Modified electricity price signals for incentivizing flexibility in hydrogen production

Motivation and Field of Research

The use of hydrogen in industry for the defossilization of process-related production steps is limited due to economic challenges. The production of hydrogen using grid electricity is constrained to a few exceptions. At the same time, the increasing share of renewable energies has a direct impact on electricity market prices and electricity-related greenhouse gas (GHG) emissions.

Industrial hydrogen production from grid electricity has the potential to act as a flexible consumer that takes advantage of low electricity prices and can achieve three things:

(1) Supply of low-cost hydrogen for industrial processes,
(2) Production of hydrogen that results in low GHG emissions,
(3) Support for the electricity system through flexible demand.

Our approach of using a regulatory instrument with modified electricity price signals to promote supply-oriented, local electricity demand from an electrolyzer in situations with low electricity prices addresses these requirements.

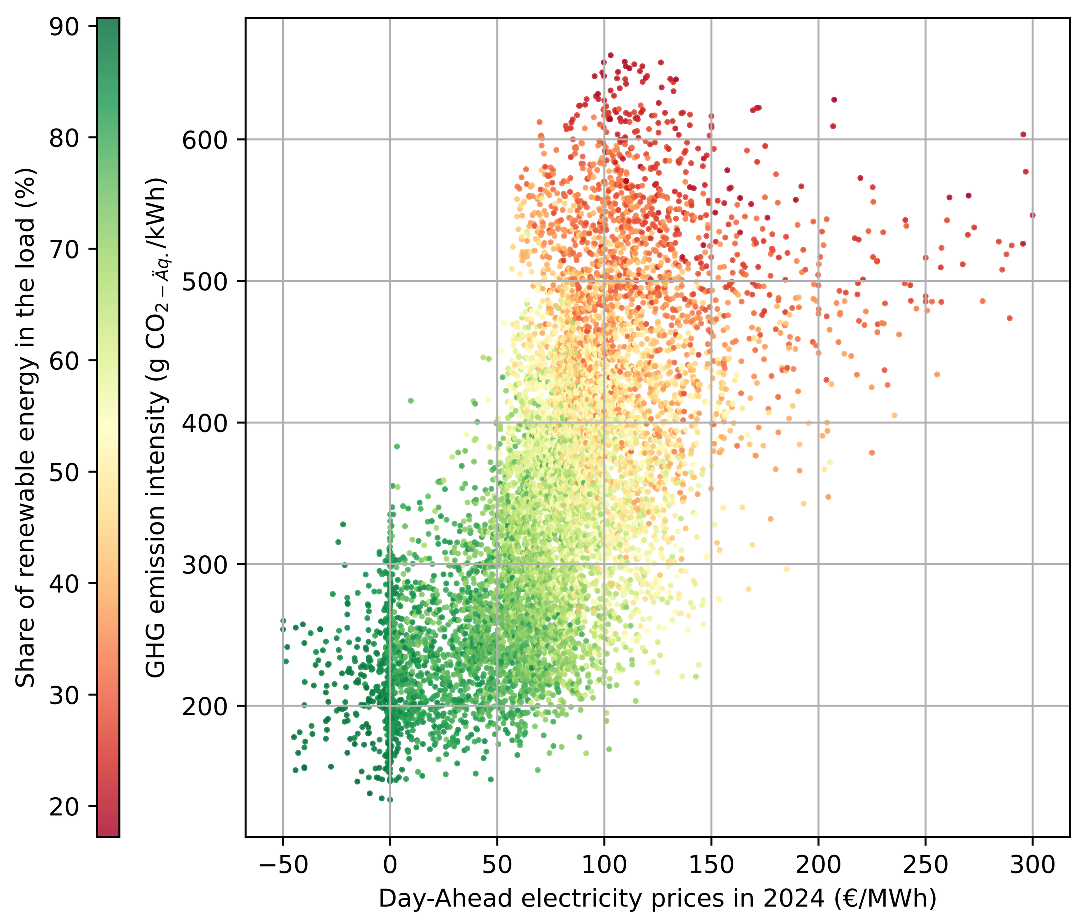

Fig. 1: GHG emission intensity of the German electricity mix and share of renewable energies in the load depending on electricity exchange prices in 2024.

Project Team

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Objective

Modification of the existing exchange electricity price signal to achieve cost-effective, low-GHG hydrogen production that supports the energy transition.

