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

Carsten Schütte
Research associate
Competence Center for Renewable Energies and Energy Efficiency (CC4E)
Hamburg University of Applied Sciences (HAW Hamburg)

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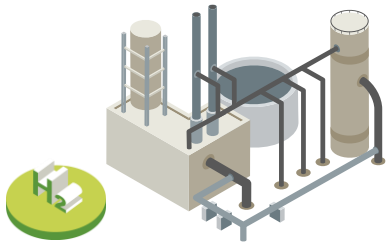
Motivation and Objective

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

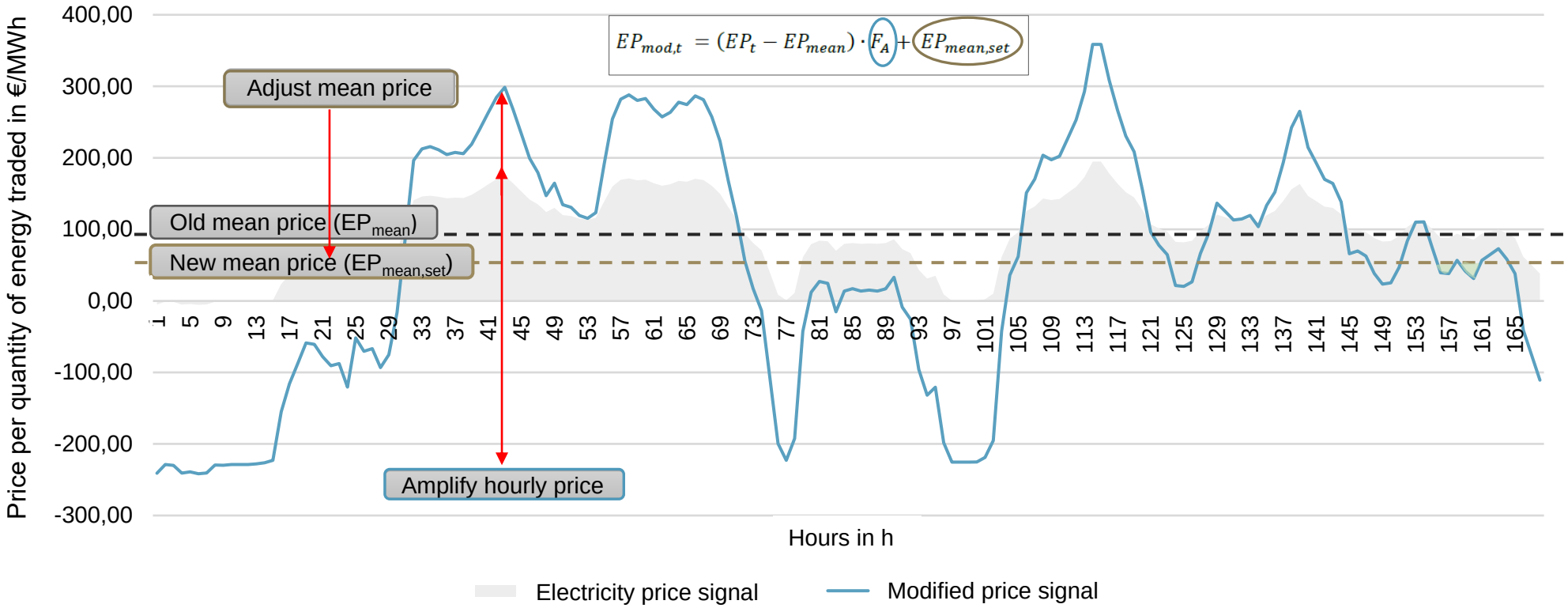
Objective

- Cost competitive use of green and low-carbon hydrogen in industry
- Stimulate grid-responsive (“beneficial”) system behavior of electrolyzers



Idea for a regulatory instrument

- Industrial hydrogen producers receive a modified hourly electricity price signal
  - Based on the electricity exchange with adjusted amplitude (F_A) and mean value ($EP_{mean,set}$)
  - Enables economical on-site H_2 production with grid electricity
  - Electricity demand in situations of low electricity prices (e. g. electricity surplus situation)



"Modifying electricity price signals in Germany for supply-oriented electricity demand and economical hydrogen use in industry."
20th International Conference on the European Energy Market (EEM24) on August 12th 2024 at Kadir Has University, Istanbul. See: https://ieeexplore.ieee.org/document/10608917

