
Modifying electricity price signals in Germany targeting a supply-oriented electricity demand and economical hydrogen use in industry assessing GHG emissions.

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INREC

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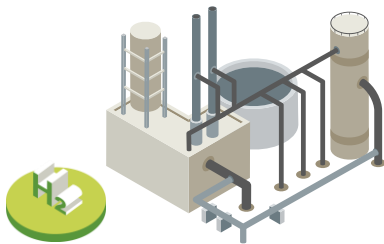
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Motivation

- Limited use of green hydrogen in industry so far
- Economical use will need the support of a policy instrument to close the cost-gap to existing technologies and fuels

Objective

- Cost competitive use of hydrogen in industry

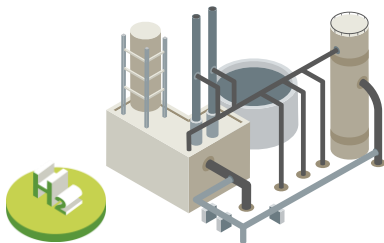


- RE expansion is slowed down by inflexible electricity demand
- Volatile electricity production will increase with the expansion of renewable energy in the grid

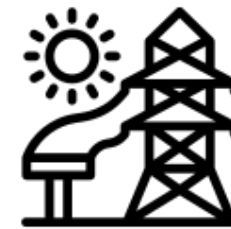
- Stimulate grid-responsive (“beneficial”) system behavior of electrolyzers



- Industrial hydrogen producers receive a modified price signal
 - Price signal based on the electricity exchange with adjusted amplitude and mean value
 - Price signal enables economical on-site H₂ production



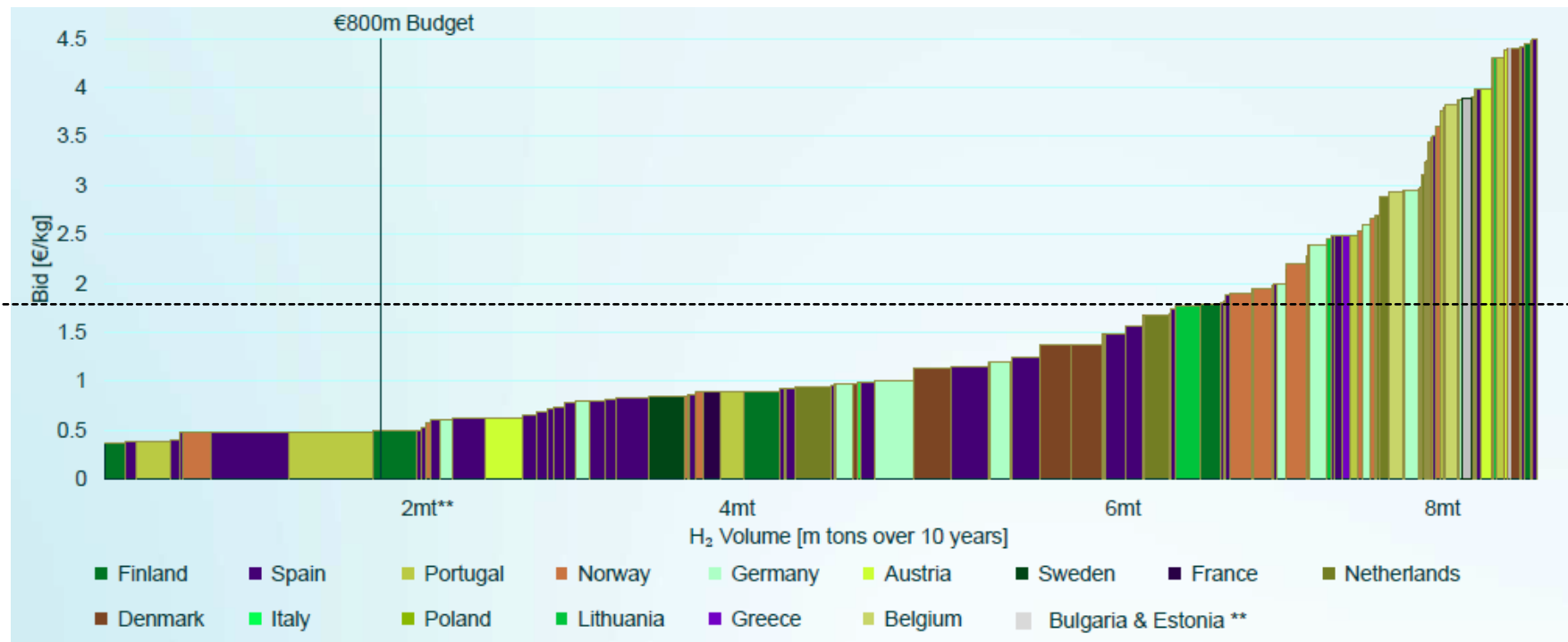
- Electricity demand resulting from hydrogen production is beneficial to the system
 - Electricity demand in situations of low electricity prices (electricity surplus situation)
 - Avoidance of electricity demand at times of high electricity prices



Hydrogen-supporting instruments (overview)

- Demand Side Management measures: Peak Shaving, Demand Response, Balancing services, ...
- Supporting financial instruments: CCfD, GHG reduction quota, EU-ETS, subsidy of Capex/Opex, H₂Global, European Hydrogen Bank (EHB)

Median bid price off-taker in industry = 1.80 €/kg_{H2}



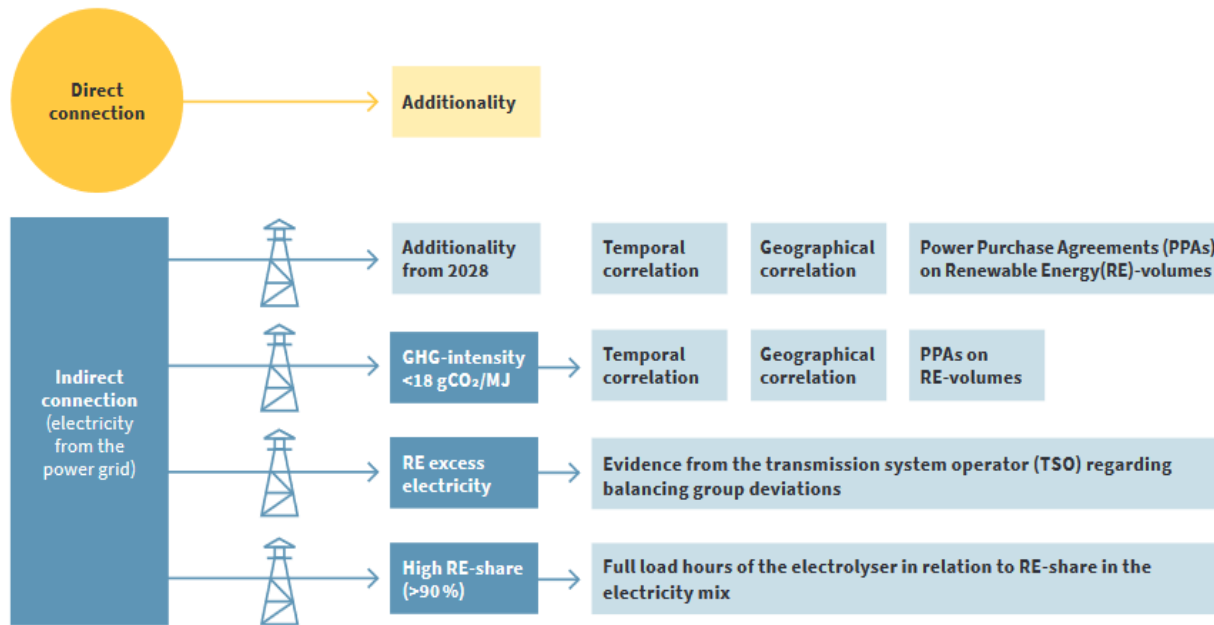
* Bid curve includes 130 bids (i.e. including 13 bids found inadmissible or ineligible, as well as bids not passing or not being evaluated on qualification criteria due to cascade approach – see call text).