1 Modification Electricity price signal
2 Calculation Levelized Cost of Hydrogen
3 GHG accounting for hydrogen production

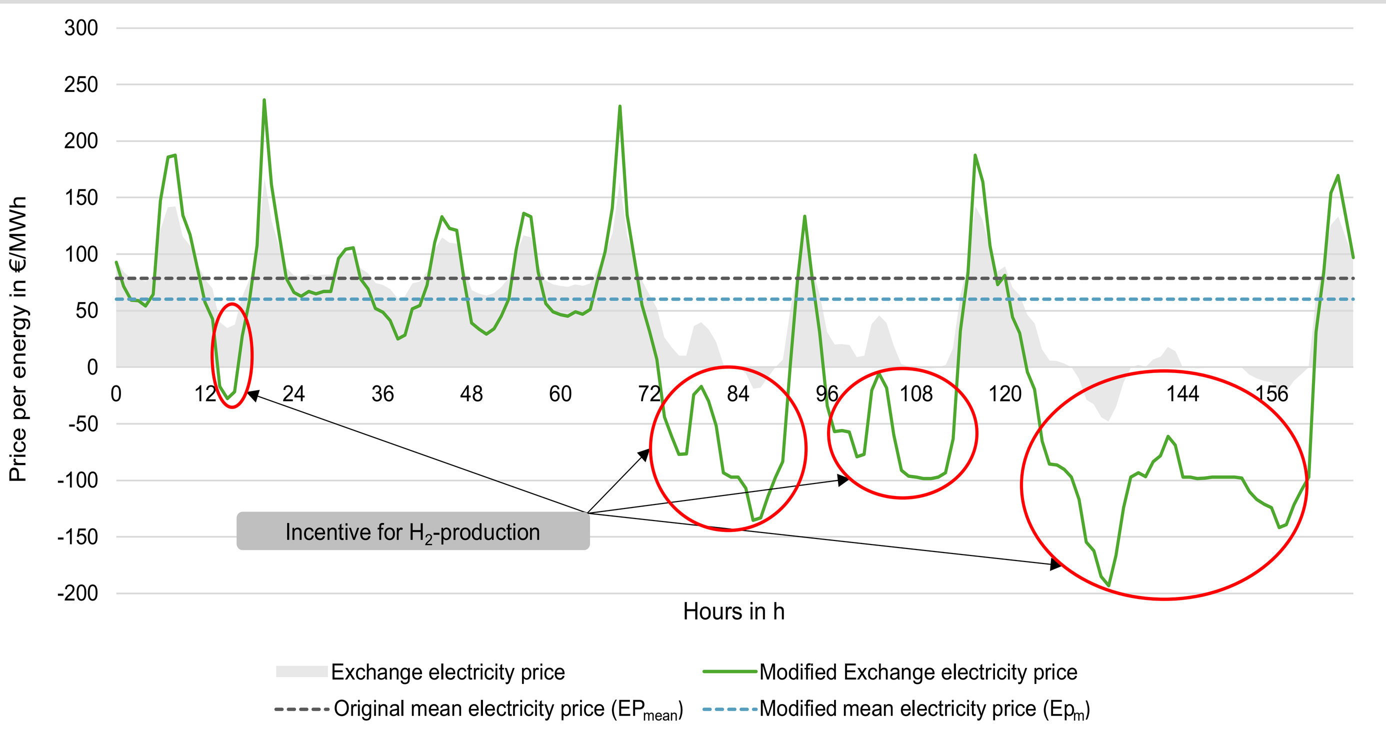

Fig. 2: Modified electricity price signal (schematic) with amplification factor („F_A“) of 2.2 and modified mean electricity price („EP_m“) of 60 €/MWh.

Methodology

❶ The modification of the exchange electricity price consists of two parts:
(1) Adjusting the annual mean price („EP_m“)
(2) Amplifying the hourly electricity price by a factor („F_A“). The factor changes the amplitude of the price around the annual mean price.
Sorting of electricity prices in ascending order. The cumulative electricity prices up to time t are based on the full-load hours of the electrolyzer.

❷ Analysis of potential combinations of modifications in a perfect foresight approach. Different combinations result in hydrogen production costs of 1.80/kg (selected “target price” for case study) and corresponding full-load hours for an electrolyzer. Only the most cost-effective production hours are considered. Analysis of various production profiles.

❸ Assessment of hydrogen production based on hourly GHG emission intensity of the German electricity mix in $CO_{2\text{-}\ddot{a}q.}$/kg H_2. Values are sorted in ascending order with electricity prices. The sum of the cumulative specific GHG intensity up to time t is related to the full-load hours of the electrolyzer.

