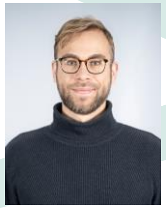
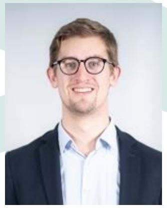
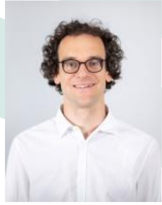
YEARS DIW BERLIN

Strommarkttreffen „Speicher“

# Coping with the Dunkelflaute: Power system implications of variable renewable energy droughts in Europe

Martin Kittel, Alexander Roth, Wolf-Peter Schill
Berlin, 21.03.2025

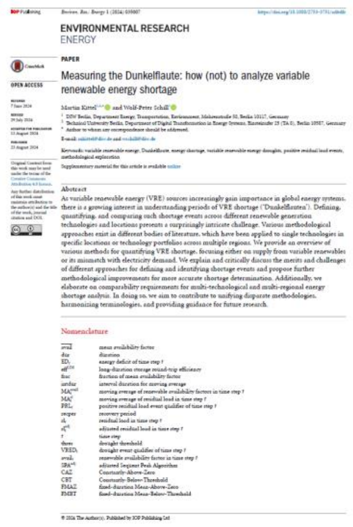
  

EINSTEIN Foundation.de

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

KOPERNIKUS PROJEKTE
Ariadne
Die Zukunft unserer Energie

# Recent research on *Dunkelflaute* and long-duration storage at DIW Berlin


ENVIRONMENTAL RESEARCH
ENERGY

Measuring the Dunkelflaute: how (not) to analyze variable renewable energy shortage

Martin Kittel and Wolf-Peter Schill

## Kittel, Schill 2024 *Environ. Res.: Energy*

- Focus on methods for defining and measuring renewable energy shortage
- Literature review and terminology


Quantifying the Dunkelflaute: An analysis of variable renewable energy droughts in Europe

Martin Kittel, Wolf-Peter Schill

## Kittel, Schill 2024 *arXiv:2410.00244*

- Focus on renewable time series analysis, using multiple thresholds
- Quantification of portfolio and balancing effects
- EU, 38 weather years


Coping with the Dunkelflaute: Power system implications of variable renewable energy droughts in Europe

Martin Kittel, Alexander Roth, Wolf-Peter Schill

## Kittel, Roth, Schill 2024 *arXiv:2411.17683*

- Focus on long-duration electricity storage needs for *Dunkelflaute*
- Power sector model DIETERpy
- EU, 36 weather years

## Schmidt, Roth, Schill *work in progress*

- Focus on effects of electric heating on long-duration storage and heat storage
- Power sector model DIETERjl
- EU, 78 weather years

# Research questions

- What is the impact of **variable renewable energy droughts** on **long-duration storage (LDS) needs** in a fully renewable European energy system?

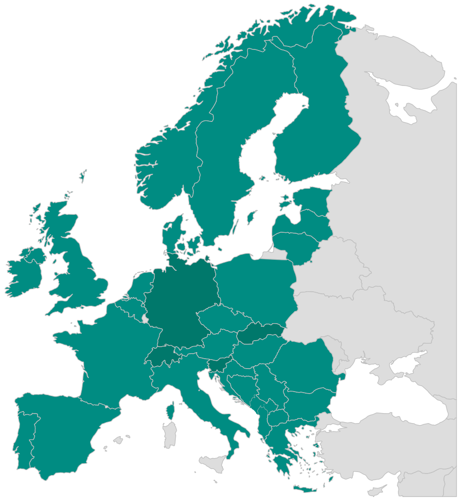
- To what extent can **cross-border exchange** mitigate storage needs?

- Which **weather years are appropriate** for modeling weather-resilient scenarios?