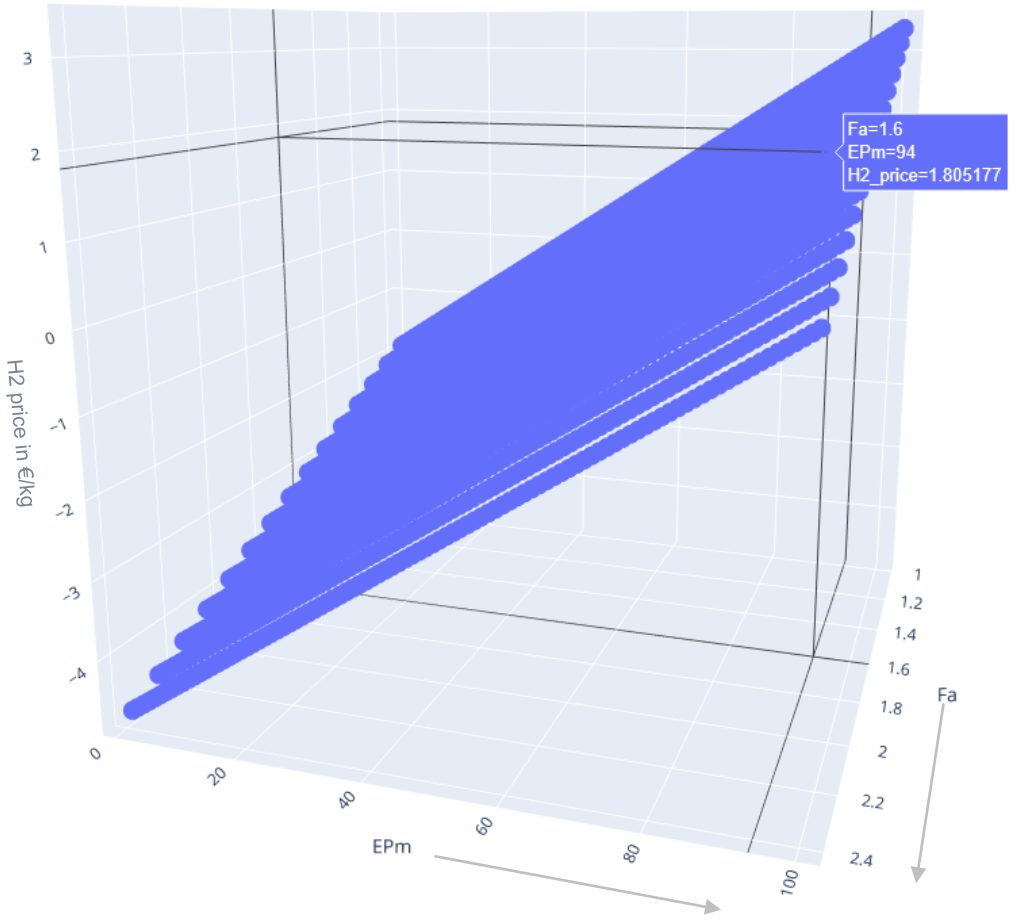
General framework

- The electricity price signal is modified by
  - Fa = modulation factor (amplify hourly price)
  - EPm = Electricity price mean

