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Modified electricity price signals as a flexibility incentive for hydrogen production –the impact of hydrogen production profiles on costs and GHG emissions.

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The increasing share of renewable energy has a direct impact on spot prices and electricity-related greenhouse gas (GHG) emissions. Low marginal costs for solar and wind reduce spot prices, especially in times with a high share of renewable electricity production. GHG emissions tend to decrease as the share of renewables increases throughout the year, again, particularly in times with a high share of renewable electricity.
Hydrogen production from grid electricity shows the potential to serve as a flexible consumer making use of low electricity and serving threefold: (1) supplying low-cost hydrogen for e.g. industrial processes (2) producing hydrogen leading to low GHG emissions and (3) serving the electricity system through a flexible demand.
A policy instrument with modified electricity price signals to stimulate flexible electricity demand from an electrolyzer has been presented (Schütte & Timmerberg, 2024). The modification consists of two parts: (1) the annual average is adjusted and (2) the hourly resolved electricity price is changed. The factor changes the amplitude of the price. It was analyzed which combinations of adjustments lead to a target price of €1.80/kg for hydrogen. Results show that higher price amplitudes lead to shorter electrolyzer operating times. This could be an incentive for flexibility on the consumer side.
This research examines how different hydrogen demand profiles affect costs and GHG emissions under the policy instrument, aiming for a target price. A demand profile is understood as a recurring, constant demand. Hydrogen production is considered in different time periods –per day, per week or per month –where the electrolyzer is operated at the least cost hours.

The methodology consists of (1) 'Modification of the electricity price signal', (2) 'Calculation of hydrogen production costs with different demand profiles'and (3) 'GHG accounting of hydrogen production'in order to find the best modifications for the electricity price to reach the H_2 target price and to answer the research question and its sub-questions.

–It is assumed that a modified electricity price signal is provided to companies interested in producing hydrogen electrolytically in response to this signal. This electricity price signal could, for example, be provided by a government agency or a government-commissioned company. It is based on the electricity exchange price adjusted by a calculation rule. This rule considers the average annual electricity price and the deviation of the exchange electricity price in an hour from this average.
–It is assumed that the hydrogen-producing company operates an electrolyzer flexibly, producing hydrogen when electricity is at low cost. The company's objective is to produce a fixed amount of hydrogen cost-effectively within a defined period, without considering specific pro-duction times. The company produces hydrogen based on its knowledge of the electricity price trend for the entire period under consideration (perfect foresight). Capital and operating costs are included.
–The GHG emissions assessment accounts for hourly variations in grid electricity emissions.

The modified electricity price signal $EP_{\text{mod},t}$ is derived from hourly electricity price values EP_t. The average annual electricity price EP_{mean} is calculated using equation (1). The modified hourly electricity price $EP_{\text{mod},t}$ results from an amplification factor F_a and a modified mean annual electricity price $EP_{\text{mean,set}}$ (equation (2)). For $F_a > 1$, the modified electricity price signal shows a greater deviation from the mean value than the original price signal.
1) $EP_{\text{mean}} = \frac{1}{N} \sum_{t=1}^{n} EP_t$

2) $EP_{\text{mod},t} = (EP_t - EP_{\text{mean}}) \cdot F_a + EP_{\text{mean,set}}$

The modified electricity prices with equation (2) are sorted in ascending order, forming a series $EP_{\text{mod},t}$. The sum of the electricity prices up to time t is related to the electrolyzer's full load hours (FLH), yielding a cumulative average electricity price for each timestep (equation (3)).

3) $EP_{\text{mod,sort}} = \frac{\sum_{t=1}^{t} EP_{\text{mod},t}}{\text{FLH}}$

The hourly GHG emissions GHG_t in CO_2eq. of the German electricity mix are sorted alongside exchange electricity prices. The cumulative sum of hourly GHG emissions up to t is related to the FLH.

4) $THG_{\text{EP,sort}} = \frac{\sum_{t=1}^{n} THG_t}{FLH}$

To assess the GHG intensity of the hydrogen produced, the net calorific value of hydrogen LHV_{H_2} and the electrolyzer efficiency $\eta_{\text{Ely,LHV}}$ are used:

5) $THG_{H_2} = \frac{THG_{\text{EP,sort}}}{\eta_{\text{Ely,LHV}}} \cdot \text{LHV}_{H_2} \quad (2)$

Calculations are performed for various years and demand profiles. The data is resorted for each period. The additional costs and GHG emissions from different demand profiles compared to an annual design of the instrument are analyzed comparatively.

This scientific study analyzes which amplification factor F_a and average annual target electricity price $EP_{\text{mean,set}}$ can be used to achieve a given production price for hydrogen.

The effect of various hydrogen demand profiles on costs and GHG emissions is also analyzed. For the use of the policy instrument at a predefined target price, the factor is expected to increase for shorter demand profiles. Shorter periods are expected to increase production costs if the factor remains unchanged.

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