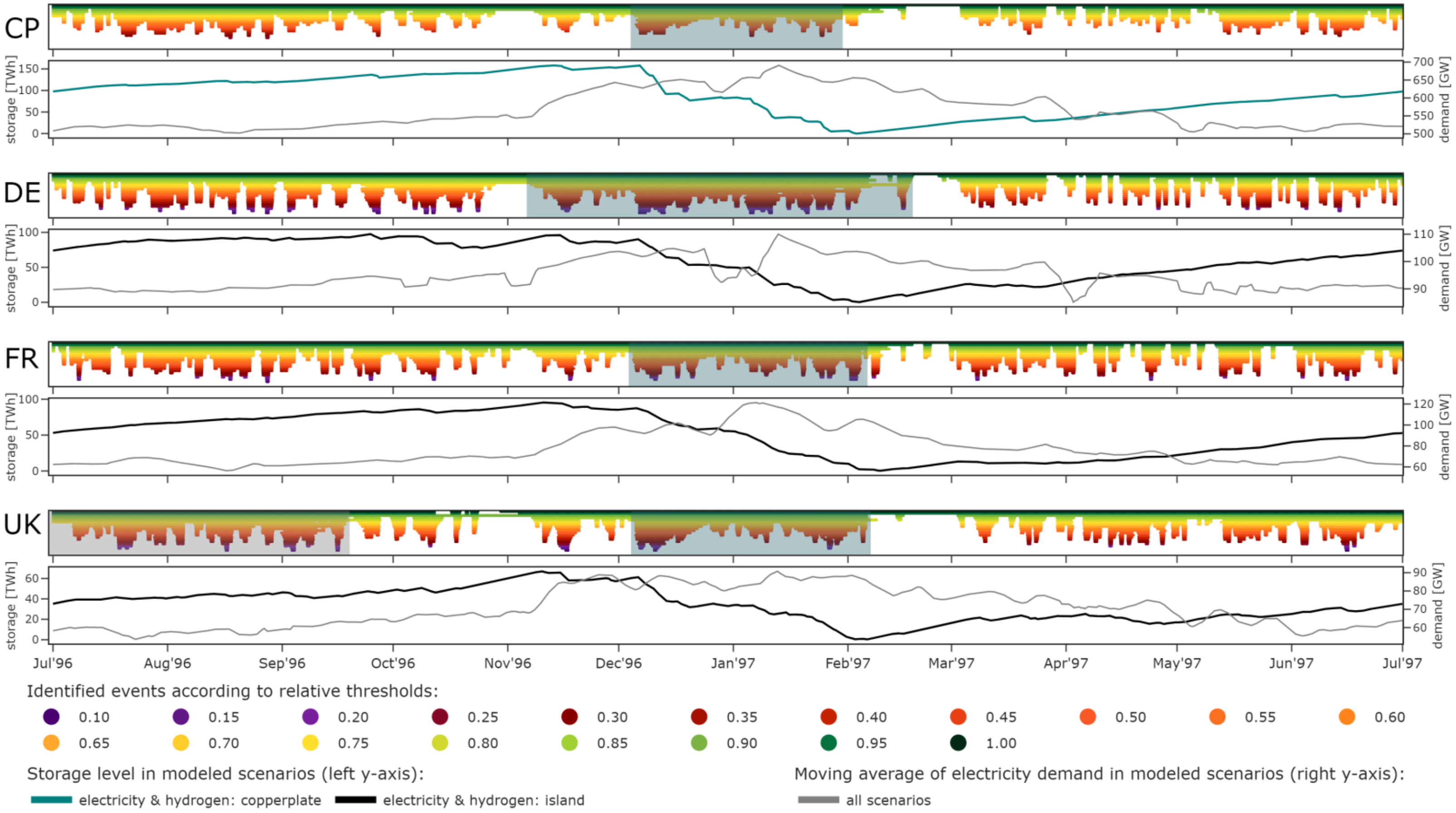
# Methods and data

- We combine two methods
  - Analysis of renewable availability time series VREDA
  - Capacity expansion model of the power sector DIETERpy