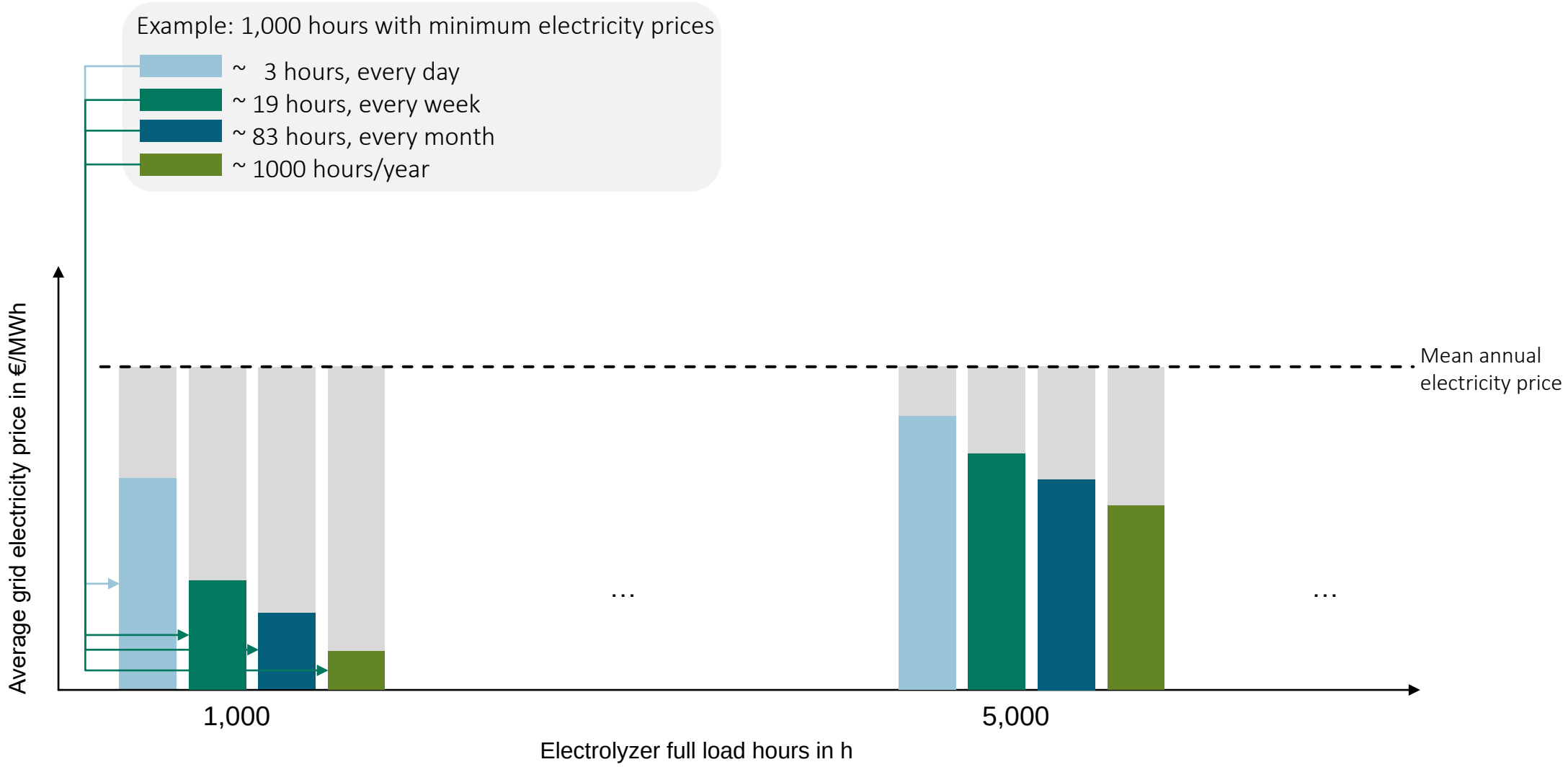
- **Least-cost hours**
  The electricity price signal is provided to companies interested in producing hydrogen flexibly in response to this signal when electricity is at least-cost.

- **Perfect foresight**
  The company produces hydrogen based on its knowledge of the electricity price trend for the entire period under consideration.

- **Demand profile**
  The company's objective is to produce a fixed amount of hydrogen cost-effectively within a defined period (day, week, month), without considering specific production times.



