

# Three Pillars of Hourly Matching: A Tour From Model Land to Real World

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## Setting the scene

- Voluntary 24/7 CFE procurement in electricity, Delegated act for H2 Regulation
- Both focus on the “Three Pillars” – set of rules on temporal, spatial and additionality aspects of matching demand and clean power supply
- Today we go through the **three pillars** and discuss:
  - how the pillars are implemented in the real world
  - how the pillars are implemented in mathematical models
  - caveats and challenges of model implementations
  - impact of model setups on results and policy recommendations

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# I Pillar: Temporal matching

**Discussion:** Implementing stricter regulations requires assessing the impact on hydrogen production costs.

**Hourly electricity matching is the only reliable way to reduce emissions from green hydrogen: study**

Annual correlation of additional renewable power can push green H<sub>2</sub> carbon intensity above that of blue hydrogen made with abated fossil gas, say German researchers

**Proposed stringent EU rules on green hydrogen 'would put the brakes on development'**

New plans on 'additionality' and strict hour-by-hour coupling of wind and solar output to electrolyzers would increase the price of renewable H<sub>2</sub>, says RWE



Publication: 13 October 2022 • 06:45

Sustainaweekly - Not-so-green hydrogen perhaps a necessary evil

Sustainability Energy transition



**'Far from perfect' | Strict rules in new delegated act will 'make green H<sub>2</sub> projects more expensive': Hydrogen Europe**

Announcement is nevertheless welcomed by industry as it will enable companies to 'finalise investment decisions and business models'

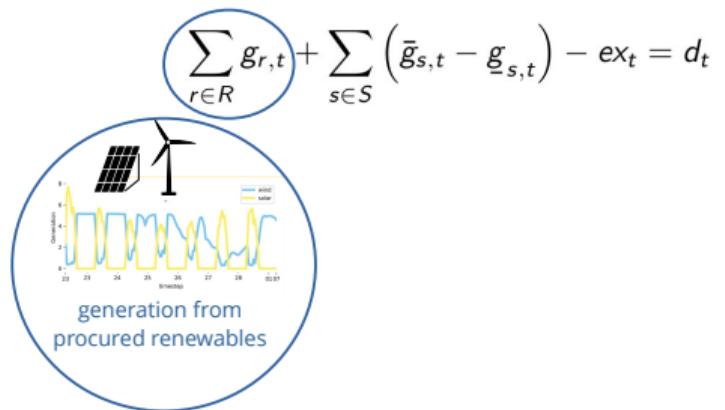
## Temporal matching: definition

**Hourly matching** is modelled with a constraint, which matches electricity demand for electrolysis process with generation of renewable resources on an hourly basis.

$$\sum_{r \in R} g_{r,t} + \sum_{s \in S} (\bar{g}_{s,t} - \underline{g}_{s,t}) - ex_t = d_t$$

