Insights from model based studies on 24/7 CFE and green hydrogen regulation

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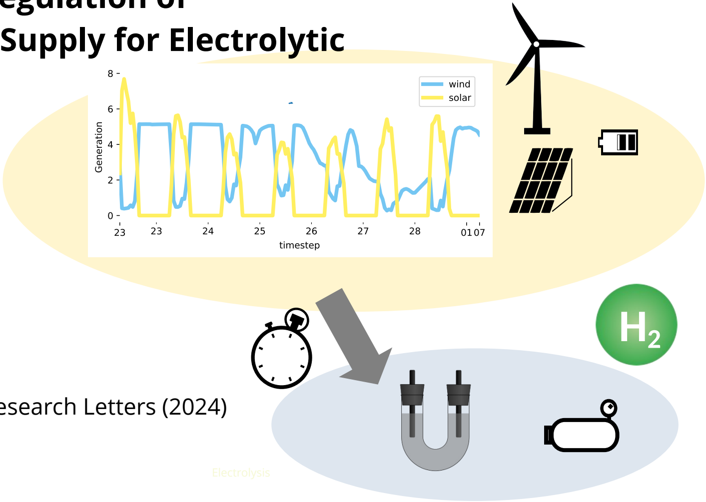
Clean Electricity Procurement

How to **match** renewable generation with electricity demand?

- A concept of **hourly matching** got into the spotlight with debates on clean hydrogen regulation
- Also a foundation for voluntary 24/7 carbon-free electricity (CFE) procurement

ChatGPT4 hallucination, 2024

Temporal Regulation of Renewable Supply for Electrolytic Hydrogen



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Iegor Riepin,
Tom Brown

Environmental Research Letters (2024)

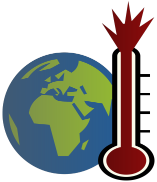
Motivation - The Urgency of Green Hydrogen Standards

Challenge: Rapid scale up of affordable green hydrogen production without emissions increases.

What happened so far:

- Various standards are under discussion, differing in how strictly renewable generation must align with the electrolysis electricity demand.
- The EU adopted a Delegated Act in 2023, hourly matching from 2030
$\rightarrow$ **Delegated Act** is subject to **review in July 2028**.

Questions We Want to Answer in This Study



How do **various certification** standards affect **emissions**?

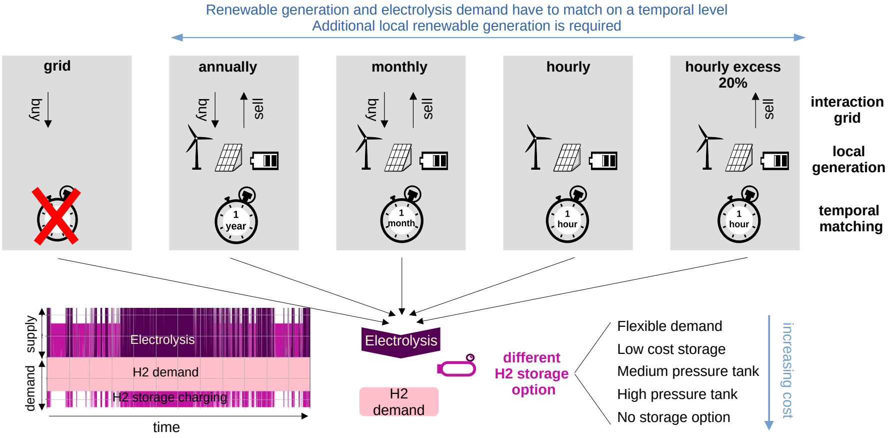
How do regulations impact **hydrogen production costs**?

Scientific Novelty

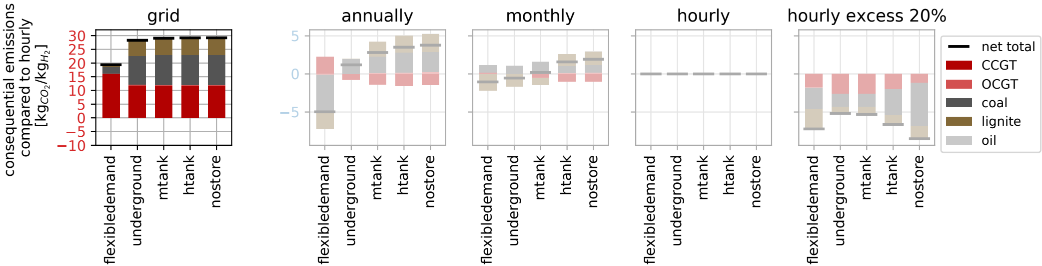
Quantify impact of individual modelling assumptions: This includes hydrogen storage options, the background grid, and the methods used to model additionality.