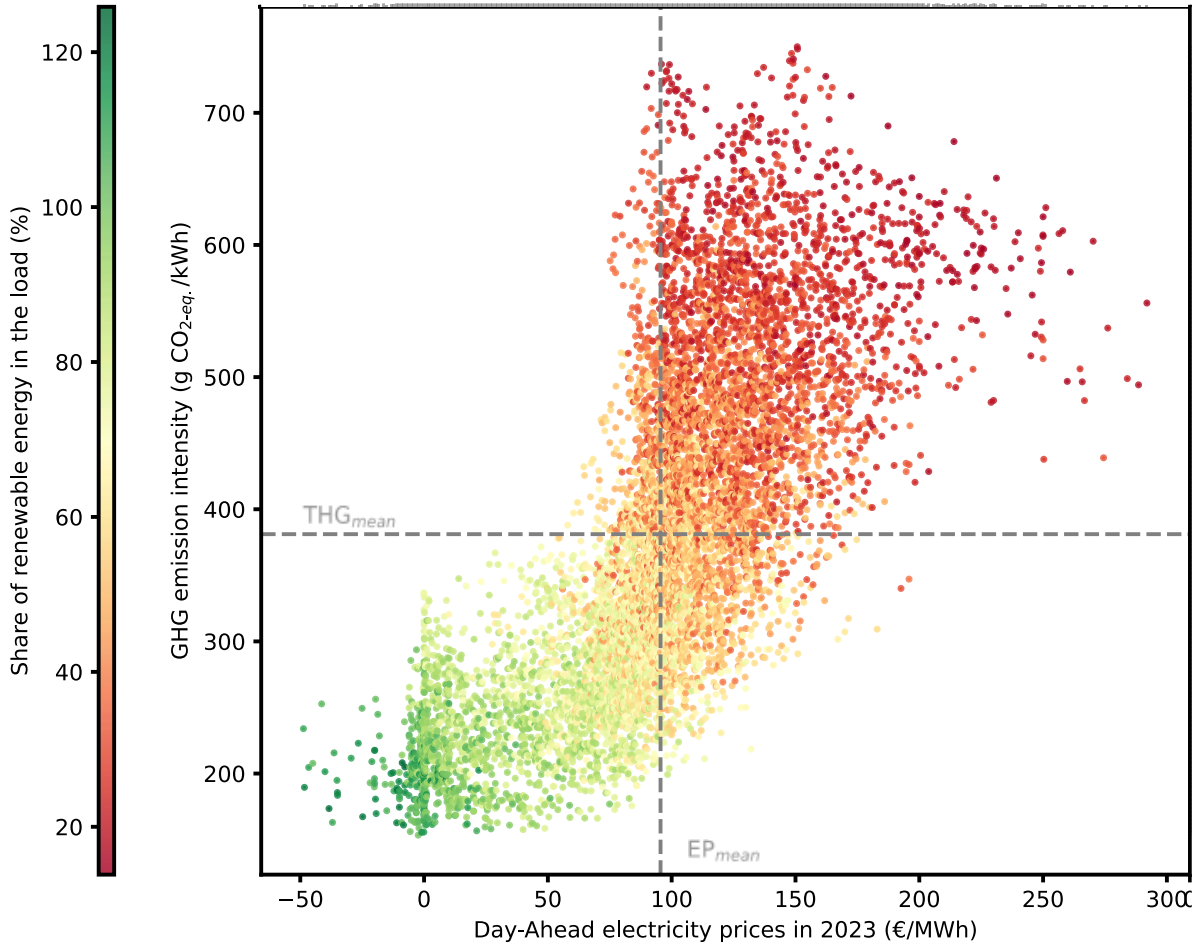
Demand profile | Hourly resolved electricity price signal



Data basis | Hourly resolved GHG emissions and Day-ahead prices

- Day-ahead electricity prices from 2019-2023

- Hourly GHG emissions (in g $CO_{2eq.}$) from FfE (https://greengrid-compass.eu/) according to GHG Protocol
- GHG other than CO_2 are converted into $CO_{2eq.}$
- GHG emissions of the electricity mix are ordered according to the least-cost hours