Results

The analyses for ❶ modifying the electricity price signal and ❷ calculation hydrogen production costs show that

- a variation in the amplification factor F_A affects the number of full-load hours of the electrolyzer. The higher F_A, the lower the full-load hours are.
- the adjustment of the mean price EP_m directly affects the price of hydrogen. The higher EP_m, the higher the price for hydrogen.
- different modifications of the electricity price profile leads to varying full-load hours while the hydrogen price remains constant.

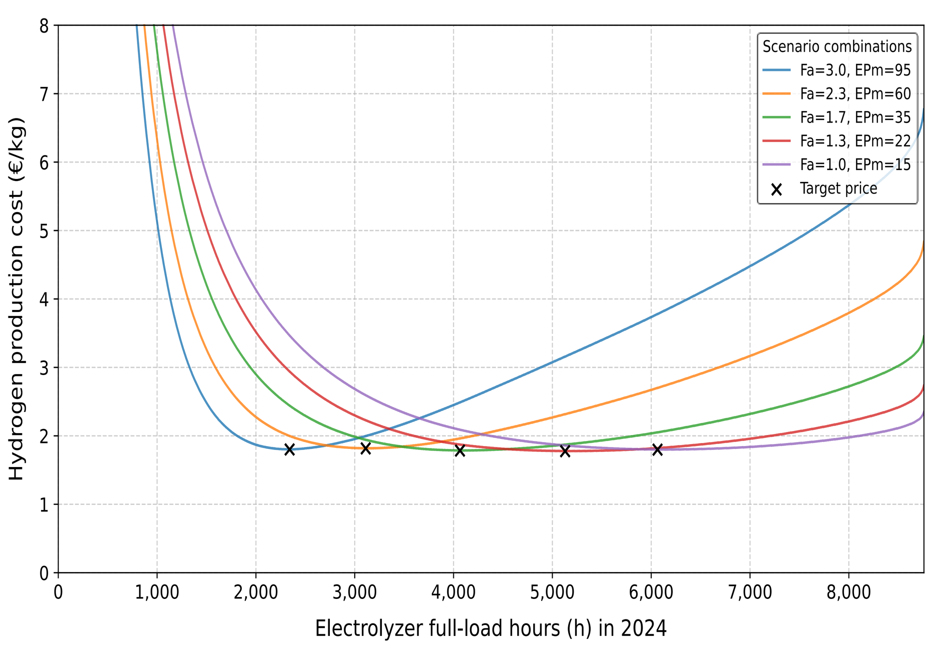

Fig. 3: Combinations of amplification factor F_A and mean electricity price EP_m, with different electrolyzer full-load hours resulting in levelized cost of hydrogen = 1,80 €/kg (case study).

Analysis of different demand profiles
Case Study – A company aims to produce a certain amount of hydrogen at minimal cost within a specific period (daily, weekly, monthly). The exact production time during the day is not considered.

The analyses for the demand profiles show that

- shorter demand profiles lead to higher hydrogen production costs.
- as the number of full-load hours increases, the costs of the different demand profiles rise to meet the annual hydrogen production costs.