Methods - Modelling Hydrogen's Temporal Regulation

Hydrogen production in one selected European country with a **constant** hydrogen demand of 28 $\mathrm{TWh_{H_2}/a}$.



Results - Emission Impacts of Hydrogen Production: Germany 2025



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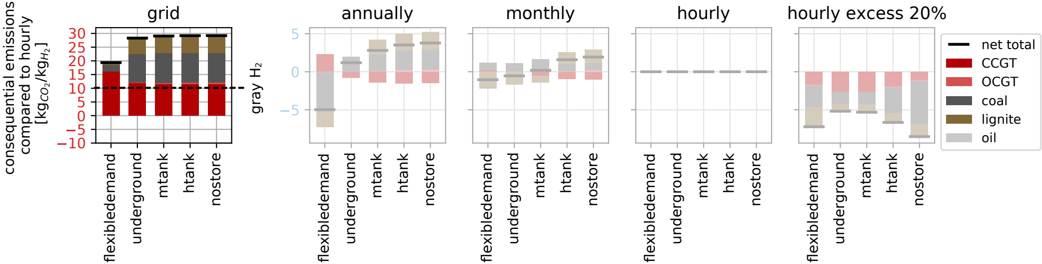

- **Additional local procurement** is **essential** to prevent emission increases

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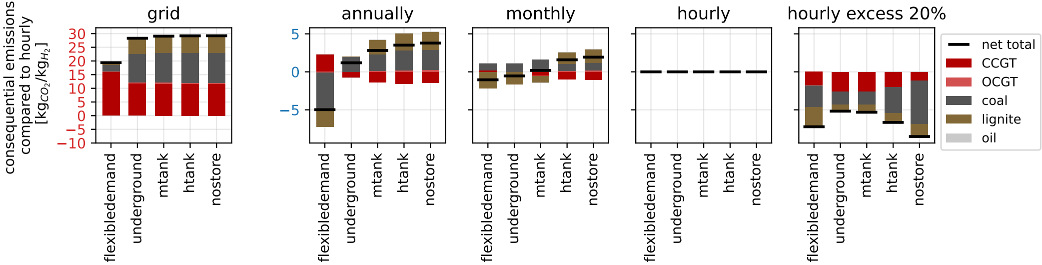
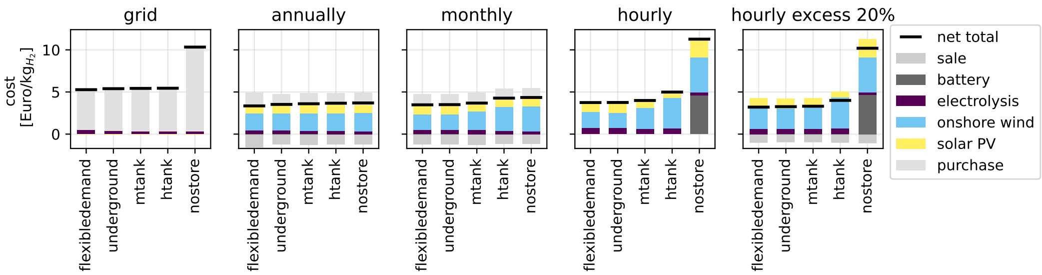


