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

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DTU, 04 July 2024

Clean Electricity Procurement

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

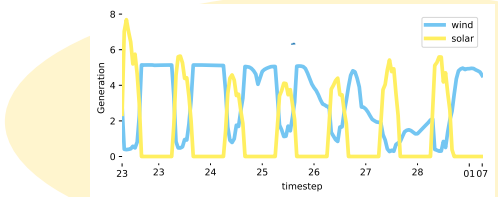
- A concept of **hourly matching** got into the spotlight with debates on clean hydrogen regulation
- Also a foundation for voluntary 24/7 carbon-free electricity (CFE) procurement

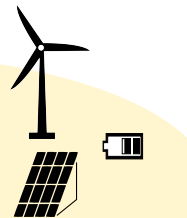
ChatGPT4 hallucination, 2024

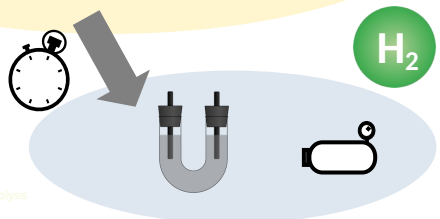
Temporal Regulation of Renewable Supply for Electrolytic Hydrogen

Elisabeth Zeyen,
Iegor Riepin,
Tom Brown

Environmental Research Letters (2024)







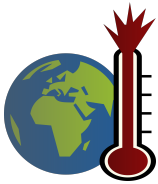
Motivation - The Urgency of Green Hydrogen Standards

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**?

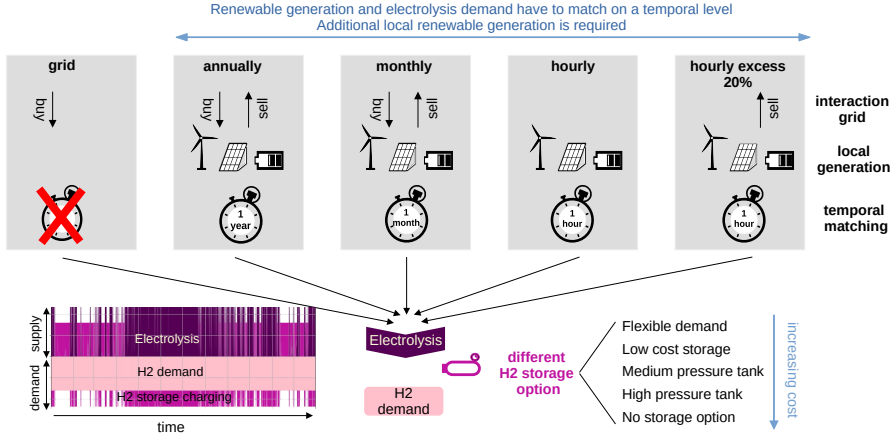
How do regulations impact **hydrogen production costs**?

Scientific Novelty

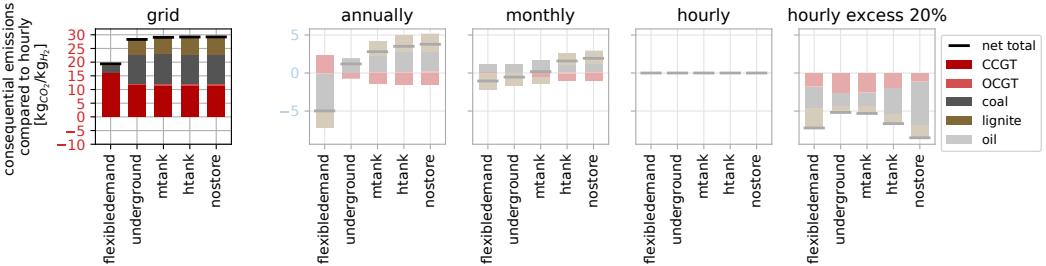
Quantify impact of individual modelling assumptions: This includes hydrogen storage options, the background grid, and the methods used to model additionality.