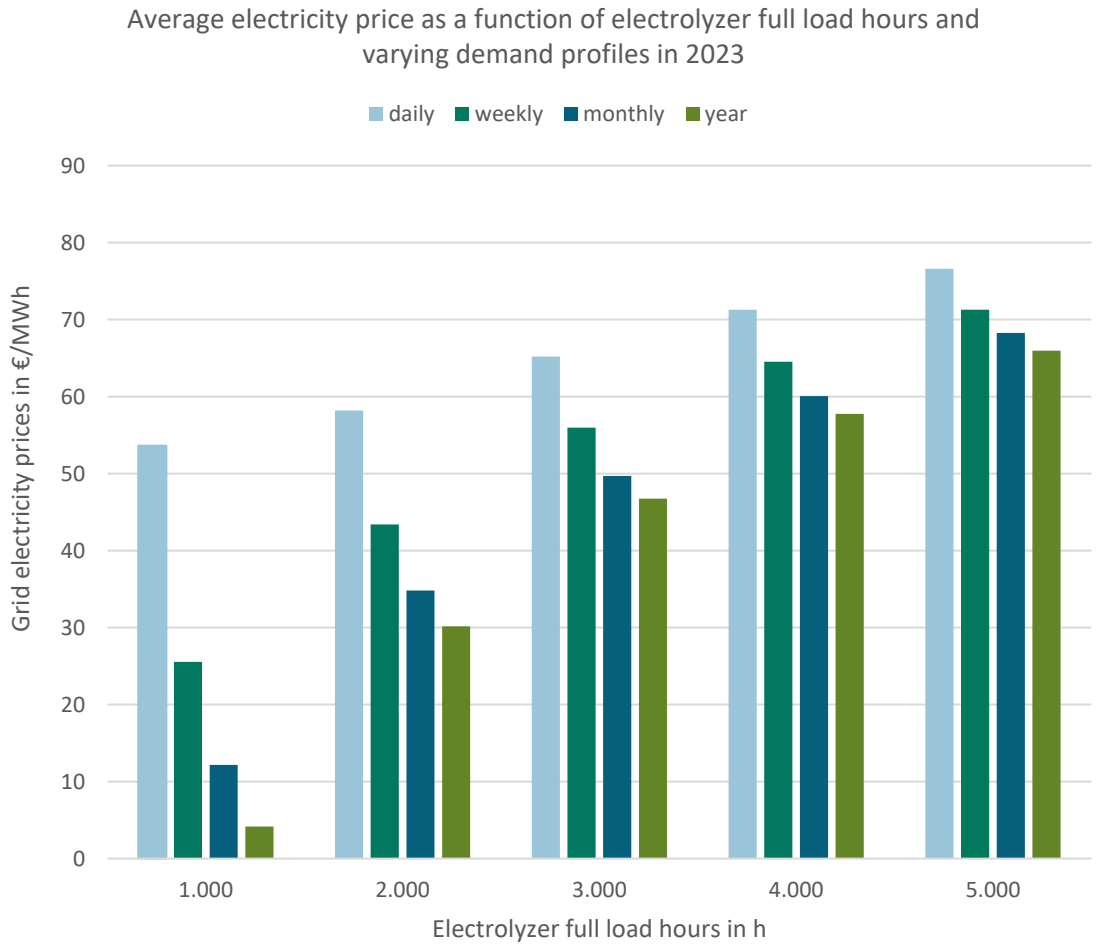
Preprint: "Correlation analysis of GHG emissions in the German electricity mix and exchange electricity prices using a sigmoid function.."
See: https://www.researchgate.net/profile/Carsten-Schuette