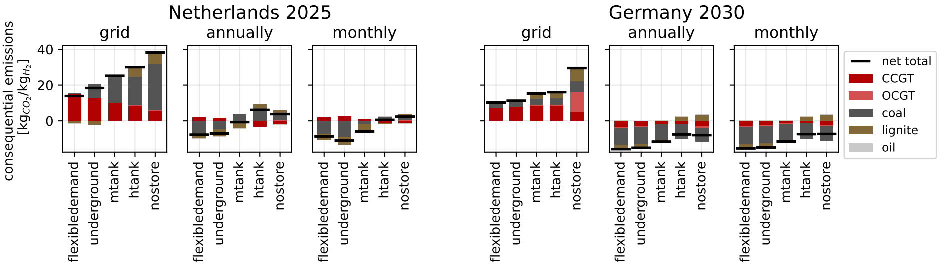
- **Additional local procurement** is **essential** to prevent emission increases
- The effects of annual and monthly matching are complex: **flexible operations reduce** emissions, but **constant** operations **increase** them

Results - Hydrogen Production Costs: Germany 2025



Small Cost Premium: Hourly matching has a 7–8% cost premium over annual matching, given low-cost hydrogen storage or flexible demand

Comparing Hydrogen Production in Carbon-Intensive vs. Clean Grids



Lower RES share of 49%

Emissions can **rise** to nearly **4x** the intensity of **grey hydrogen**.

Higher RES share of 80%

With **higher decarbonisation**, temporal **regulation** of hydrogen production matters **less**.

Take Aways - Temporal Regulation of Green Hydrogen Production

Green hydrogen certification: Low emissions & low costs require

Additional local renewable generation

Temporal matching either

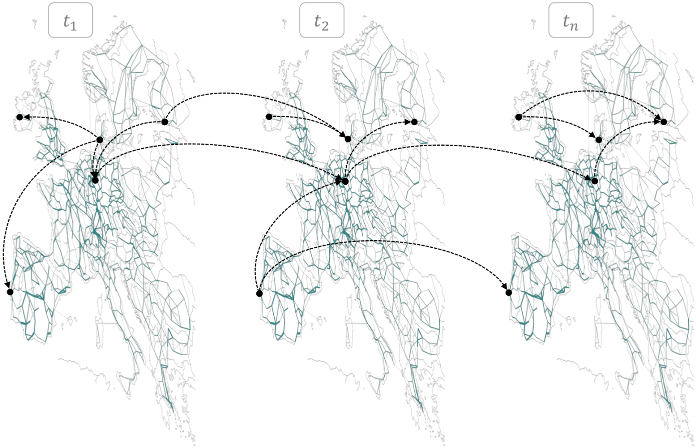
- Hourly with flexible demand or low-cost storage
- Annual with limited electrolysis full load hours
- Annual with a largely decarbonised background grid

H_2

Further interesting insights:

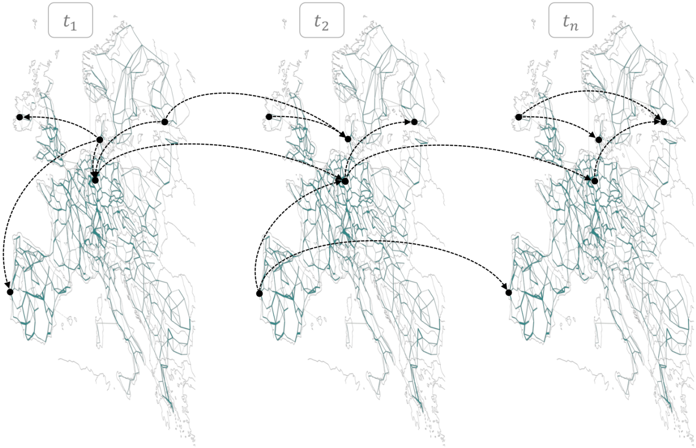
- High dependency of consequential emissions on the background system
- Impact on how additionality is modelled

New study: The value of space-time load-shifting flexibility for 24/7 carbon-free electricity procurement (July 2023)