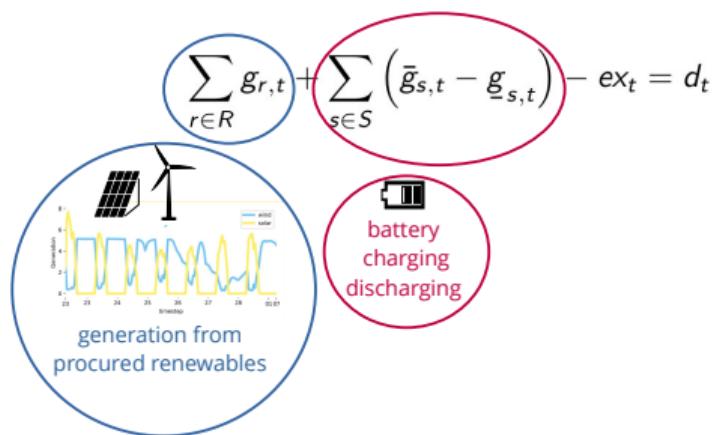
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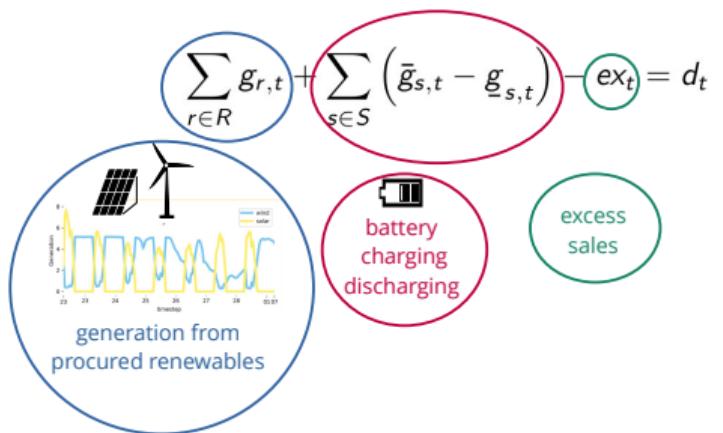
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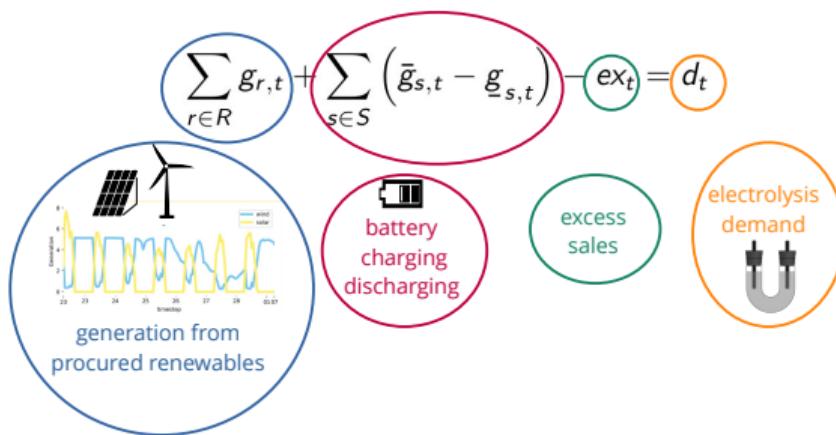
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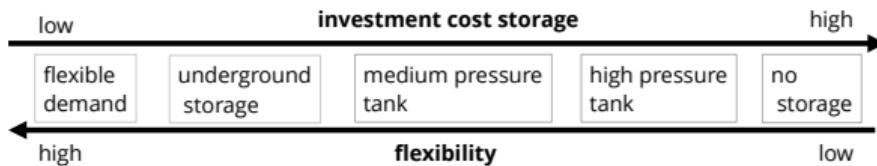