Methods - Modelling Hydrogen's Temporal Regulation

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



Results - Emission Impacts of Hydrogen Production: Germany 2025



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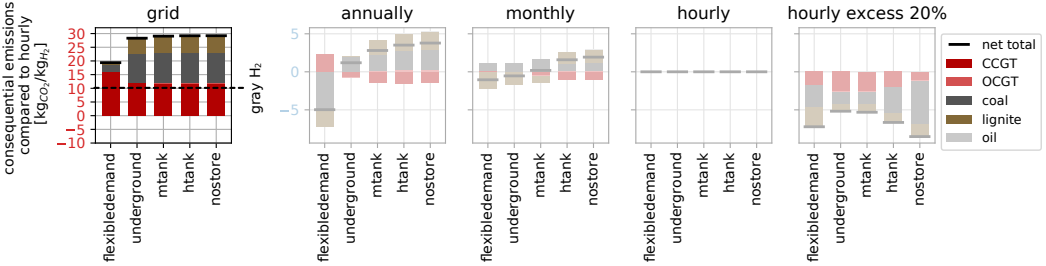
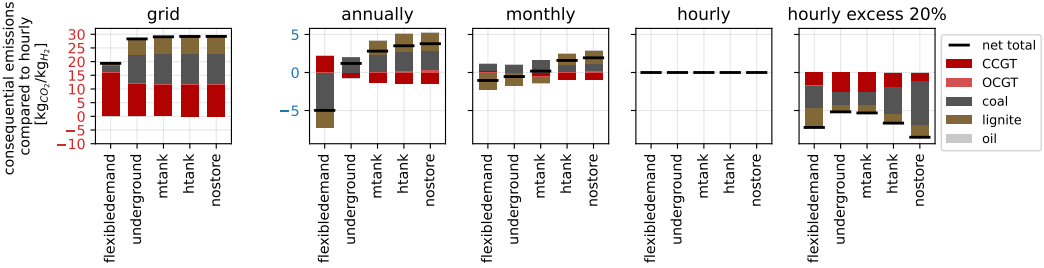


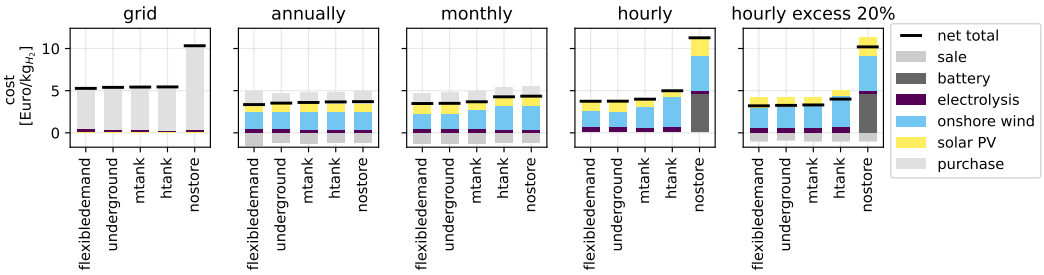
- **Additional local procurement** is **essential** to prevent emission increases

Results - Emission Impacts of Hydrogen Production: Germany 2025



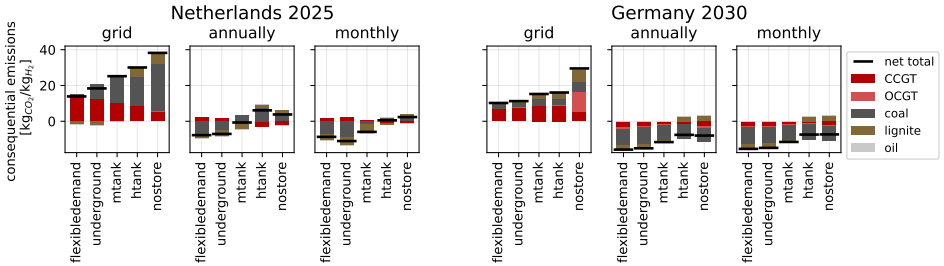
- **Additional local procurement** is **essential** to prevent emission increases
- The effects of annual and monthly matching are complex: **flexible operations reduce** emissions, but **constant** operations **increase** them

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

Further interesting insights:

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

Spatio-temporal load shifting for truly clean computing

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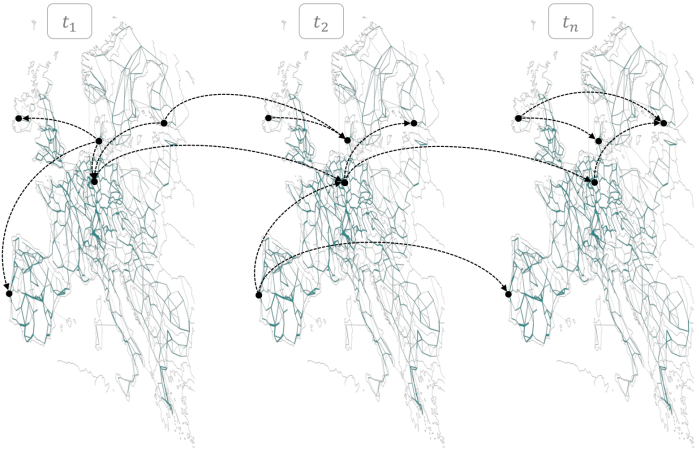

Iegor Riepin
Tom Brown
Victor M. Zavala

Working paper (2024)

Code

Research on datacenter load flexibility

ELSEVIER

Electric Power Systems Research
Volume 212, November 2022, 108586

Using geographic load shifting to reduce carbon emissions

Julia Lindberg, Bernard C. Lesieutre, Line A. Roald

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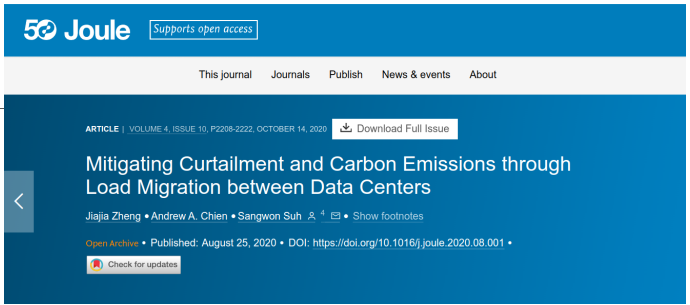
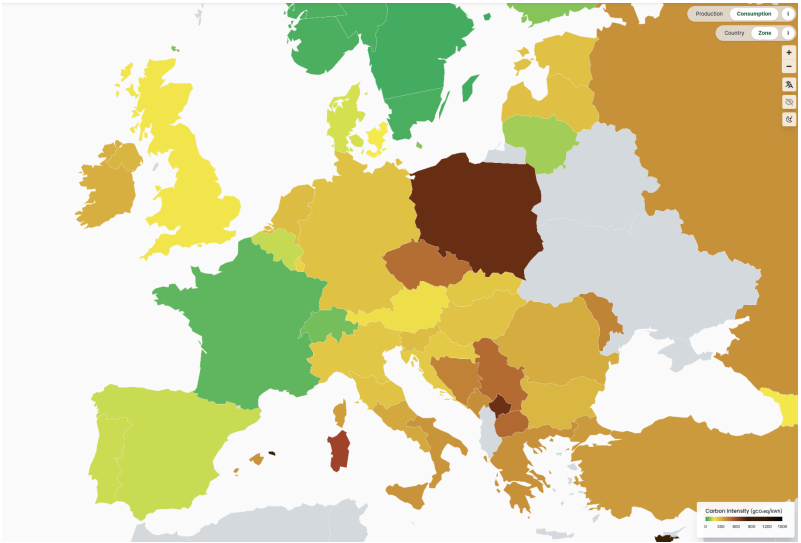
https://doi.org/10.1016/j.epsr.2022.108586



Lindberg et al. (2022): doi.org/10.1016/j.epsr.2022.108586,
Zheng et al. (2020): doi.org/10.1016/j.joule.2020.08.001

Market data and forecasts



Carbon intensity of electricity consumed
Source: electricitymaps.com/map

ICT companies work on concepts and technical solutions

DATA CENTERS AND INFRASTRUCTURE

Our data centers now work harder when the sun shines and wind blows

Apr 22, 2020 · 3 min read

Ana Radovanovic
Technical Lead for Carbon-Intelligent Computing

Share

Addressing the challenge of climate change demands a transformation in how the world produces and uses energy. Google has been carbon neutral since 2007, and 2019 marks the third year in a row that we've matched our energy usage with 100 percent renewable energy purchases. Now, we're working toward 24x7 carbon-free energy everywhere we have data centers, which deliver our products to billions of people around the world. To achieve 24x7 carbon-free energy, our data centers need to work more closely with carbon-free energy sources like solar and wind.