- Input data
  - 33 European countries
  - 36 weather years (1982-2016)
  - Pan-European Climate Database
  - Renewable capacity (bounds) from TYNDP 2022 / 2024
  - Scaled demand profiles from ERAA 2021



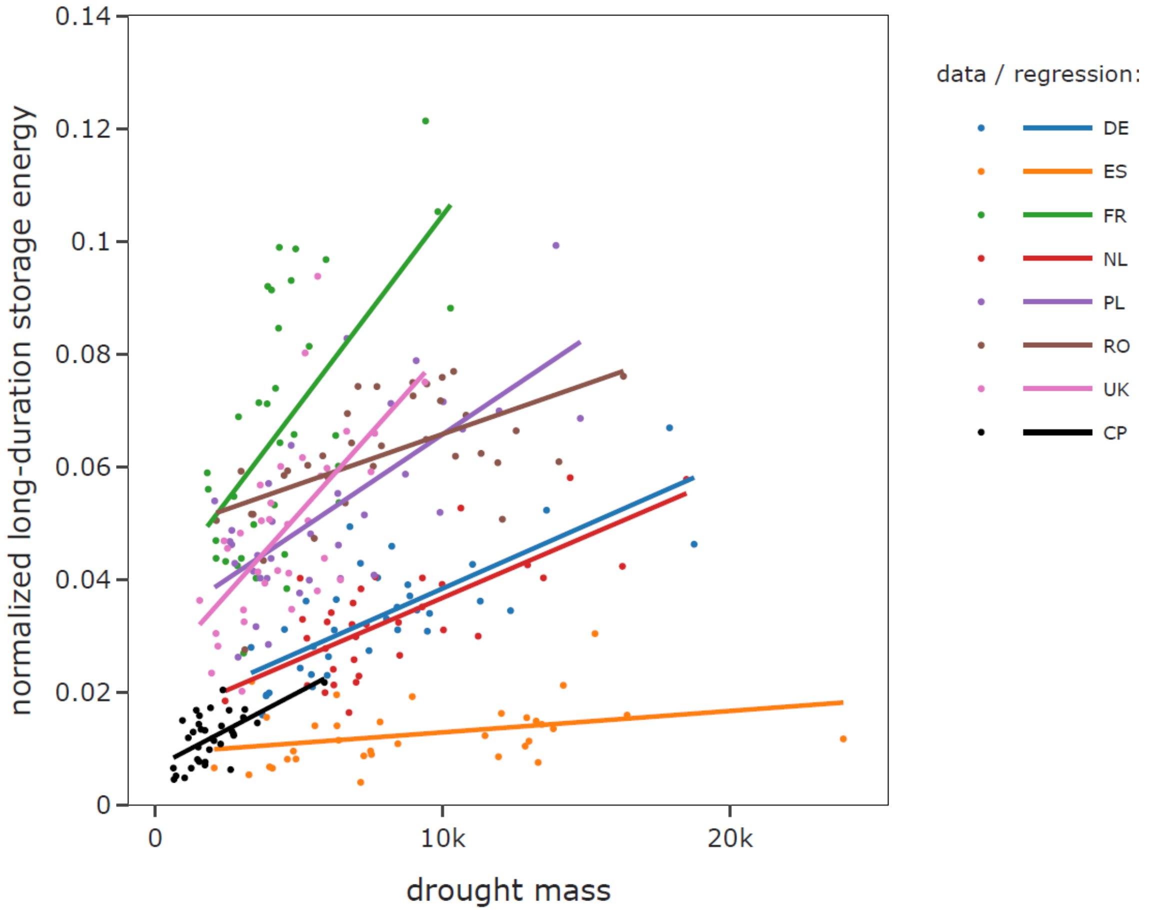
# Results: Bringing both methods together