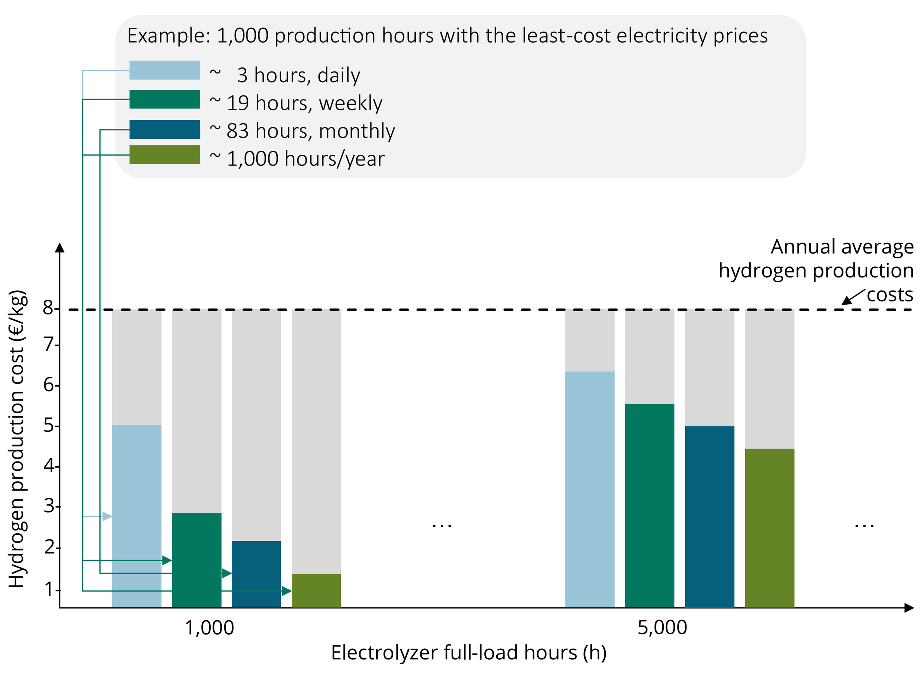

Fig. 4: Average hydrogen production costs depending on electrolyzer full-load hours and different demand profiles (schematic).

Analyses of ❸ the GHG balance of hydrogen production show that

- reduced electrolyzer full-load hours lead to lower cumulative GHG intensity.
- the GHG intensity of the electricity mix tends to be lower when electricity prices are low and the share of renewable energies is high.
- the GHG intensity of the hydrogen produced does not meet the legal requirements for RFNBO/low-carbon hydrogen in any scenario. The reason for this is the high average GHG intensity of the electricity mix in Germany.

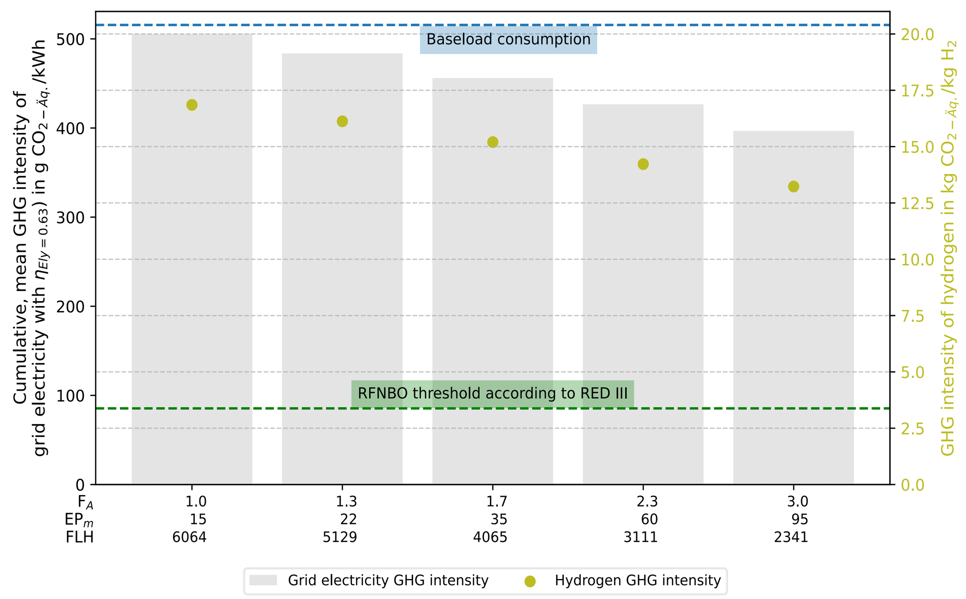

Fig. 5: Cumulative specific GHG intensity of the electricity mix depending on the electrolyzer full-load hours and average GHG emissions caused by hydrogen production in 2024 in the context of the requirements for renewable fuels of non-biological origin (RFNBO) in accordance with the 37th Federal Immission Control Ordinance (BImSchV).

Fields of application

- **Stimulate local industrial electricity demand (demand response)!** Without flexible electricity consumption and storage, there will be a cannibalization effect on market revenues.
- **Energy transition-friendly operation of large consumers** such as large-scale electrolyzers for the production of low-carbon hydrogen or RFNBO (Renewable Fuels of Non-Biological Origin).
- **Support** for the emerging hydrogen economy.
- **Possible relief for the power grid** (avoidance of grid congestion, redispatch measures) and avoidance of negative consequences, including the attractiveness of new investments in renewable energies, federal budget (EEG account, grid expansion).

Let’s discuss about the next steps!

Research collaborations – Further development and questions:

– What signals already exist today that describe the grid load?
– What is a suitable local signal for the mechanism?
– What other aspects (e.g., GHG emissions) should be reflected in the electricity price?
– How can local electricity demand be stimulated in a systematic manner?

Interested individuals – Possible applications in the energy industry:

– Where can the mechanism be used; industry, large-scale consumers? What aspects must also be considered?
– At which locations/regions, where not, and why? What are the criteria?

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