SUSTAINABILITY

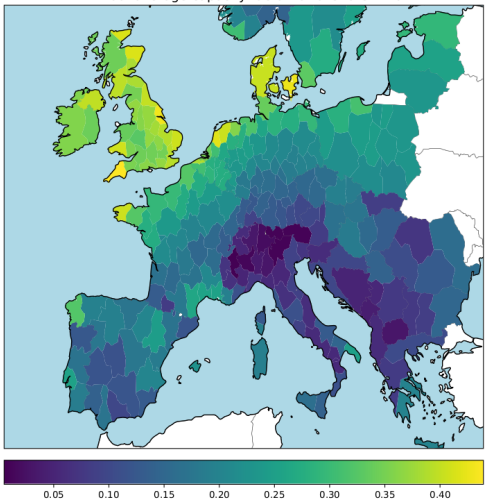
We now do more computing where there's cleaner energy

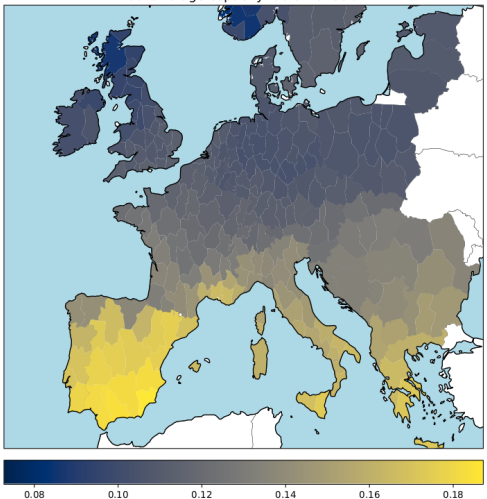
May 18, 2021 · 2 min read

Ross Koningstein
Co-founder, Carbon-Intelligent Computing

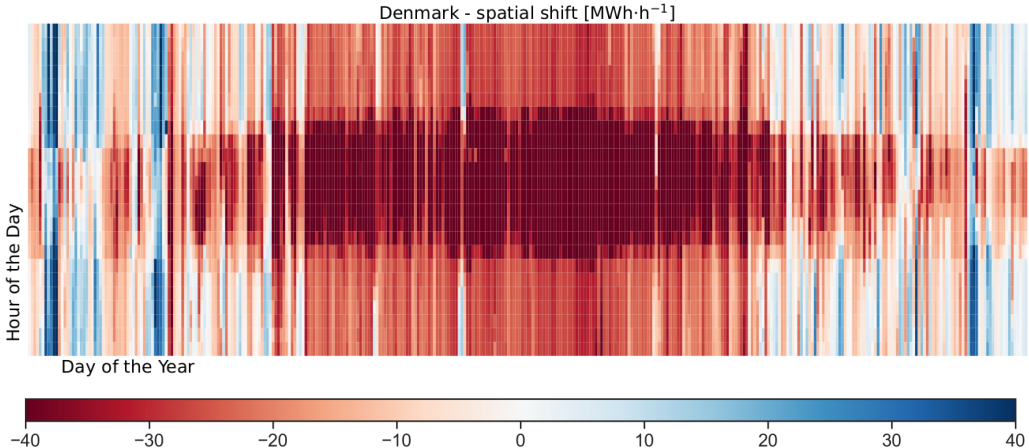
Sources:
blog.google/data-centers-work-harder-sun-shines-wind-blows
blog.google/carbon-aware-computing-location