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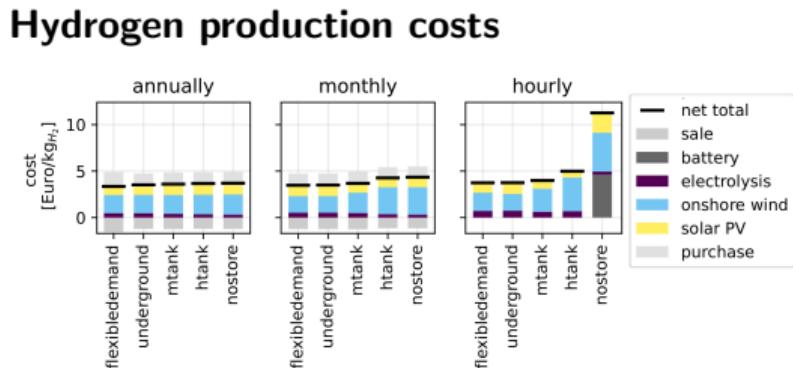
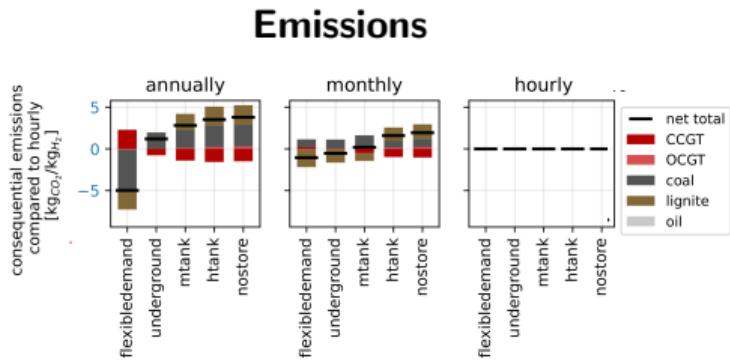
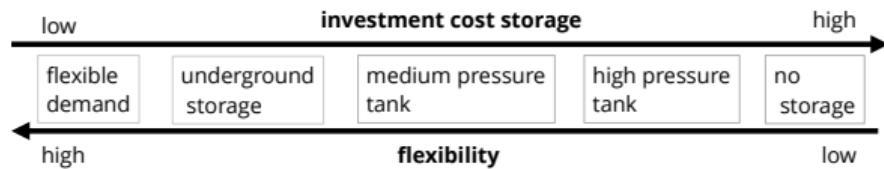
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# Temporal matching: flexibility changes everything



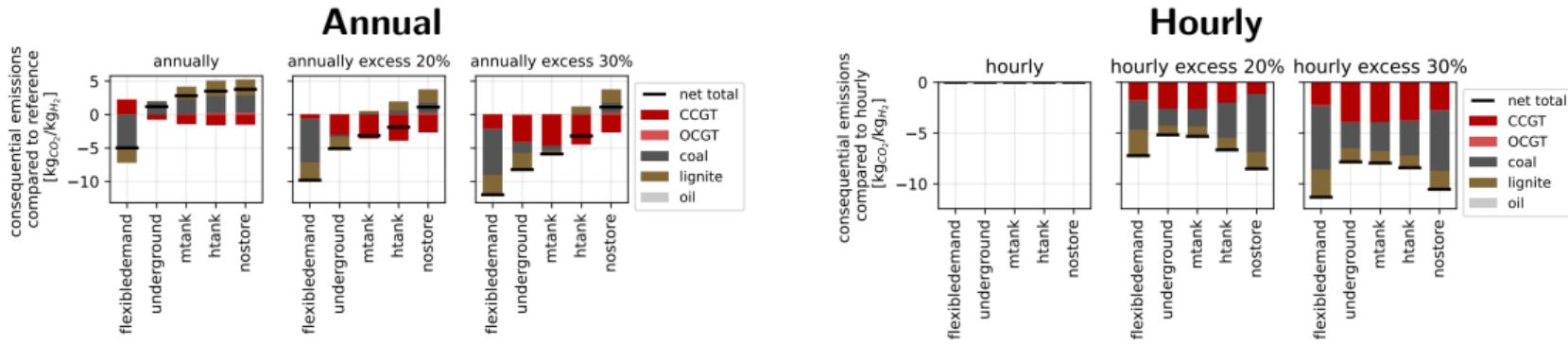
## Temporal matching: flexibility changes everything



Flexibility **reduces** emissions and costs.

# Temporal matching: higher excess sales reduce emissions and costs

The **costs of hydrogen production decrease** by up to 30% in case of flexible demand + hourly matching due to the larger profits from excess sales.