→ Extreme events: series of contiguous shorter droughts

→ Maximum (winter) drought mass coincides with storage discharging period

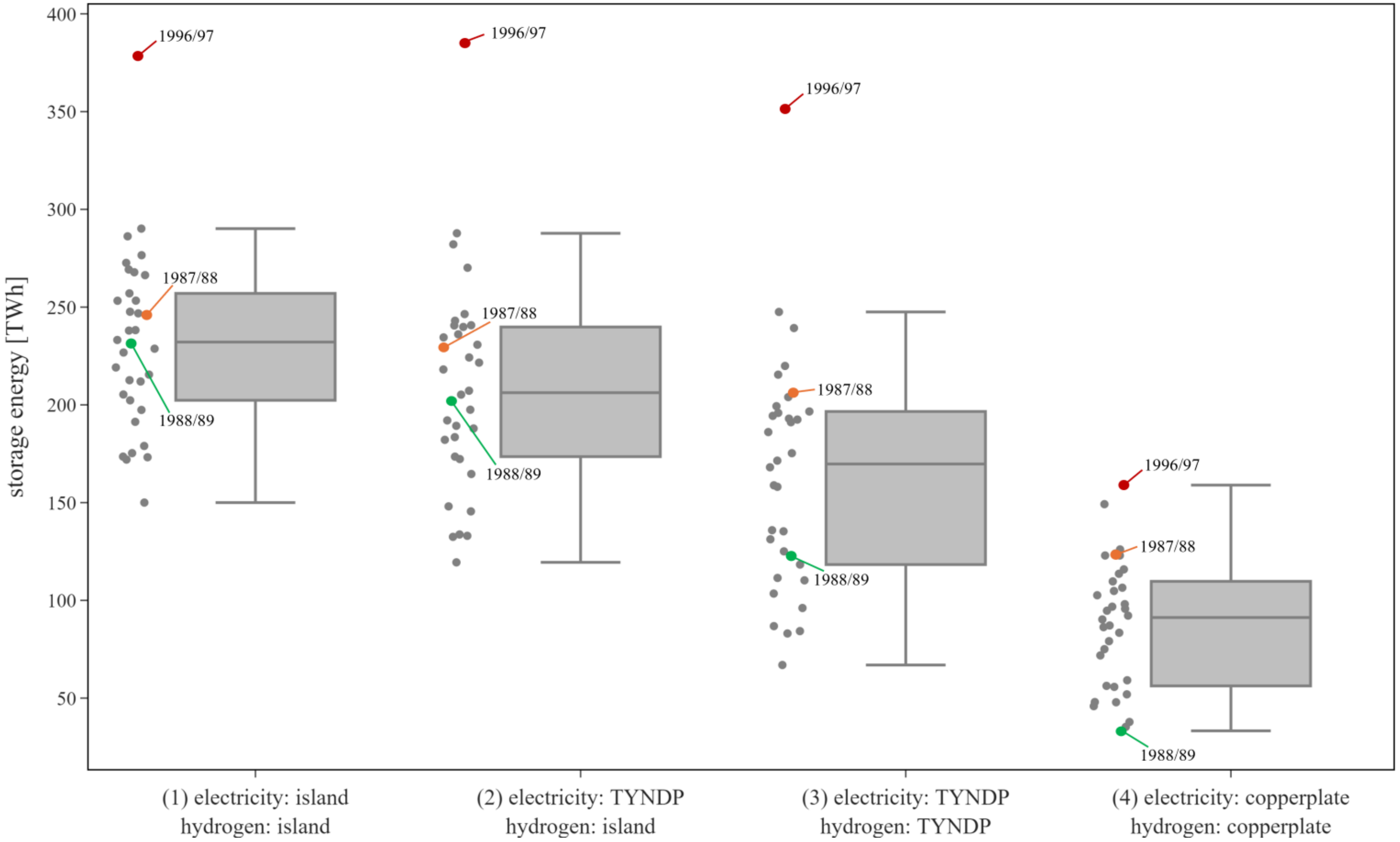
# Results: Correlation of drought mass and (normalized) storage energy