Signal 1: quality of local renewable resouces



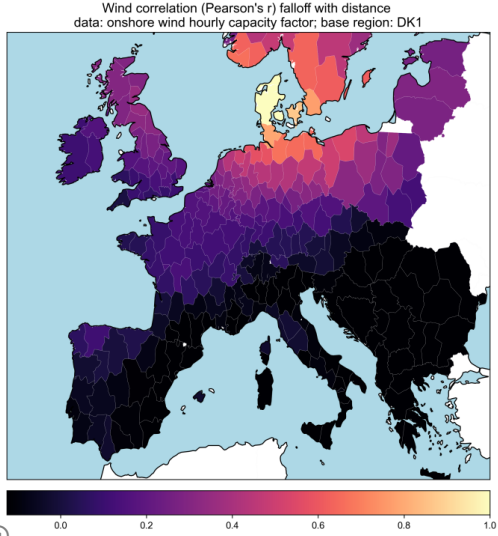


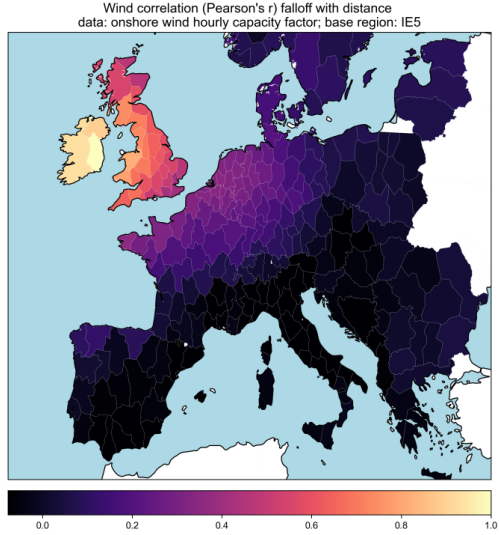
Time-series of optimized spatial load shifts



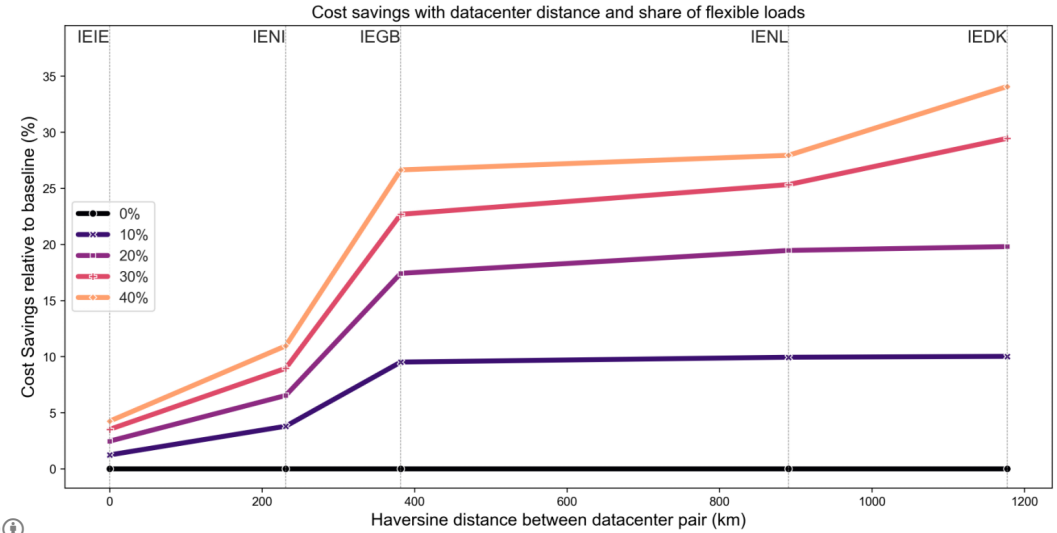
Negative values mapped to red color represent decrease of a load
Positive values mapped to blue color represent increase of a load

