On space-time load-shifting flexibility for 24/7 carbon-free electricity procurement

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Eurelectric 24/7 Carbon Free Energy (CFE) Hub meeting
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Open and reproducible model-based research on 24/7 CFE

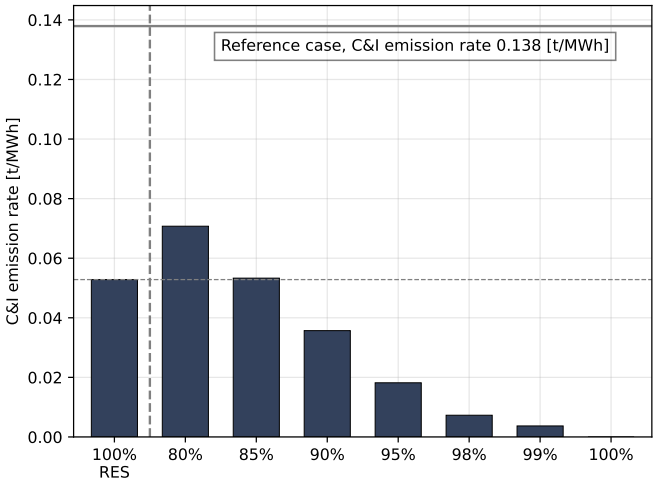


Figure from study "System-level impacts of 24/7 CFE procurement in Europe" (2022) **doi.org/10.5281/zenodo.7180098**

- Prior study highlights:
  - 24/7 CFE **reduces emissions** for participants and the system;
  - Reaching CFE for 90-95% of the time is possible with a small cost premium. Costs increase rapidly **above 95% CFE target**;
  - 24/7 CFE **stimulates innovation** and creates an early market for advanced technologies; LDES or clean firm technologies can help reducing the cost premium.
- Open question:
  What role can **demand flexibility** play for 24/7 CFE?

Data centers 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

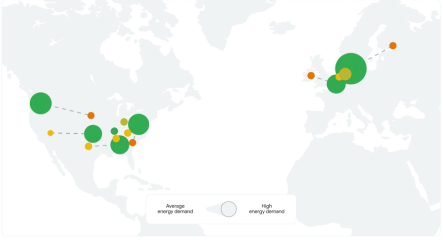
Addressing the challenge of climate change demands a transformation in how the world produces and uses energy. Google has been carbon neutral since 2007, and 2019 marks the third year in a row that we've matched our energy usage with 100 percent renewable energy purchases. Now, we're working toward 24x7 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

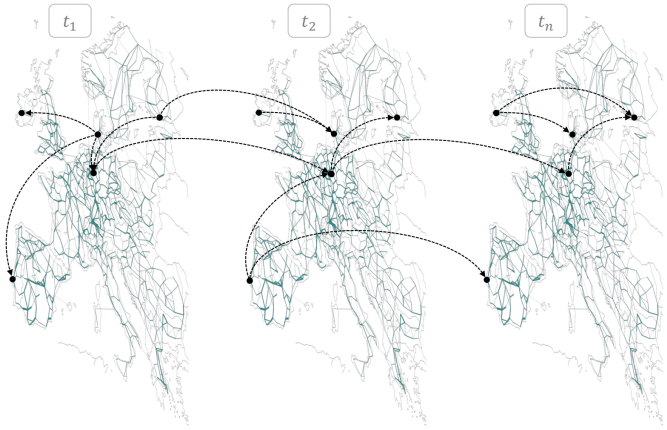
May 18, 2021 · 2 min read

Ross Koningstein
Co-founder, Carbon-Intelligent Computing



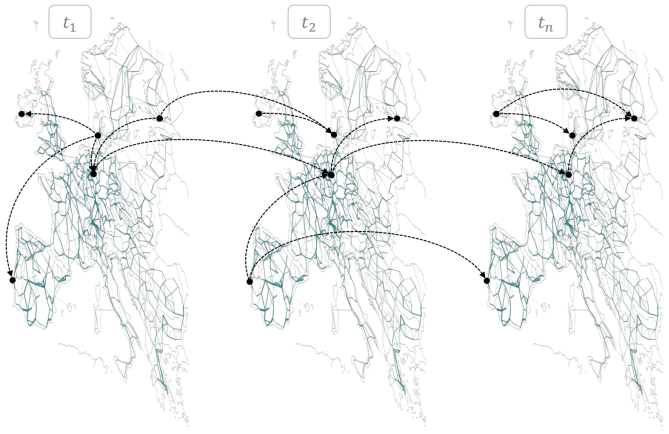
Sources:
blog.google/data-centers-work-harder-sun-shines-wind-blows
blog.google/carbon-aware-computing-location

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**

New study: experimental design



- The study is done with **PyPSA** – an open-source framework for modelling modern energy systems.
- Full **ENTSO-E area** power system clustered to individual bidding zones.
- **Optimal 24/7 CFE strategies** for participating buyers & co-optimisation of the entire European power system.
- **Five data centers** in IE, DK1, DE, FI, PT.
- **Spatial** and **temporal** load shifting mechanisms with technical constraints.
- **"Flexible loads"**, i.e. electricity loads that can potentially be shifted in space or to other times, are assumed to be in a range of {0% .. 40%}.