## Temporal matching: (CFE story)

Here, the **hourly matching** constraint is extended to include electricity consumption from the regional grid:

$$\sum_{r \in CFE, t \in T} g_{r,t} + \sum_{s \in STO, t \in T} (\bar{g}_{s,t} - \underline{g}_{s,t}) - \sum_{t \in T} ex_t + \sum_{t \in T} CFE_t \cdot im_t \geq x \cdot \sum_{t \in T} d_t \quad (1)$$

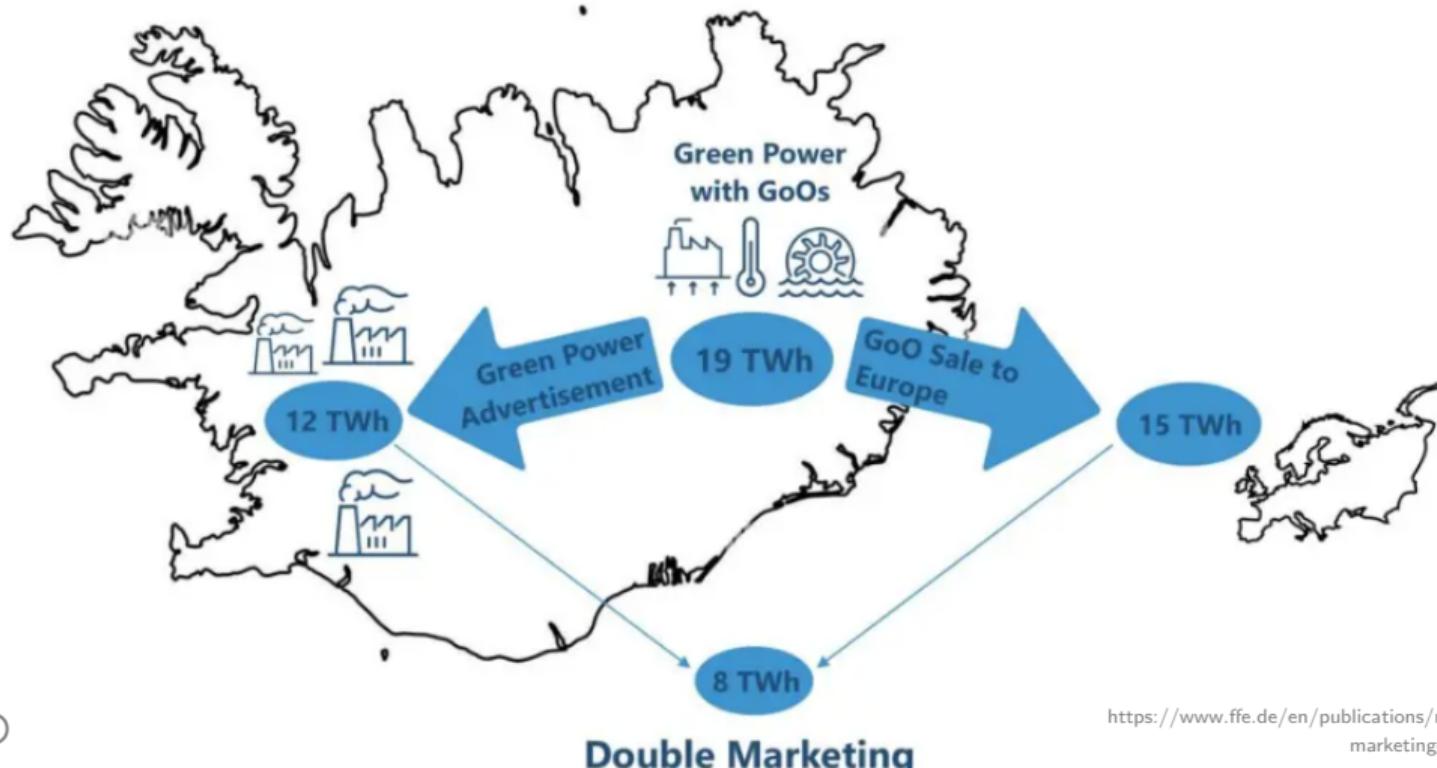
The **grid CFE factor**  $CFE_t$  in eq. (1) defines the share of carbon-free electricity in grid imports.