Research questions

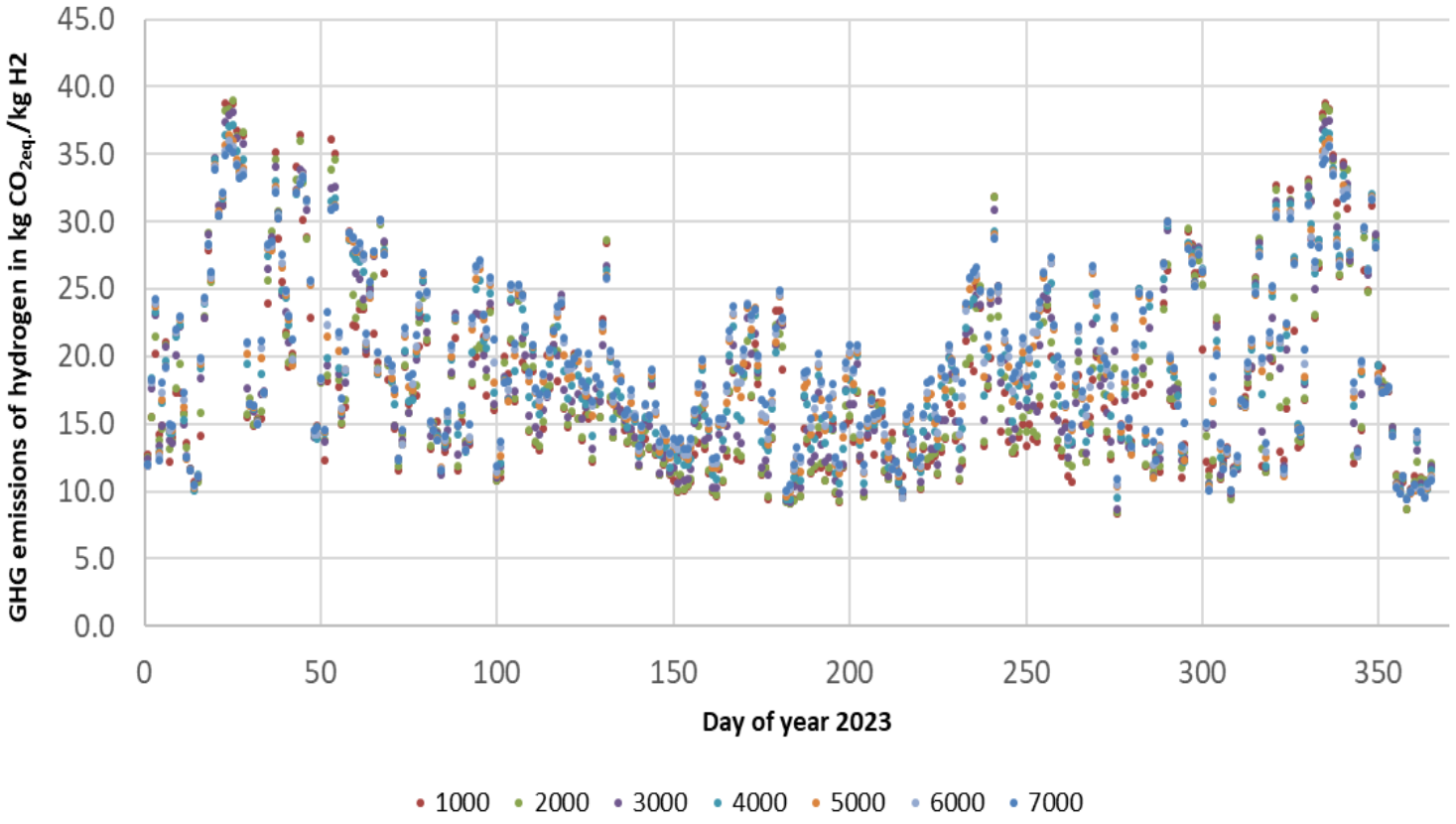
- How do the costs and GHG emissions of the H_2 production vary with different demand profiles?
- What is the change in average electricity prices if a hydrogen price with the same amplification factor is to be targeted?
- What do the findings imply for our regulatory instrument in general?

How do the electricity costs of the H_2 production vary with different demand profiles?

- The shorter the operating time, the higher the average electricity price.
- At 1,000 full load hours per year, the electricity price for daily production is twice as high as for weekly production and twice as expensive as for monthly production.
- This effect decreases as the number of production hours increases.