** Estonia and Bulgaria aggregated for anonymisation reasons, as only 1 bid per country was received.

H₂ production using renewable energies.

Rules for electricity to count as fully renewable

(Delegated Act on electricity procurement criteria according to Art. 27 RED II)

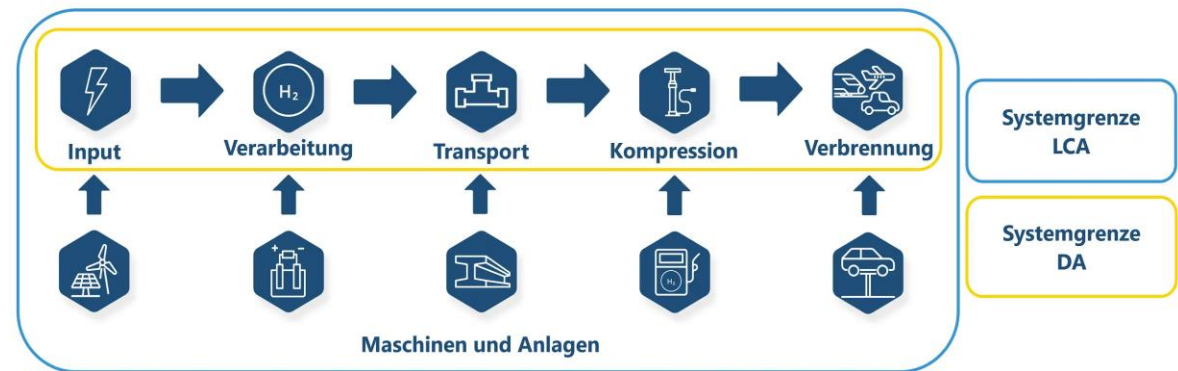


Ref.: https://www.now-gmbh.de/wp-content/uploads/2024/01/Factsheet_REDIII.pdf

H₂ production using grid electricity – CO₂ emission accounting.

System boundaries

- Delegated Act (EU) 2023/1185
 - Consideration of all fossil primary energy sources for gross electricity generation (extraction, refining, supply, combustion), upstream emissions of biomass production, conversion efficiencies, own plant's electricity consumption
 - GHG emissions other than CO₂ are converted into CO_{2-Äq.}
 - Electricity from renewable sources is balanced with zero CO_{2-Äq.}
- Life Cycle Assessment – LCA
 - + CO₂ emissions from the construction of plant and equipment



Ref.: <https://www.ffe.de/veroeffentlichungen/emissionsbilanzierung-wann-zaehlt-wasserstoff-als-gruen/>