Procurement as a function of load flexibility (100% CFE)

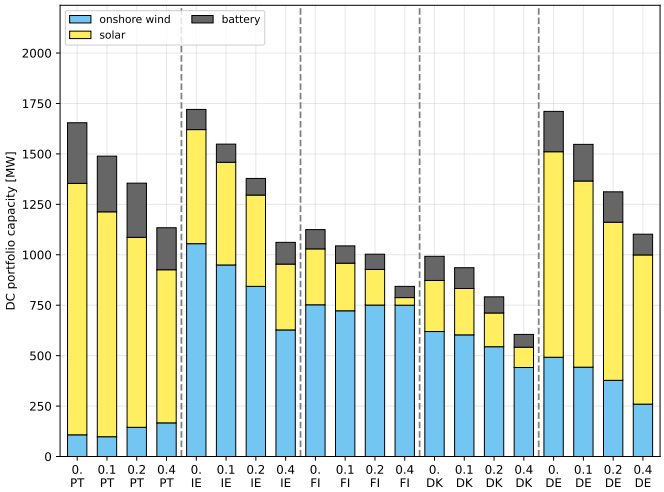
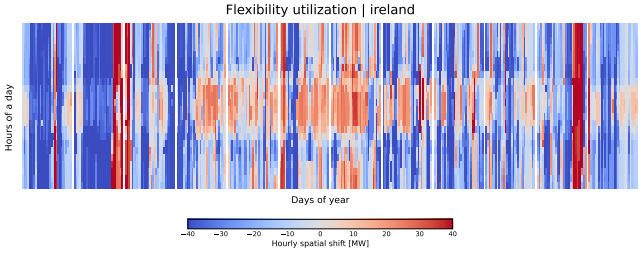


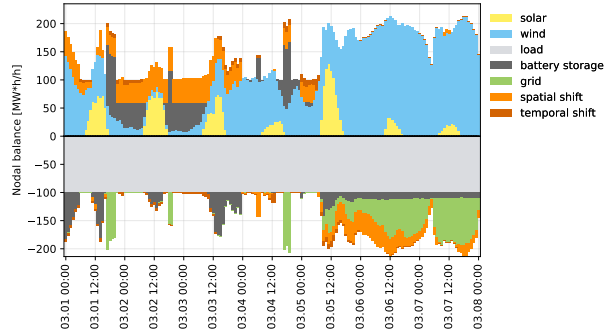
Figure: optimal procurement strategies to match 100 MW consumers with 24/7 CFE displayed per consumer location and share of flexible loads {0% .. 40%}

- The required portfolio capacity is **significantly reduced** when load shifting becomes possible.
- Demand flexibility facilitates the **efficiency and affordability** of 24/7 CFE matching. Costs are reduced up to 34%.
- Demand flexibility is **especially helpful for resource-constrained locations** where hourly matching with 24/7 CFE is difficult.

Scenario: 24/7 CFE 100% with 100% score, commercially available technologies, co-optimised spatial & temporal load shifts

Insights from time-series data for optimized space-time load shifts





- The hourly profiles of wind power generation have a **low correlation over long distances** due to different weather conditions.
- Spatial load flexibility enables the system to move load to **locations when and where there is high wind generation**, thus saving costs of energy storage and reducing curtailment of excess generation.
- Here is a simulated situation on 3-4 March, where the data centre in Ireland shifts loads on wind-calm days to other locations, and takes jobs from other locations when wind is abundant.

Selected data centers in IE
Scenario: 24/7 CFE 100% with 100% score, commercially available technologies, co-optimised spatial & temporal load shifts, 40% of flexible loads (40 MW)

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;
- **Signals** for optimal utilisation of spatial and temporal demand flexibility;
- Analysis of **net load migration** across locations;
- Simulated **energy balances** for individual consumers.

Take aways

Space-time load-shifting...

- ...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.

Let's do it!

Contacts, Resources, Acknowledgements

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

🔓 study: **zenodo.org/records/8185850**

🔓 code: **github.com/PyPSA/247-cfe**

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