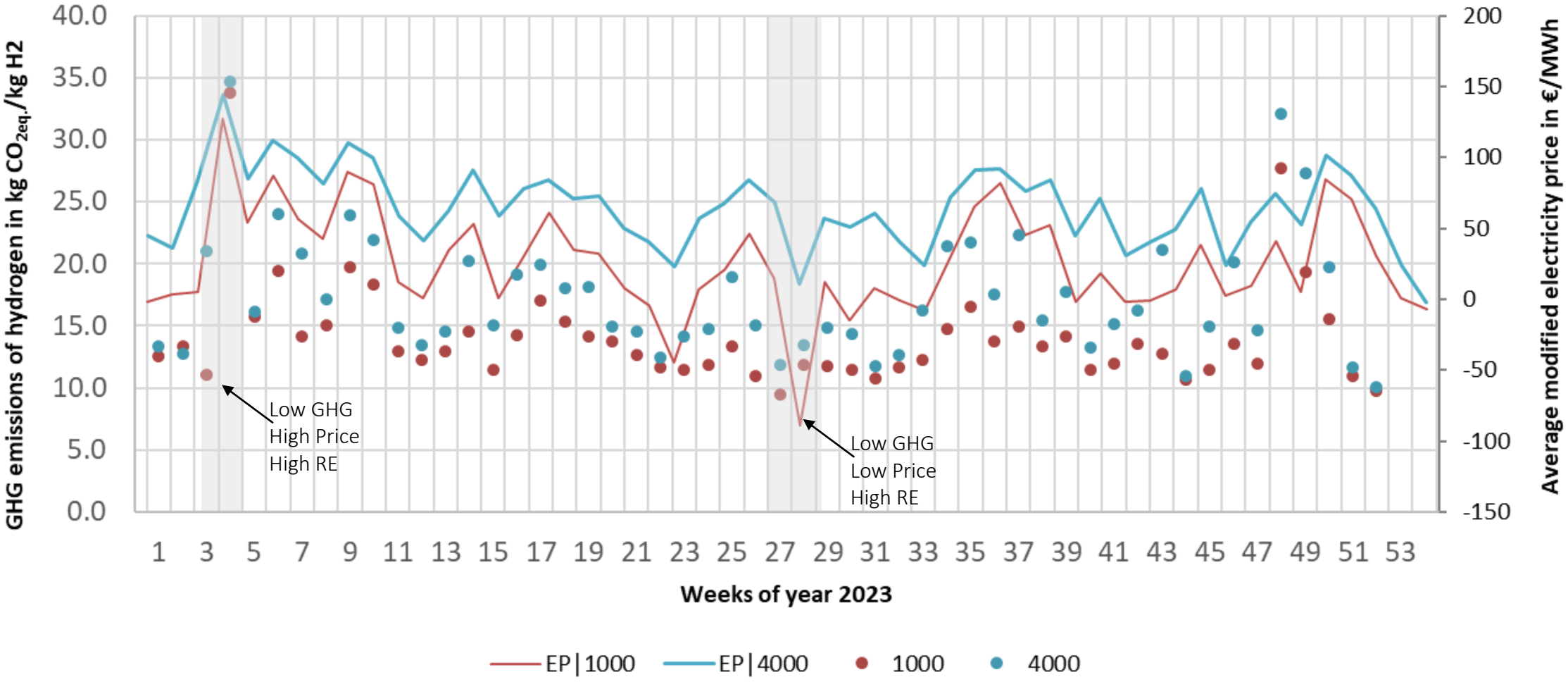


How do the GHG emissions of the H_2 production vary with different demand profiles?



- Increase in GHG emissions with
  - increase in full load hours and
  - at shorter demand profiles
- GHG emissions are up to 2,5x higher in fall in winter.
- Up to 4,5x higher emissions from the lowest to the highest day value.

How do the costs and GHG emissions of the H_2 production vary with different demand profiles?