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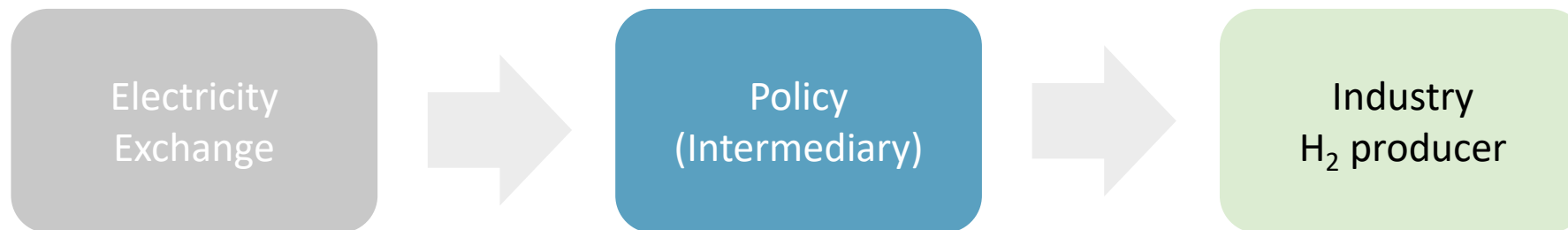
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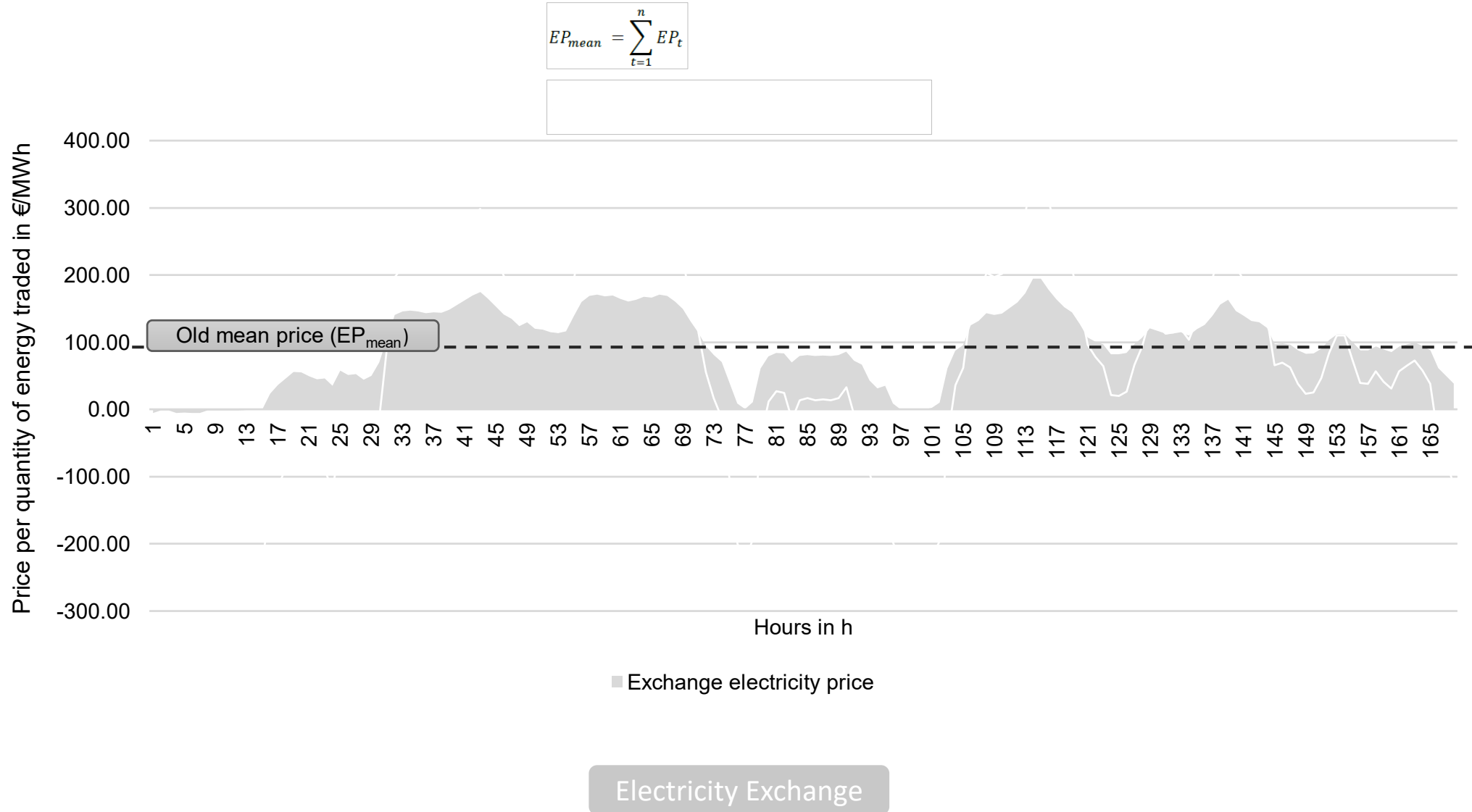
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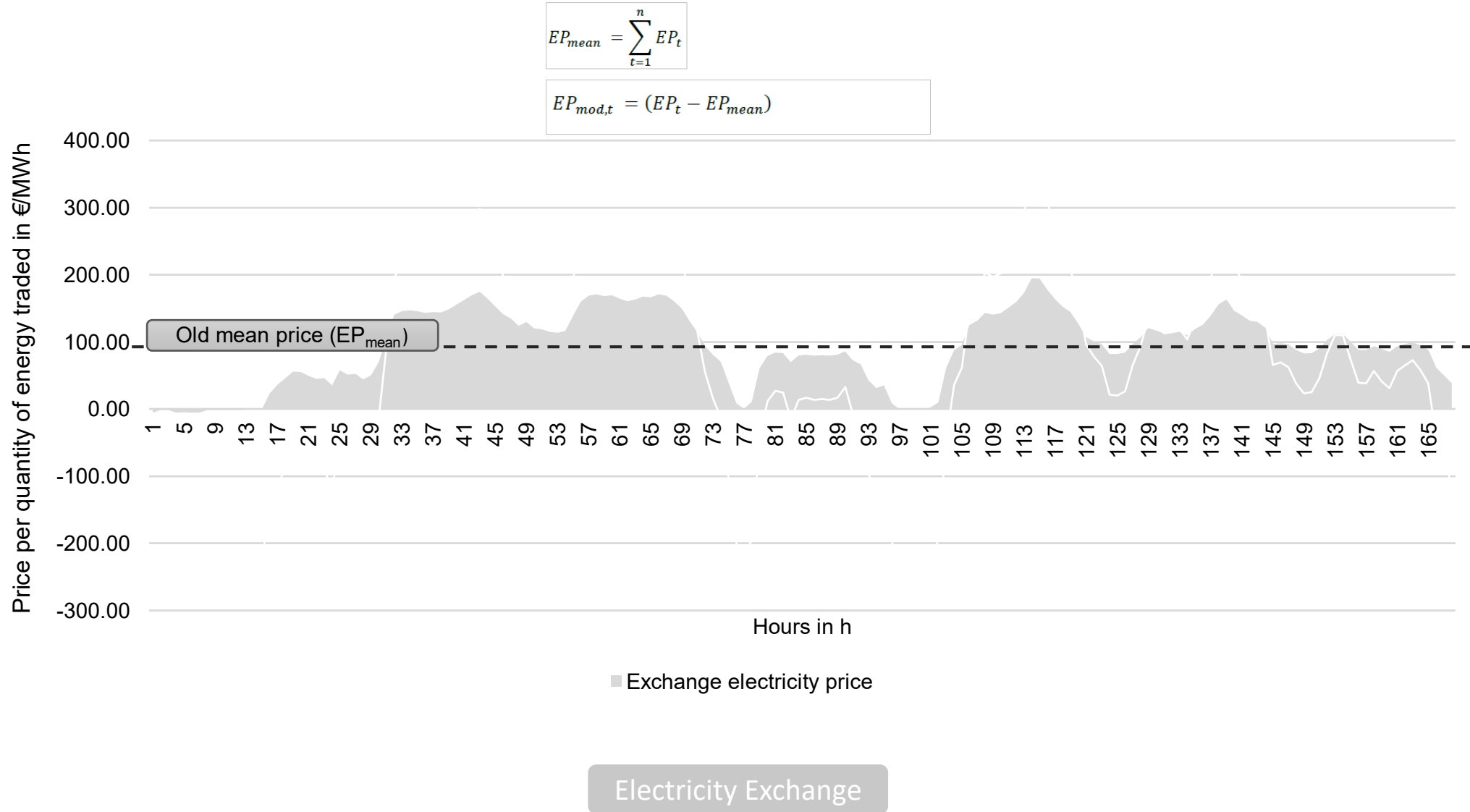
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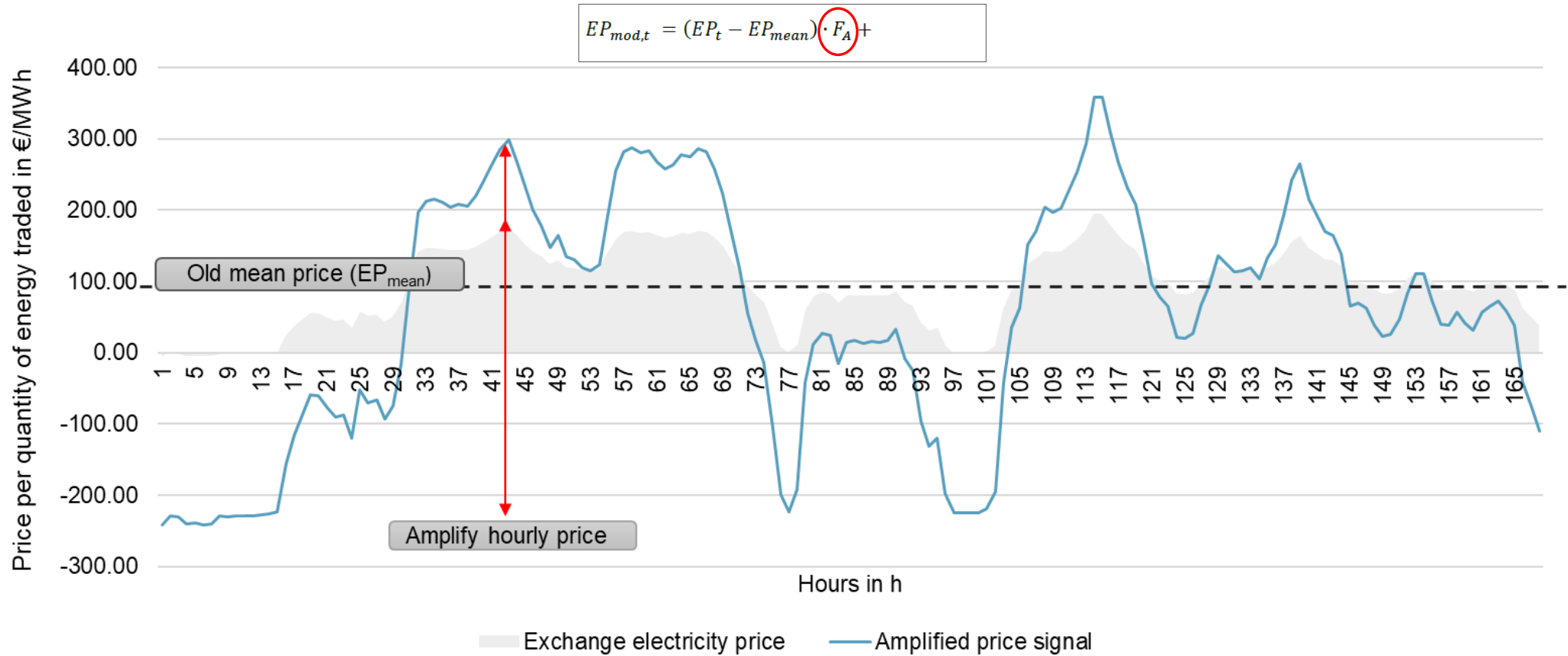
Offering a modified electricity price profile to a company...