- depends how you scope out CFE calculation
- storage tracing
- CFE isn't a parameter but a variable

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## II Pillar - Geographical matching

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## Geographical matching

# Microsoft signs 24/7 nuclear power deal with Constellation for Boydton data center

Matched carbon-free energy brings facility close to round-the clock carbon-free energy

June 30, 2023 By: Peter Judge 1 Comment



Microsoft has signed an agreement with nuclear power producer Constellation Energy, to bring a data center in Boydton Virginia closer to operating on 100 percent carbon-free energy round the clock.

The Boydton facility will receive up to 35 percent in "environmental attributes" based on Constellation's nuclear power production, which will complement Microsoft's recent wind and solar energy purchases to put the data center very close to 100 percent carbon-free electricity 24/7.

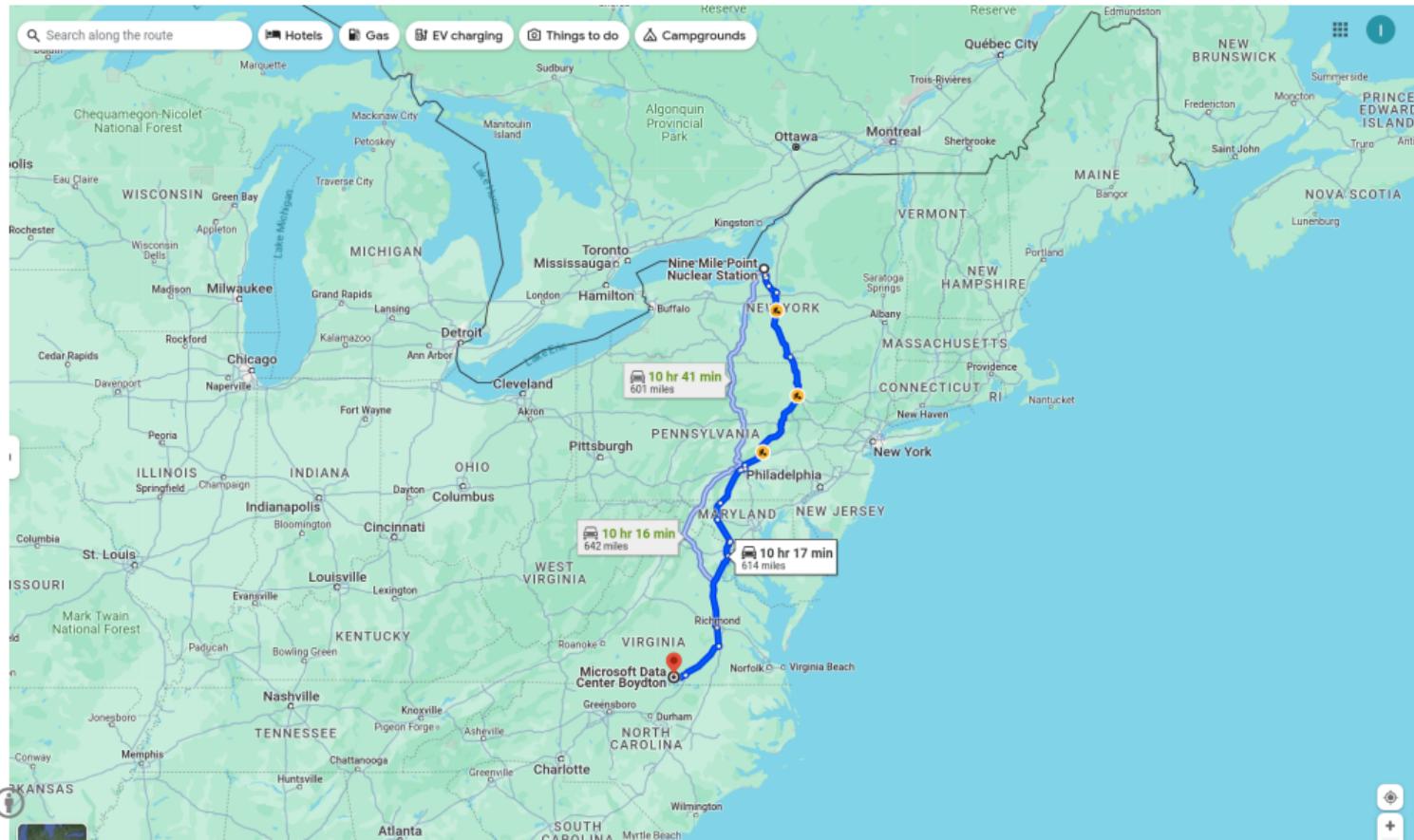


Constellation is the largest provider of carbon-free energy (CFE) in the US, with 86 percent of its output coming from the 15 nuclear power stations it owns across the US.

