctuations in the supply curve, not negating but decreasing differences between curves (horizontal shift).



*Figure 1: Generalized electricity supply and demand in highly decarbonized systems   
(D’ & S’ show periodic and seasonal shift of Demand (D) & Supply (S); P = Price; Q Quantity of Demand & Supply)*

Literatur

[1] Antweiler, Werner, and Felix Muesgens. 2021. “On the Long-Term Merit Order Effect of Renewable Energies.” Energy Economics 99 (July): 105275. https://doi.org/10.1016/j.eneco.2021.105275.

[2] Cloete, Schalk, Oliver Ruhnau, and Lion Hirth. 2021. “On Capital Utilization in the Hydrogen Economy: The Quest to Minimize Idle Capacity in Renewables-Rich Energy Systems.” International Journal of Hydrogen Energy 46 (1): 169–88. https://doi.org/10.1016/j.ijhydene.2020.09.197.

[3] COMMISSION DELEGATED REGULATION (EU) …/... Supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by Establishing a Union Methodology Setting out Detailed Rules for the Production of Renewable Liquid and Gaseous Transport Fuels of Non-Biological Origin. 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI\_COM%3AAres%282022%293836651&qid=1653291274660.

[4] Glenk, Gunther, and S. Reichelstein. 2019. “Economics of Converting Renewable Power to Hydrogen.” Nature Energy. https://doi.org/10.1038/S41560-019-0326-1.

[5] Green, Richard, Helen Hu, and Nicholas Vasilakos. 2011. “Turning the Wind into Hydrogen: The Long-Run Impact on Electricity Prices and Generating Capacity.” Energy Policy, Special Section: Renewable energy policy and development, 39 (7): 3992–98. https://doi.org/10.1016/j.enpol.2010.11.007.

[6] Huber, Claus. 2004. “Green-X: Deriving Optimal Promotion Strategies for Increasing the Share of RES-E in Dynamic European Electricity Market.” Firth Framework Programme of the European Commission. DG Reasearch.

[7] NEA, and OECD. 2019. “The Costs of Decarbonization: System Costs with High Shares of Nuclear and Renewables.” 7299. NEA. Paris: OECD.

[8] Roach, Martin, and Leonardo Meeus. 2020. “The Welfare and Price Effects of Sector Coupling with Power-to-Gas.” Energy Economics 86 (February): 104708. https://doi.org/10.1016/j.eneco.2020.104708.

[9] Ruhnau, Oliver. 2022. “How Flexible Electricity Demand Stabilizes Wind and Solar Market Values: The Case of Hydrogen Electrolyzers.” Applied Energy 307 (February): 118194. https://doi.org/10.1016/j.apenergy.2021.118194.

[10] Ruhnau, Oliver, and Staffan Qvist. 2022. “Storage Requirements in a 100% Renewable Electricity System: Extreme Events and Inter-Annual Variability.” Environmental Research Letters 17 (4): 044018. https://doi.org/10.1088/1748-9326/ac4dc8.

[11] Ruiz, P., W. Nijs, D. Tarvydas, A. Sgobbi, A. Zucker, R. Pilli, R. Jonsson, et al. 2019. “ENSPRESO - an Open, EU-28 Wide, Transparent and Coherent Database of Wind, Solar and Biomass Energy Potentials.” Energy Strategy Reviews 26 (November): 100379. https://doi.org/10.1016/j.esr.2019.100379.

[12] Schill, Wolf-Peter. 2020. “Electricity Storage and the Renewable Energy Transition.” Joule 4 (10): 2059–64. https://doi.org/10.1016/j.joule.2020.07.022.

[13] Vandewalle, J., K. Bruninx, and W. D’haeseleer. 2015. “Effects of Large-Scale Power to Gas Conversion on the Power, Gas and Carbon Sectors and Their Interactions.” Energy Conversion and Management 94 (April): 28–39. https://doi.org/10.1016/j.enconman.2015.01.038.

[14] Zerrahn, Alexander, Wolf-Peter Schill, and Claudia Kemfert. 2018. “On the Economics of Electrical Storage for Variable Renewable Energy Sources.” European Economic Review 108: 259–79. https://doi.org/10.1016/j.euroecorev.2018.07.004.

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