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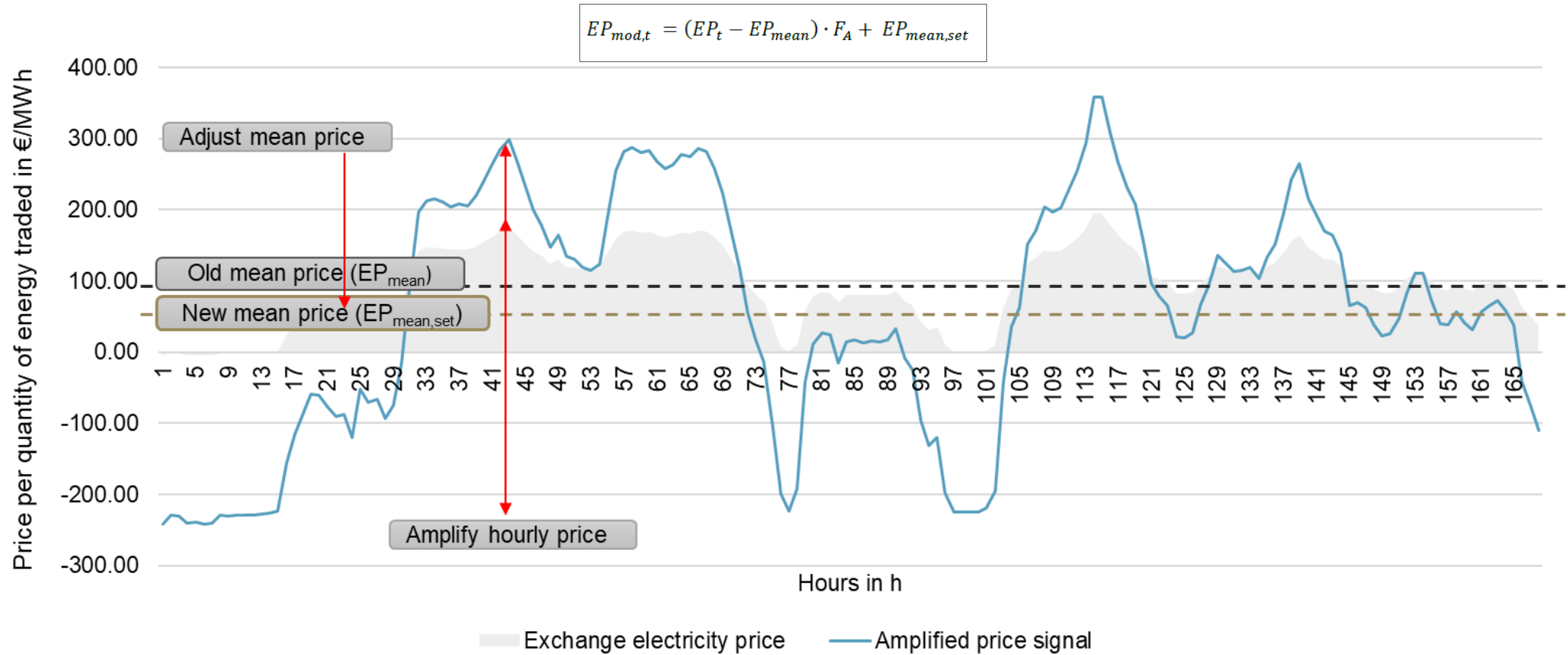


Electricity Exchange

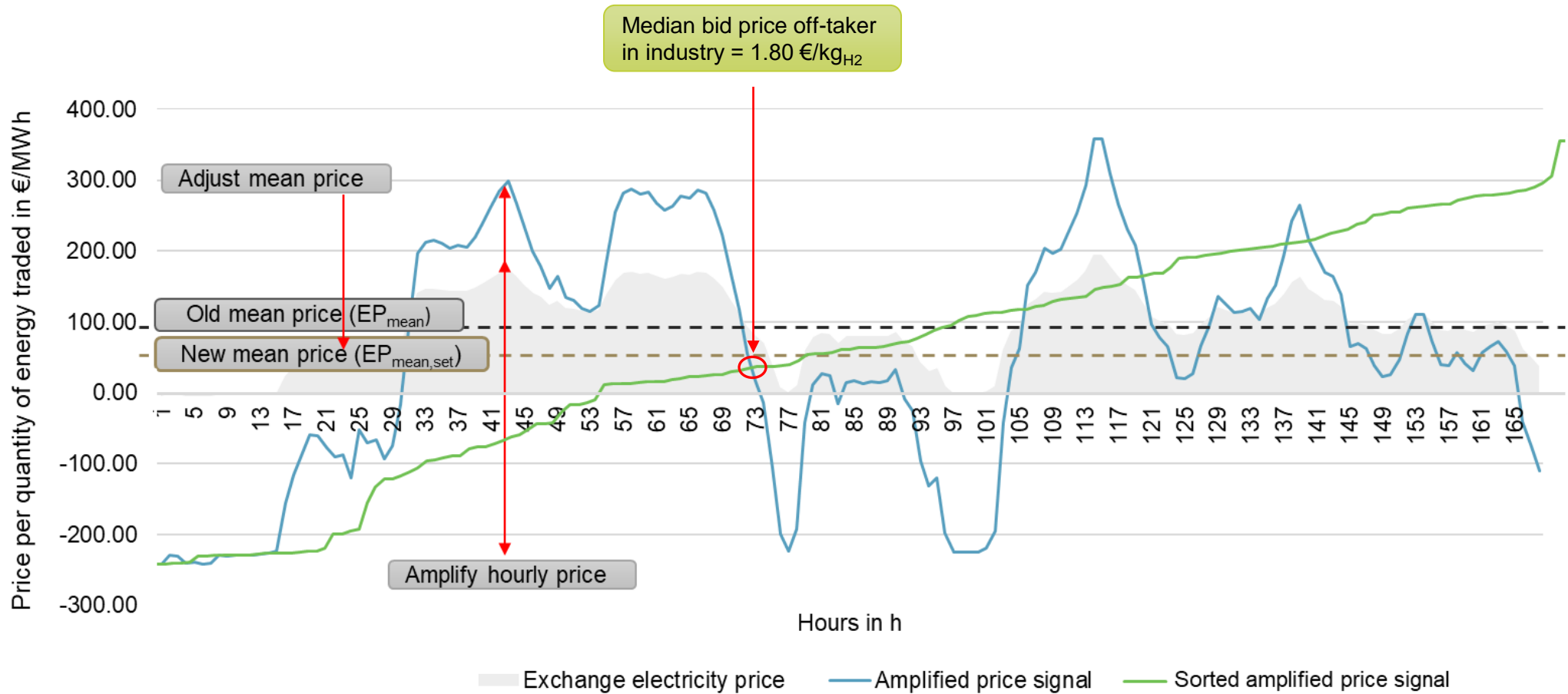


Intermediary

Offering a modified electricity price profile to a company...



Offering a modified electricity price profile to a company...