None of these nuclear plants are in Virginia, but the company uses a CFE matching platform to

datacenterdynamics "Microsoft signs 24/7 nuclear power deal with Constellation for Boydton data center" (June 30, 2023)

# Geographical matching



## Geographical matching for green hydrogen production



How far can renewable generation and electrolysis be apart?

- Regulation in the EU: Geographical matching within one **bidding zone**.
- Model implementation is straightforward.

**Challenges:** Especially in large bidding zones there can be **transmission bottlenecks** actually hindering the transport of renewable generation to the electrolysis.

## III Pillar - Additionality

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- start with the fact that it's complex and messy both in real world and in models
- define it (over MW and MWh)
- as a funny reference, we can re-use the Microsoft PPA deal example with existing nuclear power.

## Additionality: definition challenges

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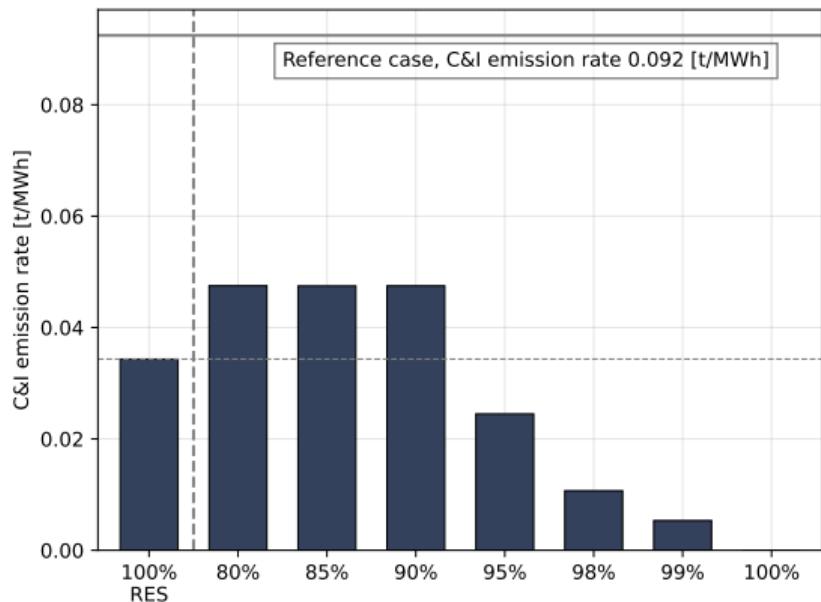
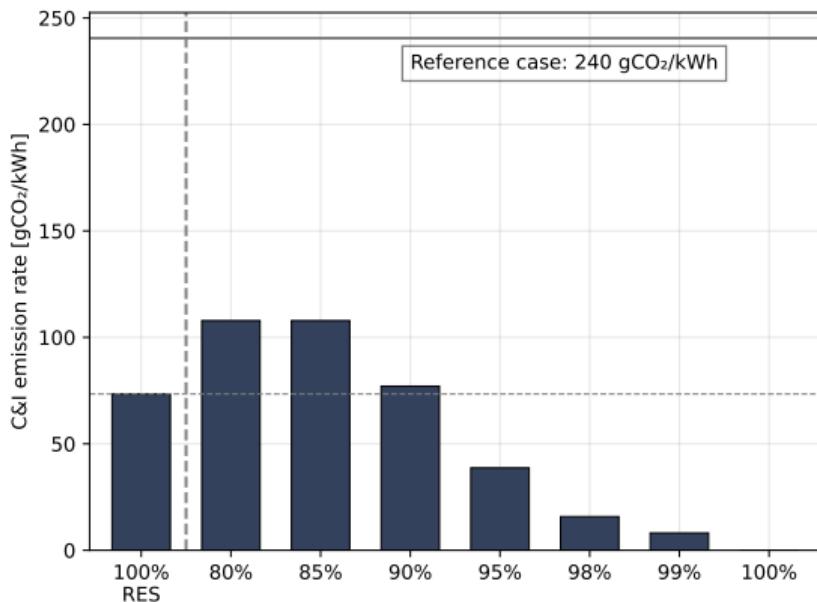
Different definitions:

- **Google:**
- **Delegated Act:** Hydrogen producer need to conclude power purchase agreement (PPA)s with new and unsupported renewable generation capacities.

**Challenge:** Hard to define if renewables are truly additional or would have been built in any case to reach national renewable generation targets.

## Additionality: how to model a background grid 1/2?

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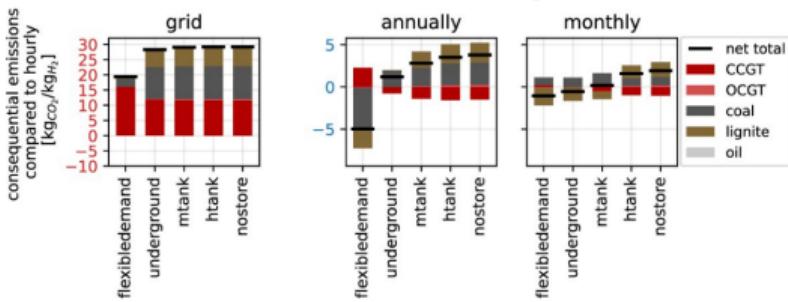


Scenario: Germany – 2025 – 24/7 CFE with 10% participation of C&I sector – baseload profile – all costs from DEA 2025. Left: Constrained RES expansion (the Easter Package), Right: Unconstrained RES expansion.

# Additionality: how we model a background grid 2/2?

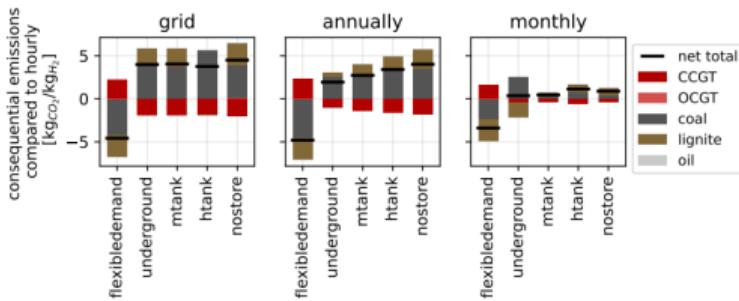
## Two step optimisation

Clear additionality



## One step optimisation

RES compete for good resources



There are many studies who analysed the impact on how additionality is modelled in more detail, e.g. Giovanello et al. (2024, Nature Energy), Langer et al. (2024).

## Take aways

- 1 Do not take results for granted, try to challenge everything!  
“We must fight our biases to see the solutions” (Auke Hoekstra)
  
- 2 Talk to others in research community, share your concerns!  
“A problem shared is a problem halved”  
(Old saying)



## 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](https://github.com/PyPSA/247-cfe)

👉 code: <https://zenodo.org/records/8324521>

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