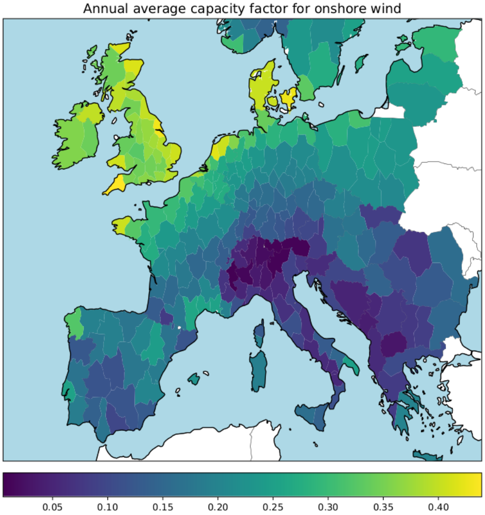
- Key focuses:
  - How can demand flexibility reduce the required **resources** and **costs** of 24/7 CFE matching?
  - What are the **signals** for optimal utilisation of demand flexibility?
  - What are the trade-offs and synergies from co-optimisation of **spatial** and **temporal** load shifting?
- Open-access research:
  - study: **zenodo.org/records/8185850**
  - code: **github.com/PyPSA/247-cfe**
- A follow-up research paper to be released in March 2024.

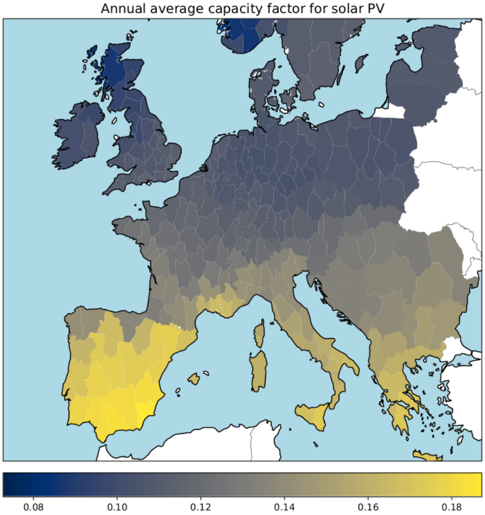
Methods and study design



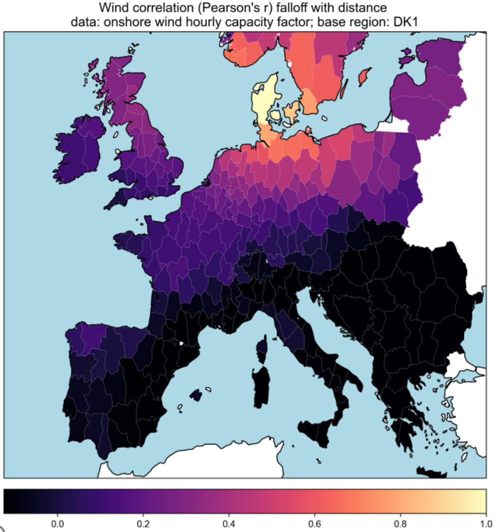
- The study is done with **PyPSA** – an open-source framework for modelling modern energy systems.
- Model scope: **ENTSO-E area** power system clustered to individual bidding zones, **hourly** temporal resolution.
- Geographically scattered datacenters that are managed collectively. An operating company follows **24/7 CFE strategy** in all locations.
- **Spatial** and **temporal** load shifting mechanisms.
- **"Flexible workloads"**, i.e. electricity loads that can potentially be shifted in space or in time, are assumed to be in a range of {0% .. 40%}.

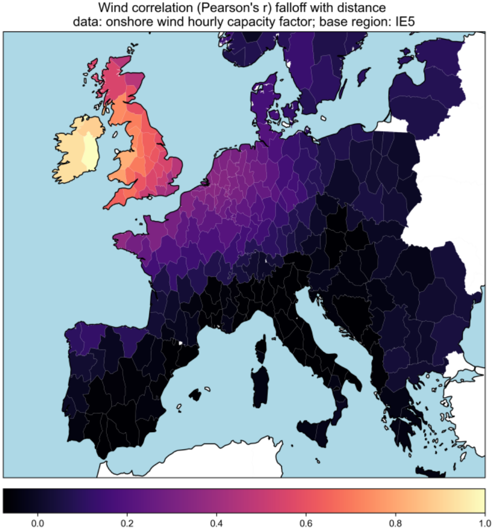
Signal 1: quality of local renewable resouces