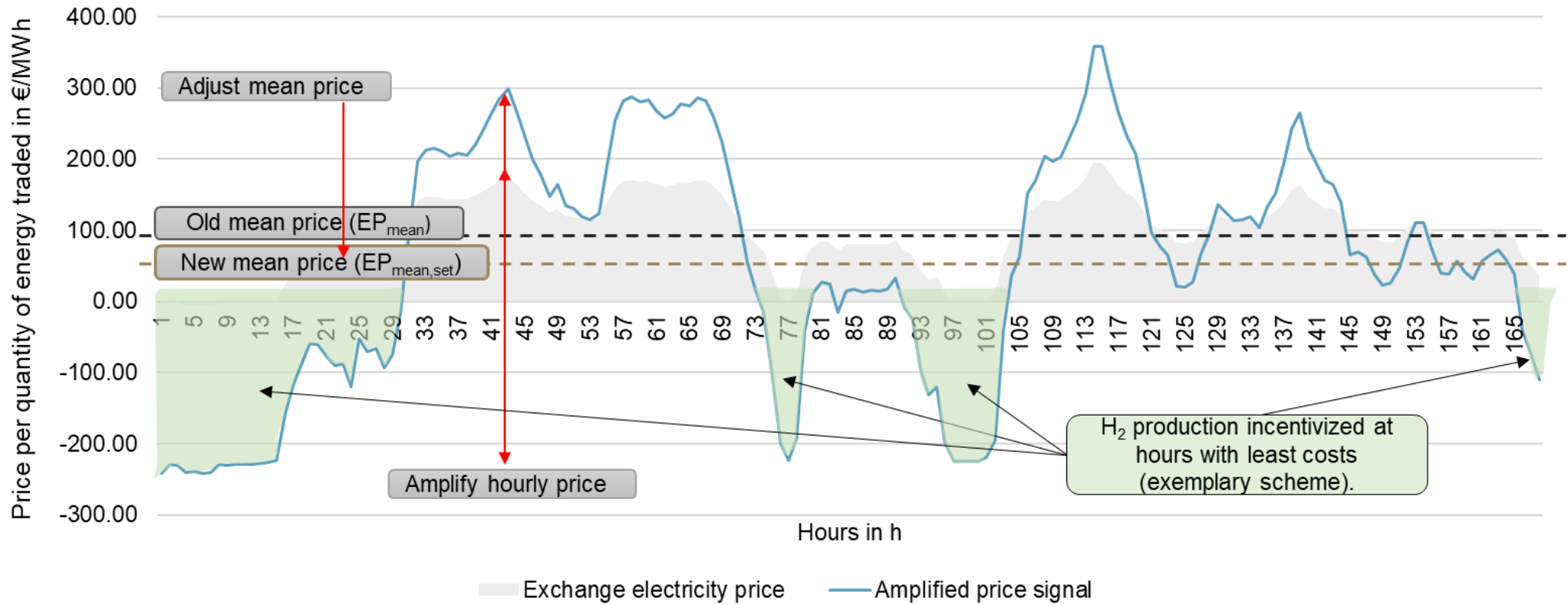


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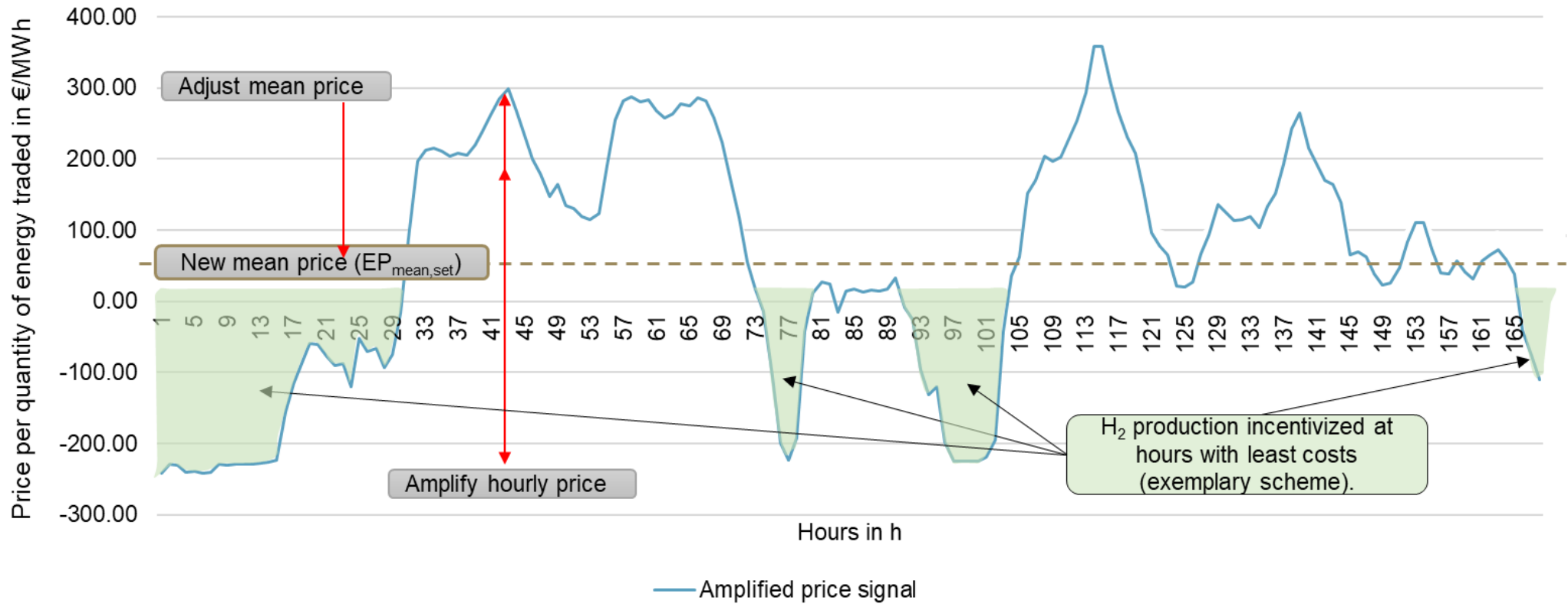


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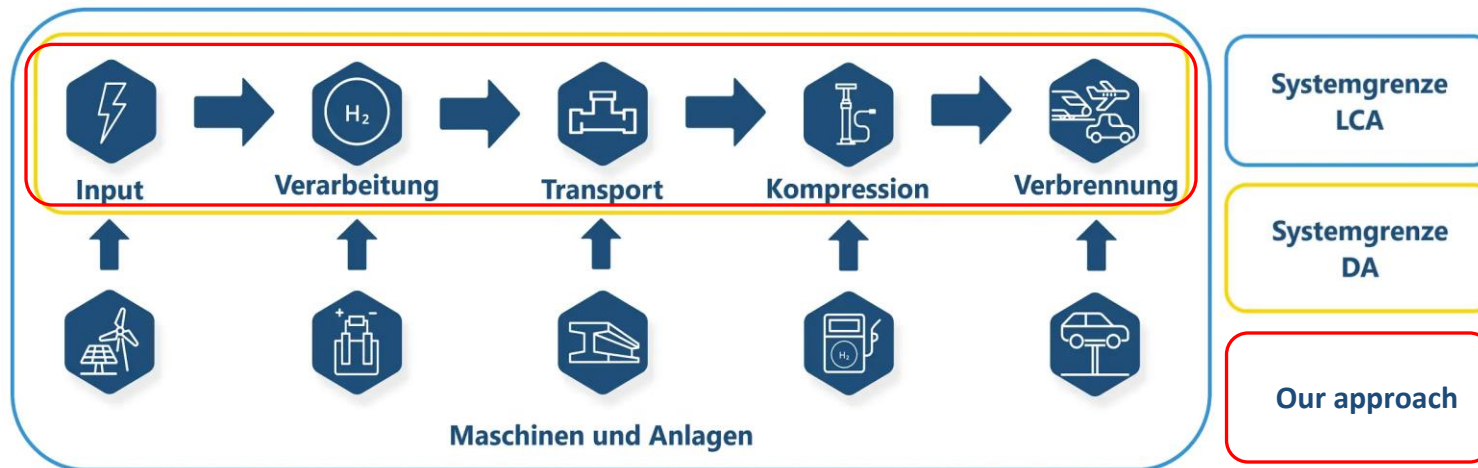