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

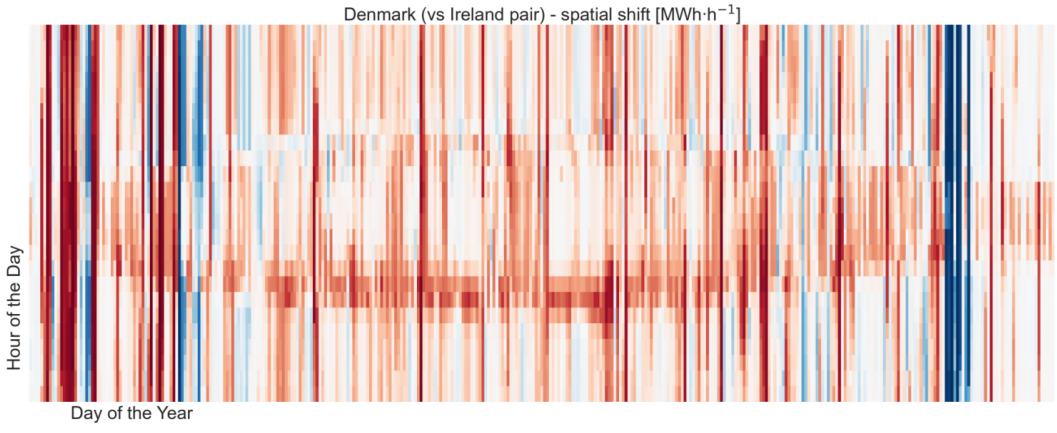




Cost savings as a function of distance between datacenter pair



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



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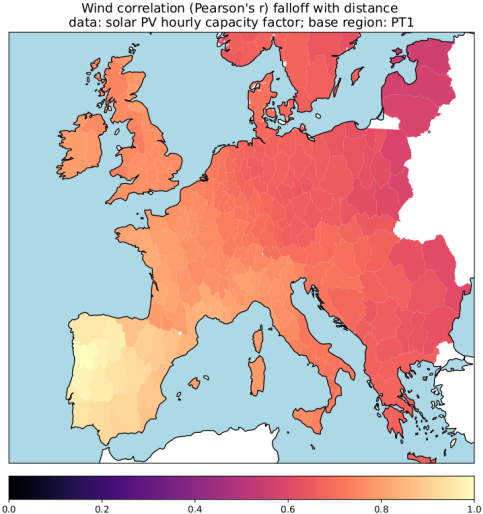
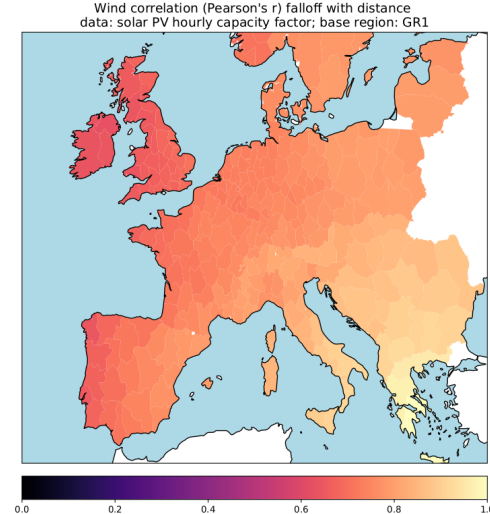
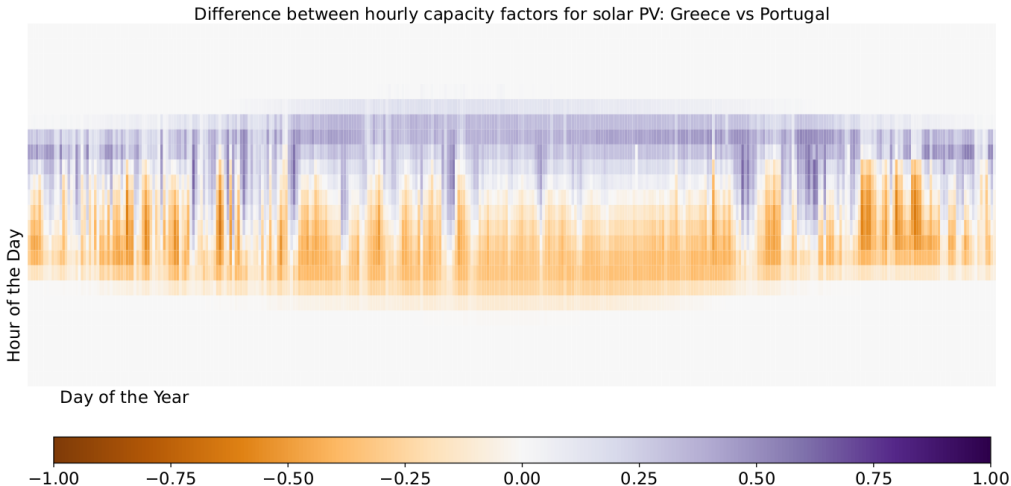
Signal 3: time lag in solar radiation peaks due to Earth's rotation (1/2)