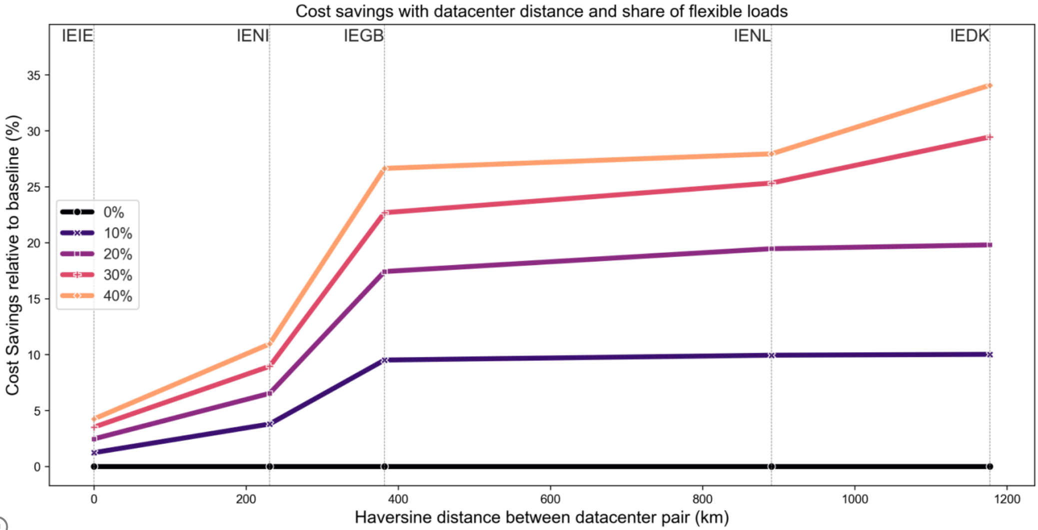


Signal 2: low correlation of wind power generation over long distances

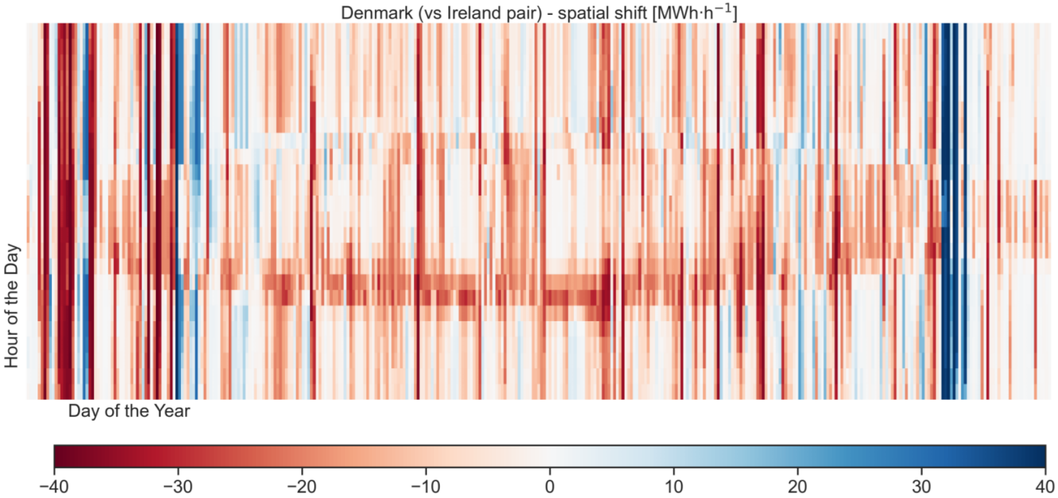




Cost savings as a function of distance between datacenter pair

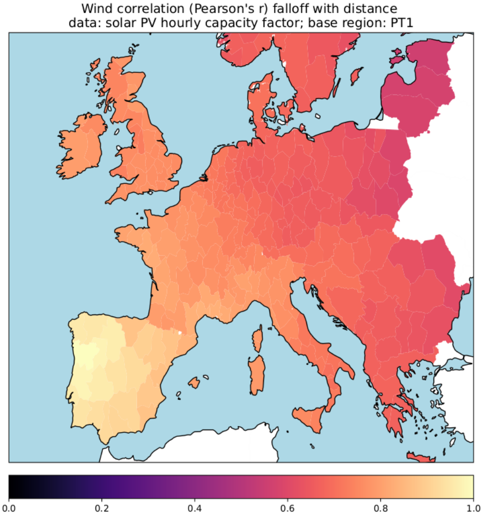


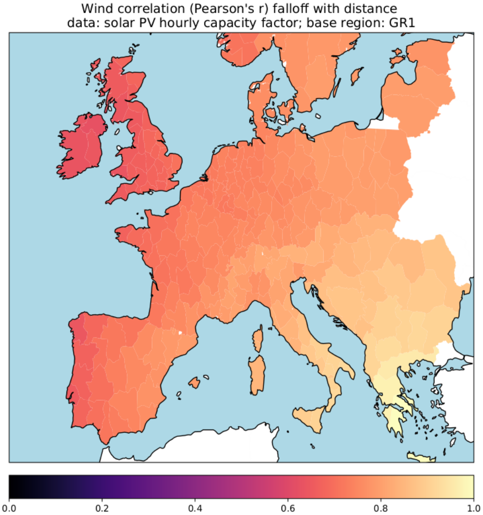
Time-series of optimized spatial load shifts (locations: DK-IE)



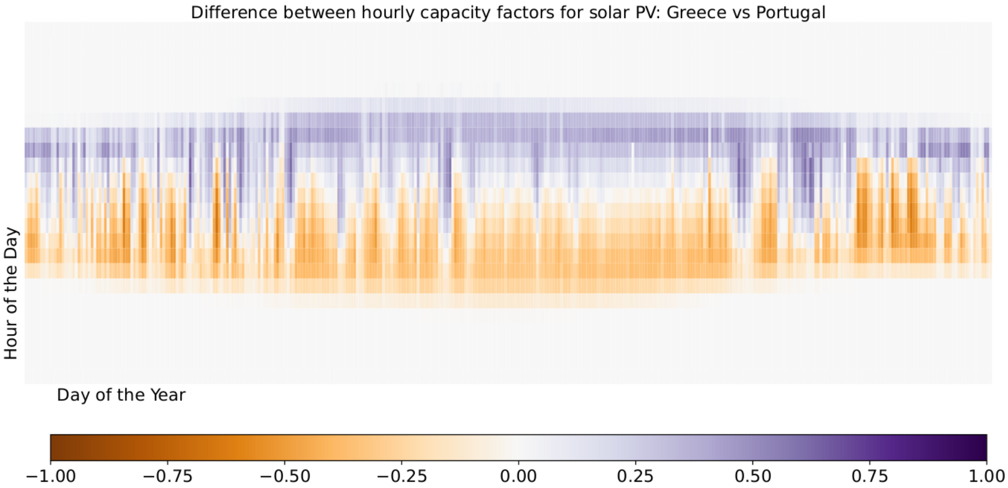
Negative values mapped to red color represent decrease of a load
Positive values mapped to blue color represent increase of a load

Signal 3: time lag in solar radiation peaks due to Earth's rotation (1/2)





Signal 3: time lag in solar radiation peaks due to Earth's rotation (2/2)



Also in the study

- Scenarios for **co-optimised** and **isolated** utilisation of space-time load-shifting;
- Scenarios for 24/7 CFE with **98% and 100%** matching targets;
- Scenarios with different **24/7 technology options** (e.g., Long Duration Energy Storage);
- 24/7 CFE **cost breakdowns** and **procurement strategies** for individual locations;
- **Synergies** and **trade-offs** between spatial and temporal load shifting;
- Analysis of **net load migration** across locations;
- Simulated **energy balances** for selected datacenters.

Take aways

There are **three signals** companies can factor into their procurement & load shaping strategies for 24/7 CFE matching:

– quality of local renewable resources;
– low correlation of wind power generation over long distances;
– time lag in solar radiation peaks due to Earth's rotation.

Overall, space-time load-shifting flexibility:

– enables **better access to clean electricity** and creates **more options** for consumers to match demand with carbon-free electricity around-the-clock;
– **lowers the costs** of 24/7 CFE matching and makes it **more attractive** to a wider range of companies.

Contacts, Resources, Acknowledgements

References: **Temporal regulation of renewable supply for electrolytic hydrogen (2023)**

References: **More about the 24/7 CFE research project (2022-2024)**

Code: This work done in a spirit of open and reproducible research:

code: **github.com/PyPSA/247-cfe**

code: **https://zenodo.org/records/8324521**

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