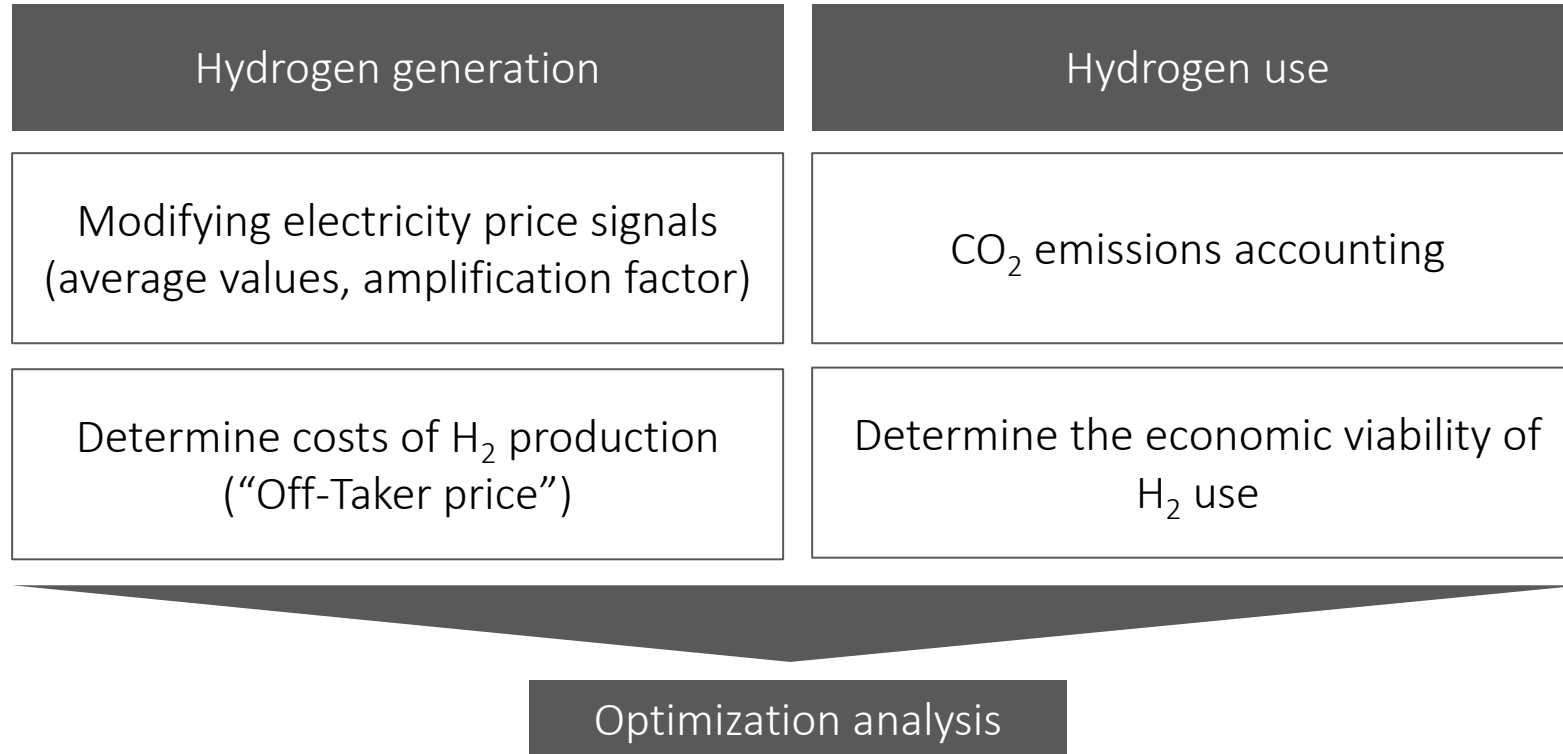
CO₂ emission accounting

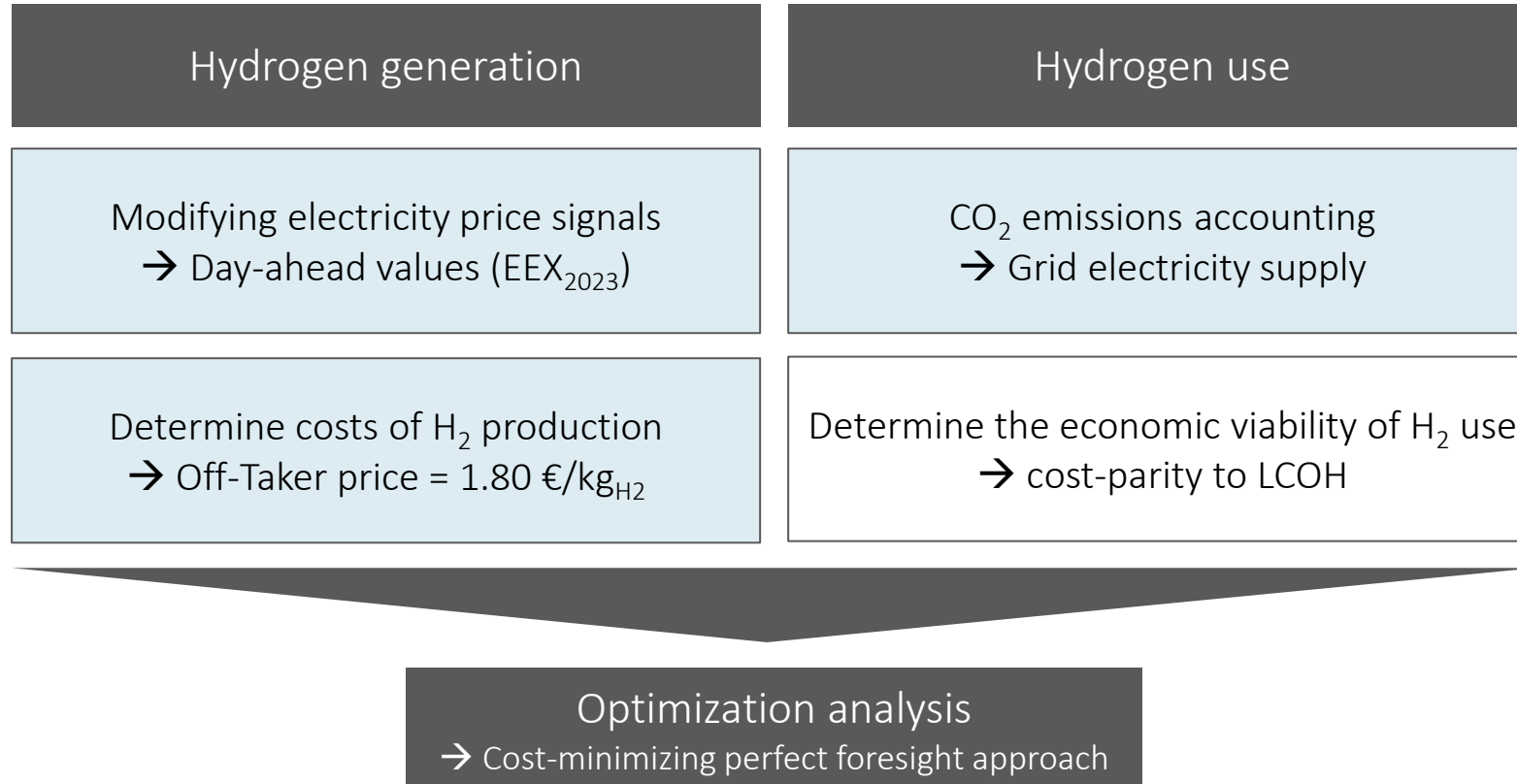


| | | |
|----|----|----|
| 29 | 30 | |
| Cu | Zn | |
| 46 | 47 | 48 |
| Pd | Ag | Cd |
| 78 | 79 | 80 |
| Pt | Au | Hg |

- Based on the requirements of CDR (EU) 2023/1185, Delegated Act (DA)
- Targeted CO₂ limit value is 3.39 kg CO_{2Äq.}/kg H₂
- Using hourly GHG emissions (in g CO_{2Äq.}) from CO₂-Monitor (<https://co2-monitor.org/>) according to GHG Protocol