→ Positive correlation, but country differences

→ EU copperplate: less severe droughts, lower storage needs

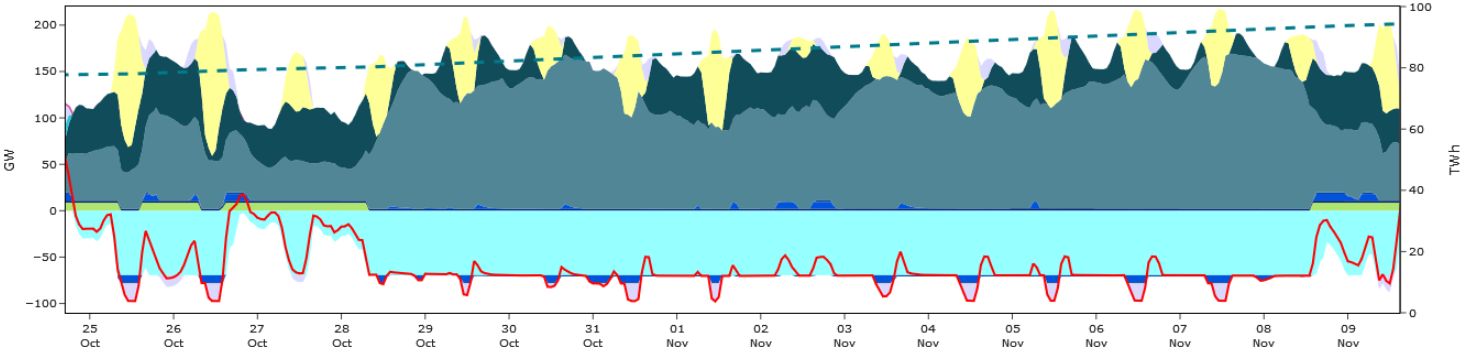
# Results: Geographical balancing mitigates storage needs