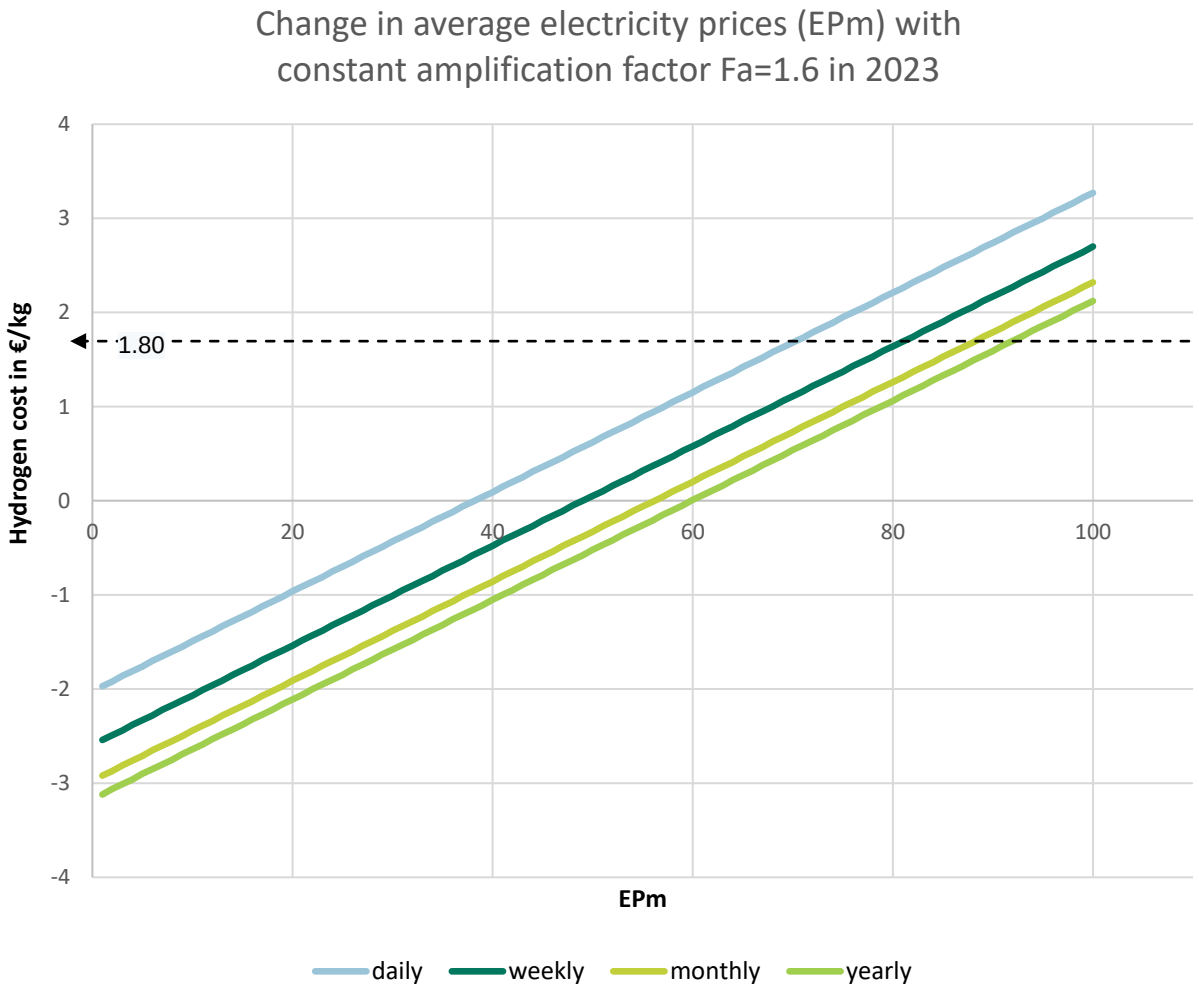


What is the change in average electricity prices if a hydrogen price with the same amplification factor is to be targeted?

- Targeted hydrogen price: 1.80 €/kg
- Amplification factor: Fa=1.6
- 4,000 least-cost full load hours

Demand profile	EP_m in €/MWh
Daily	72
Weekly	83
Monthly	90
Yearly	94

✓ Since the factor (F_A), the full load hours and the hydrogen price are constant, the average price (EP_m) must be lower for a short-term demand profile.



What is the change in average electricity prices if a hydrogen price with the same amplification factor is to be targeted?

- Targeted hydrogen price: 1.80 €/kg
- Amplification factor: Fa=1.6
- 4,000 least-cost full load hours

✓ No incentive from the instrument through the selected combination in 2022 due to sharp rise in prices and hardly any negative prices.

What do the findings imply for our regulatory instrument in general?

- The incentive for flexibility leads to higher costs.
- The hours with least electricity prices are not always the ones with the lowest GHG emissions.
- GHG emissions decrease depending on the duration of the demand profile.
- A combination can have a different effect in each demand profile (time period, year). F_A must be adjusted, or higher costs must be offset by EP_m.

+ A local signal to adjust the electricity price could stimulate grid-friendly behavior.
  → This can reduce or avoid costs for redispatch measures or grid expansion.
+ Special incentive in these hour.
+ Sorting according to GHG emissions.
+ Development of a generalized factor that adapts by learning from e. g. previous hours.

Next steps

Further research

- Investigation of how local electricity demand (demand response) can be triggered.
- Identification of a suitable, local, signal for the mechanism.
- Focus on hourly GHG emissions and production in times of low emissions.

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Thank you for your interest.

I look forward to answering any questions you may have.

Carsten Schütte
Research associate, Project manager
Competence Center for Renewable Energies and Energy Efficiency (CC4E)
Hamburg University of Applied Sciences (HAW Hamburg)
carsten.Schuette@haw-hamburg.de

Prof. Dr.-Ing. Sebastian Timmerberg
Environmental Process Engineering
Renewable fuels and energy management
Competence Center for Renewable Energies and Energy Efficiency (CC4E)
Hamburg University of Applied Sciences (HAW Hamburg)
sebastian.timmerberg@haw-hamburg.de

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