- GHG other than CO₂ are converted into CO_{2Äq.} in accordance with Renewable Energy Directive (EU) 2018/2001
- GHG emissions of the electricity mix are ordered according to the least cost production hours







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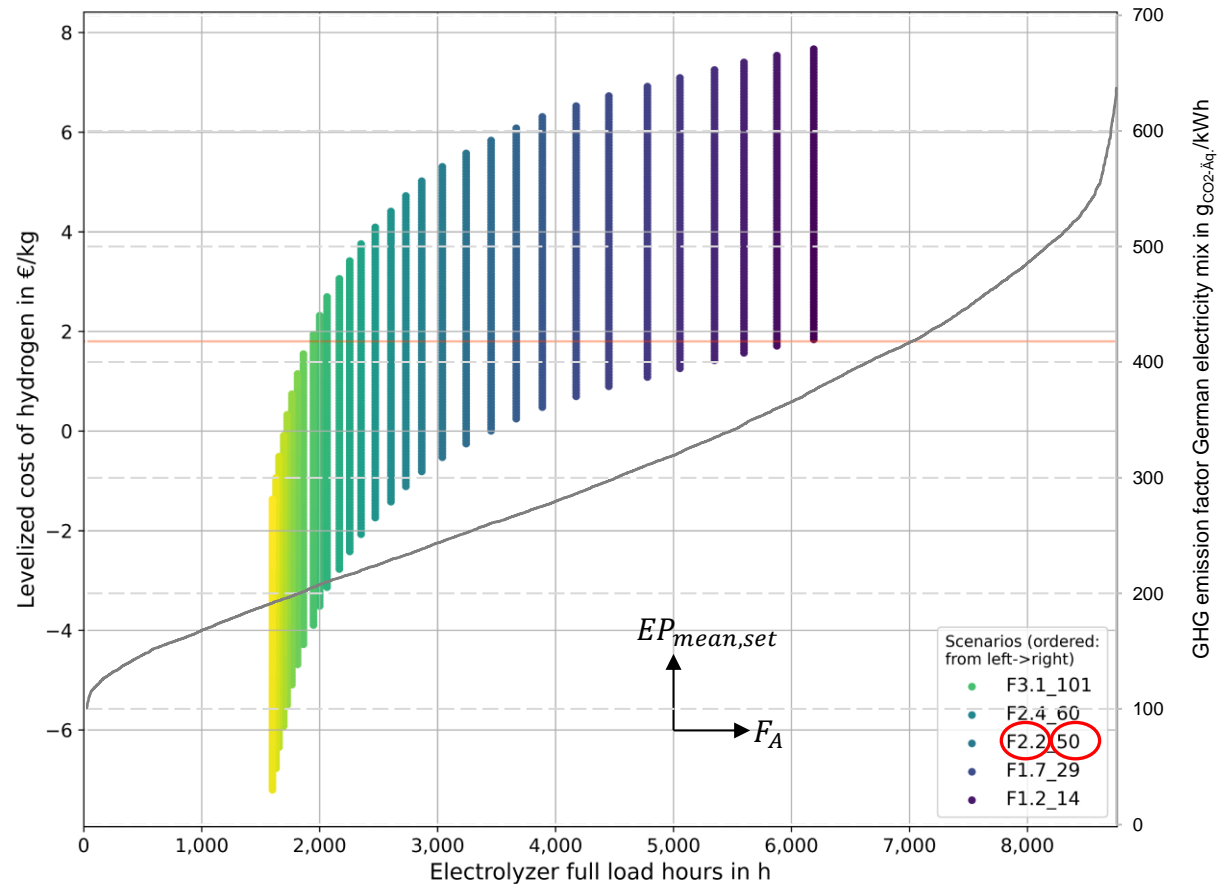
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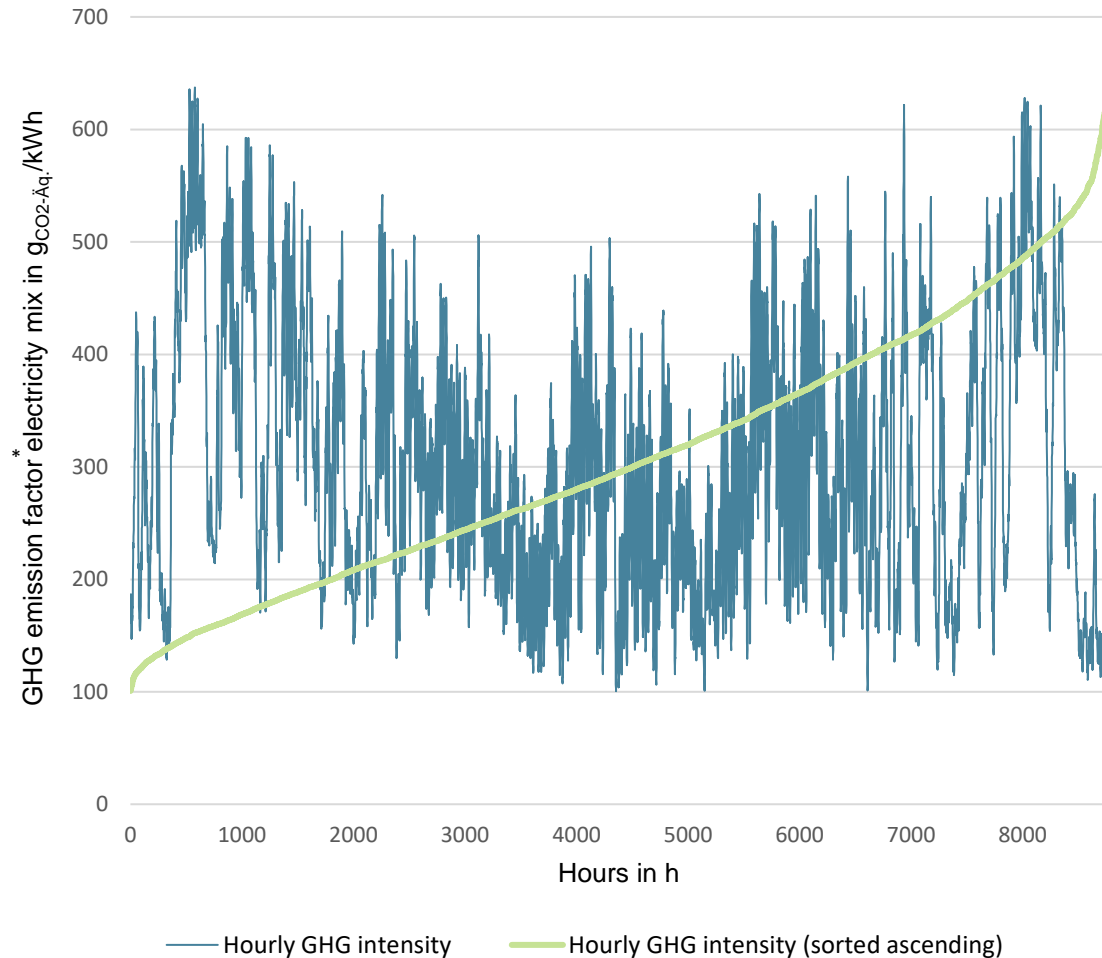
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Minimum levelized cost of hydrogen (LCOH).