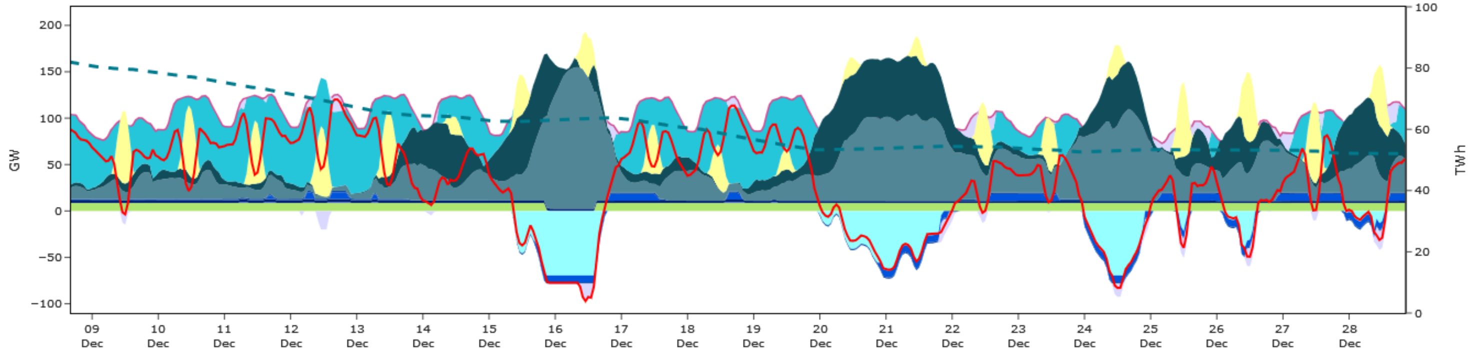

→ Variation between weather years, 1996/97 most extreme

→ Perfect interconnection substantially mitigates storage needs

# Results: Complex interactions between short- and long-duration storage

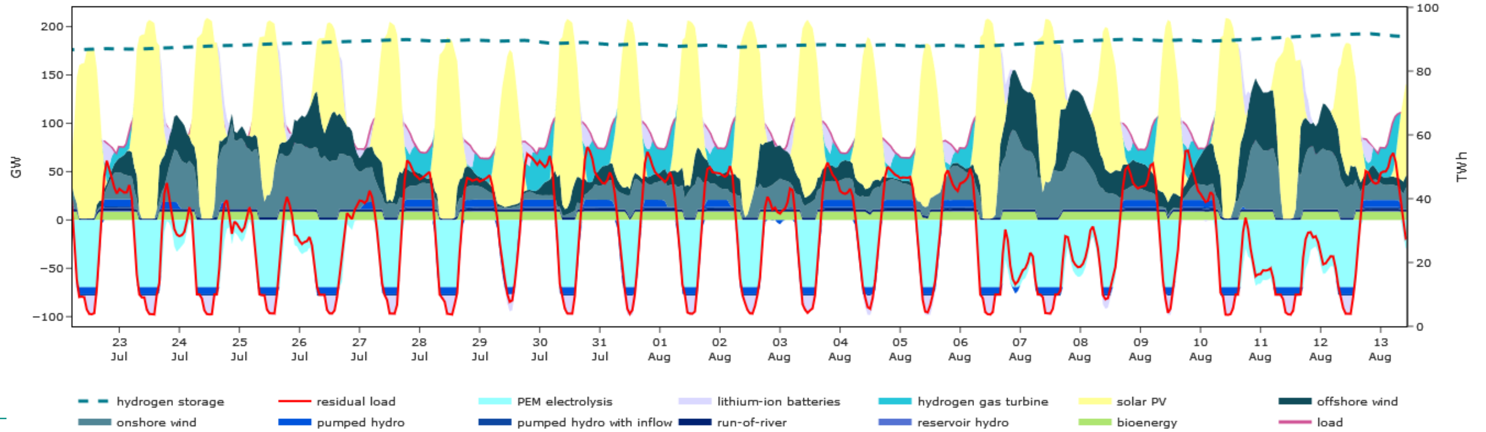



→ Other flex options sometimes discharge while LDS is charging




→ Batteries sometimes charge during LDS discharging

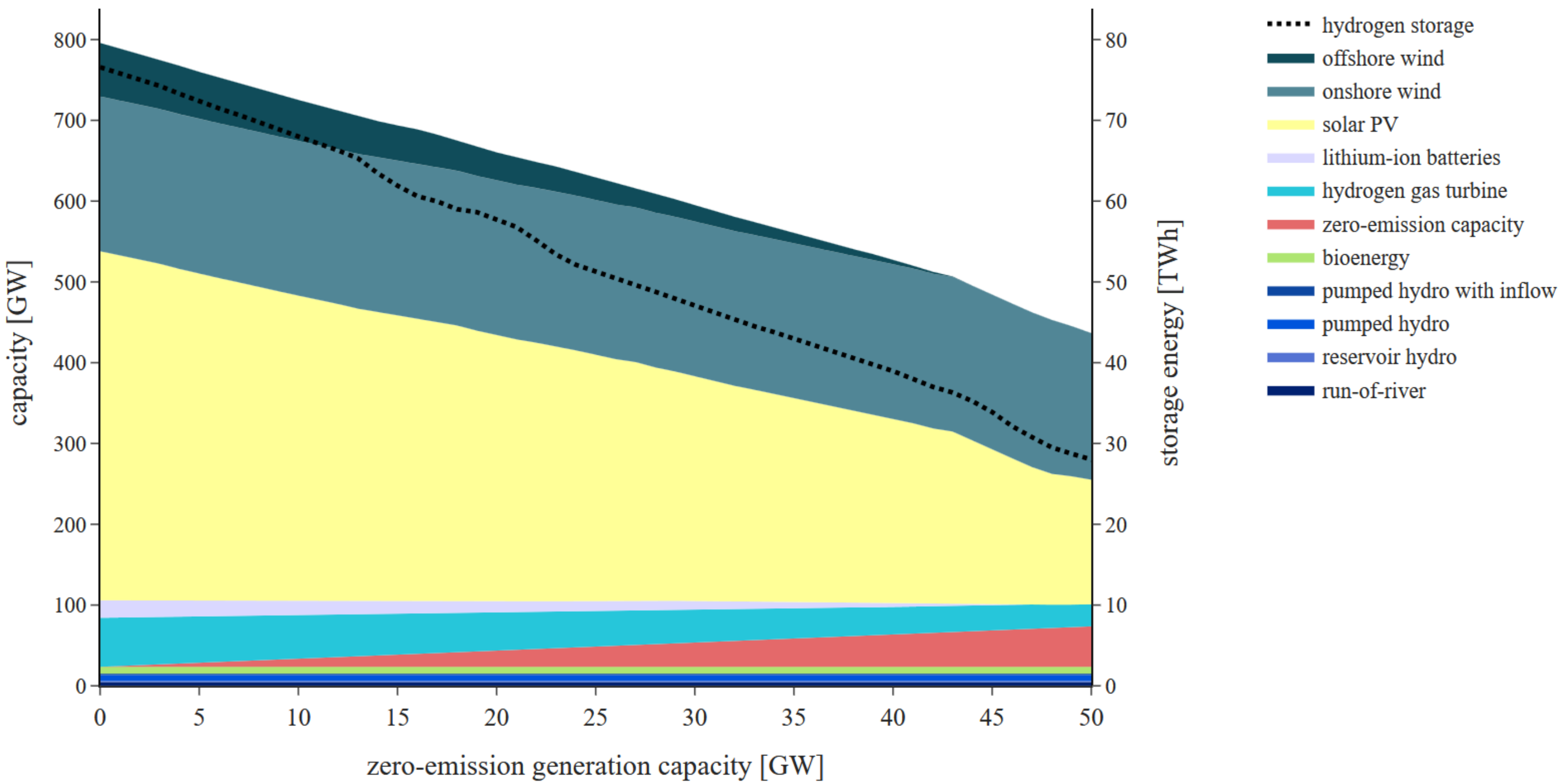
→ LDS also used for diurnal cycling in summer





DIW BERLIN

# Sensitivities: storage mitigation by nuclear or other firm low-carbon tech




→ Moderate levels of nuclear power mildly mitigate LDS needs

→ As long as VRE are present, LDS is needed

## Summary and conclusions

- **Key results**
  - Extreme VRE droughts drive LDS
  - (Perfect) interconnection substantially reduces LDS needs
    - Here: 159 TWh as EU-wide „non-regret“ storage size (3% of yearly load)
    - Today: > 200 TWh gas storage in Germany alone
  - Nuclear power mitigates LDS, but to limited extent
- **Policy implications**
  - Long lead times for new projects → start early
  - Full capacity rarely utilized → support mechamisms likely required
- **Modeling implications**
  - Choice of weather year super important for system planning
  - Summer-to-summer or multi-annual time horizon required for LDS models

Folgen #27-#29 des DIW-Energiewendepodcasts fossilfrei zum Thema Speicher:
https://www.diw.de/fossilfrei

Neuer Ariadne-Explainer zur Rolle von Speichern in der Energiewende:
https://doi.org/10.48485/pik.2025.004


## Thanks for your attention.


**DIW Berlin — German Institute for Economic Research**
Mohrenstraße 58, 10117 Berlin
www.diw.de/en

**Redaktion**
Wolf-Peter Schill | https://wolfpeterschill.de | wschill@diw.de | @wpschill@social.tchncs.de | @wpschill.bsky.social


www.diw.de/100jahre