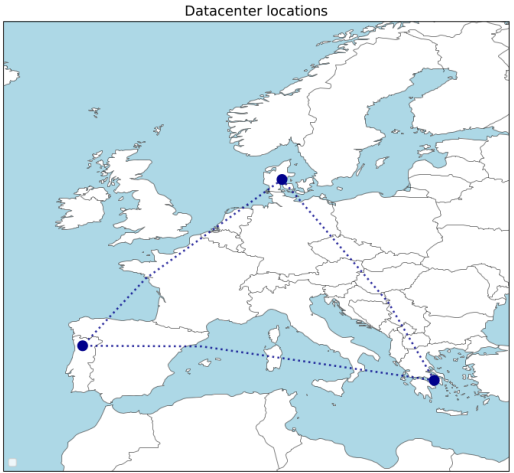


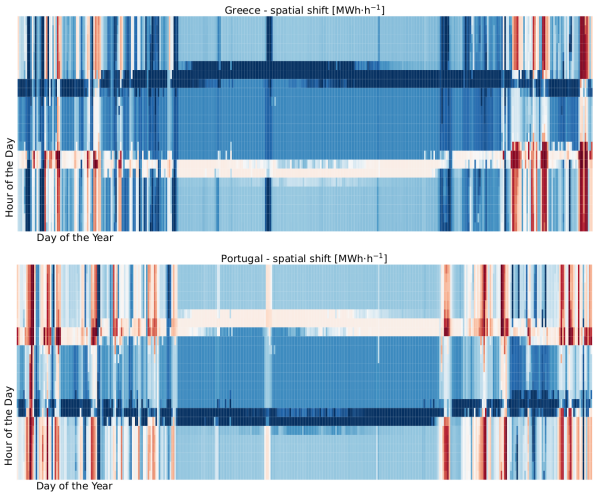


Signal 3: time lag in solar radiation peaks due to Earth's rotation (2/2)



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





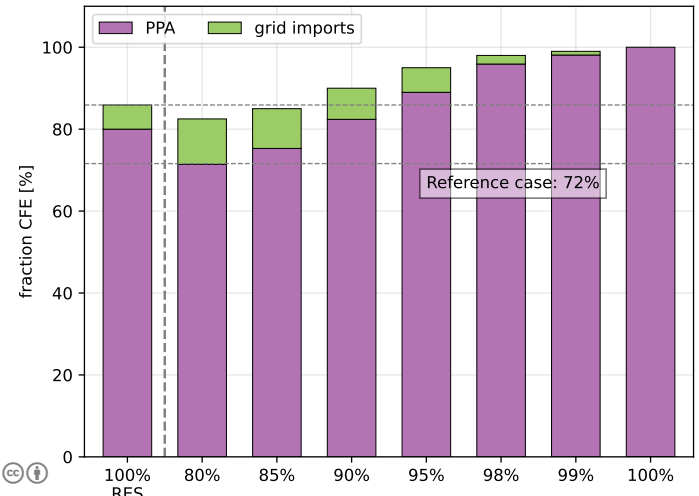
More insights in the published works

"Spatio-temporal load shifting for truly clean computing" (Mar 2024):
paper: **https://arxiv.org/abs/2405.00036**
code: **https://github.com/Irieo/space-time-optimization**

"The value of space-time load-shifting flexibility for 24/7 CFE procurement" (July 2023):
study: **https://zenodo.org/records/8185850**
code: **https://github.com/PyPSA/247-cfe/tree/v0.3**

– Results for **co-optimised** and **isolated** utilisation of space-time load-shifting
– Results for **different matching targets**
– Results for advanced **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
– The costs of 24/7 CFE are reduced by **1.29±0.07 €/MWh** for every additional percentage of flexible load

On hourly matching, grid signals and load flexibility
Fraction of hourly demand met by CFE



- Modelled region: **Ireland 2030**
- **72%**—average CFE score in the background grid
- CFE score above this treshold requires contracting **own CFE resources**
- 24/7 CFE buyer **relies more on directly contracted resources as target CFE score tightens**

Riepin and Brown (2023): https://zenodo.org/records/10407831

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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