- Cost parity of minimum LCOH with 1.8 €/kg H₂ from tendering results of the European Hydrogen Bank.
- Cost parity (red-marked area) represents the highest costs a company is willing to pay.
- The electrolyzer only runs at the least-cost production hours of the year.
- A variation in the amplification factor F_A mainly influences the values in the direction of the x-axis. The higher F_A , the lower the electrolyzer FLH.
- A variation in the new set mean annual electricity price $EP_{mean,set}$ cause a shift in the direction of the y-axis. The higher the value, the higher the LCOH.
- Policy perspective:
The lower the full load hours to be triggered, the higher the amplification factor must be selected.
- GHG emissions of the hydrogen produced are sorted in ascending order to the least-cost electricity prices.





Nowadays

- CO₂ emissions in the electricity mix, due to
 - must-run fossil power plants,
 - Electricity trading,
 - flexibility and storage needs
- Lower CO₂ emissions in times of low electricity prices
→ high RE share
- But: lowest CO₂ intensity not at lowest electricity prices
→ temporary RE curtailment?

In future

- Expansion of renewable energy in the grid
- Spatial differentiation for e.g. Hamburg?
 - No. Electricity system has only one exchange where it is decided when which power plant is switched on (Merit-Order!).
 - Yes. Power supply where a redispatch otherwise would have take place.

* Emissions for electricity production in Germany in 2023 according to CO₂-monitor.org in accordance with the GHG Protocol without upstream emissions. ("Scope 2").

Specific GHG emissions of H₂ production with grid electricity

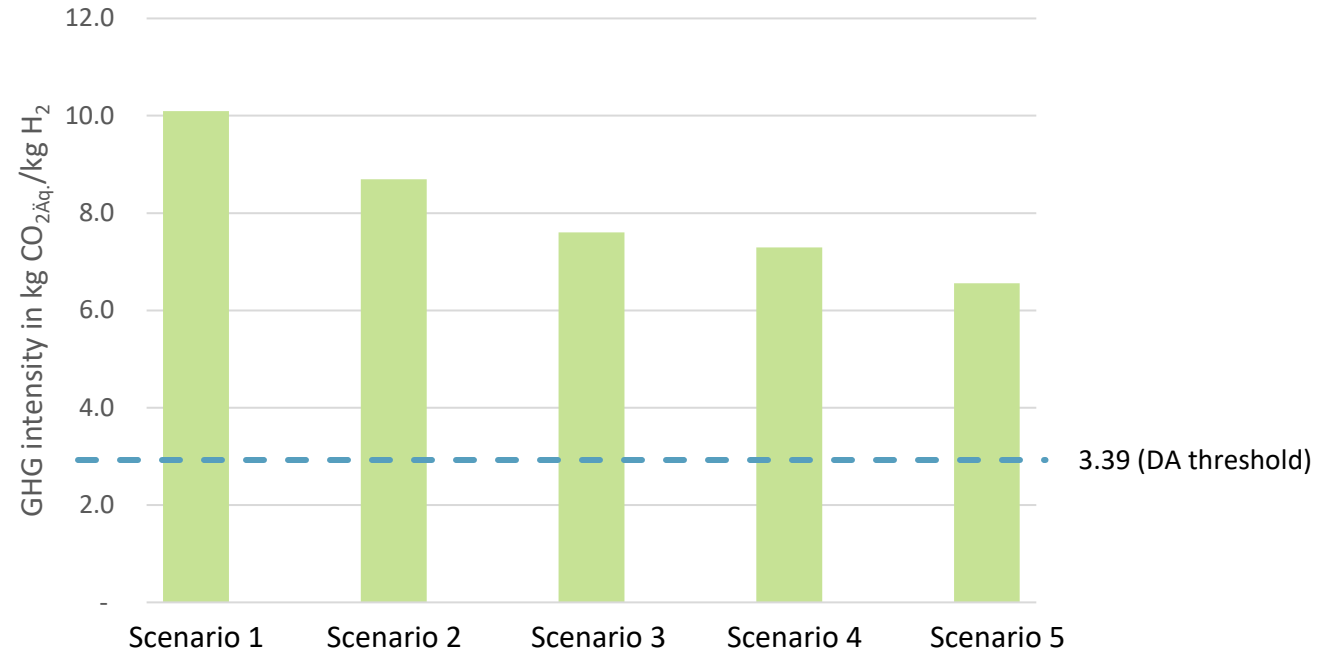
- The higher the amplification factor F_A , the lower the GHG emissions from H₂ produced
- The lower $EP_{mean,set}$ -values, the lower the GHG emissions from H₂ produced

How should the instrument be designed?

- If low CO₂ emissions are to be achieved, synthesis of amplified electricity price signals by F_A , and lowest possible $EP_{mean,set}$ -values

How could the DA criteria be fulfilled?

- Evaluation with location-based CO₂ emissions of the electricity mix
- Production of H₂ to avoid the need for redispatch



| | | | | | |
|--|-------|-------|-------|-------|-------|
| FA | 1.2 | 1.7 | 2.2 | 2.4 | 3.1 |
| EP_{mean,set} | 14 | 29 | 50 | 60 | 101 |
| Electrolyzer FLH | 5,597 | 4,174 | 3,040 | 2,731 | 2,000 |
| kg CO₂Äq./kg H₂ | 10.09 | 8.70 | 7.60 | 7.30 | 6.55 |

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Conclusion

- Amplified electricity prices lead to shorter, economical operating times
- The lower the number of full load hours to be stimulated, the higher the amplification factor must be selected
- Shorter operating times (flexibility) due to higher F_A and lower $EP_{mean,set}$, result in lower GHG emissions

Next steps

- A sensitivity analysis of assumed parameters should be performed
- Analyzing the electricity price curves of several years to develop a generalized amplification factor
- Identification of the exact electrolyzers operating hours during the year (incl. energy mix, CO₂ emissions factor)
- Analysis of the effects of the instrument on the electricity grid (expansion, costs of curtailment,)

Supported by:



on the basis of a decision
by the German Bundestag

Thank you for your interest.
I look forward to answering any questions you may have.

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