DIW BERLIN

7th International Conference on Energy & Meteorology

Variable renewable energy droughts and the power sector

A model-based analysis and implications in the European context

Martin Kittel, Alexander Roth, Wolf-Peter Schill

Padova, 27 June 2023

icem 2023

KOPERNIKUS PROJEKTE
Ariadne
Die Zukunft unserer Energie

EINSTEIN Foundation.de
Einstein Stiftung Berlin
Einstein Foundation Berlin

Agenda

1. Motivation & research question
2. Methods
3. Results (preliminary)
4. Conclusion & outlook

Decarbonization of the power sector

- „We commit to achieving a fully or predominantly decarbonised power sector by 2035." (G7 Leaders' Communique, Elmau, 2022)
- EU's climate-neutrality by latest 2050 (Regulation (EU) 2021/1119)
- Variable renewable energy (VRE) as principle source

Security of supply in a renewable power sector

- Weather dependence of VRE → interannual variability & VRE droughts
- System flexibility: long-duration storage and interconnection

1.2 Research questions

1. What is the impact of **interannual variability** and **variable renewable energy droughts** on a fully renewable European power sector?
   - Long-duration storage: investment & operation
   - Value of cross-country electricity exchange

2. Implications for energy system modeling?
   - Identification of critical historical weather years
   - Calendric vs. academic time horizon resolution

Methods: DIETERpy

Open-source tool, used in various previous publications

- Cost-minimizing, linear dispatch and investment partial equilibrium model
- Multiregional setting with simplified grid representation ("copper plate")

Input

Techno-economic parameters
- Renewable generators
- Storage
- Hydrogen + reconversion

Hourly time-series on country level
- RES availability
- Electricity & hydrogen demand

Transfer capacities

→

Model

Total system cost → MIN
- Annualized investment costs
- Fixed & variable costs

Subject to
- Minimum RES share
- System flexibility through interconnection and long-duration storage

→

Output

Investment decisions (capacity)
- Generation
- Storage

Hourly operation (energy)
- Generation & electrolysis dispatch
- Storages operation

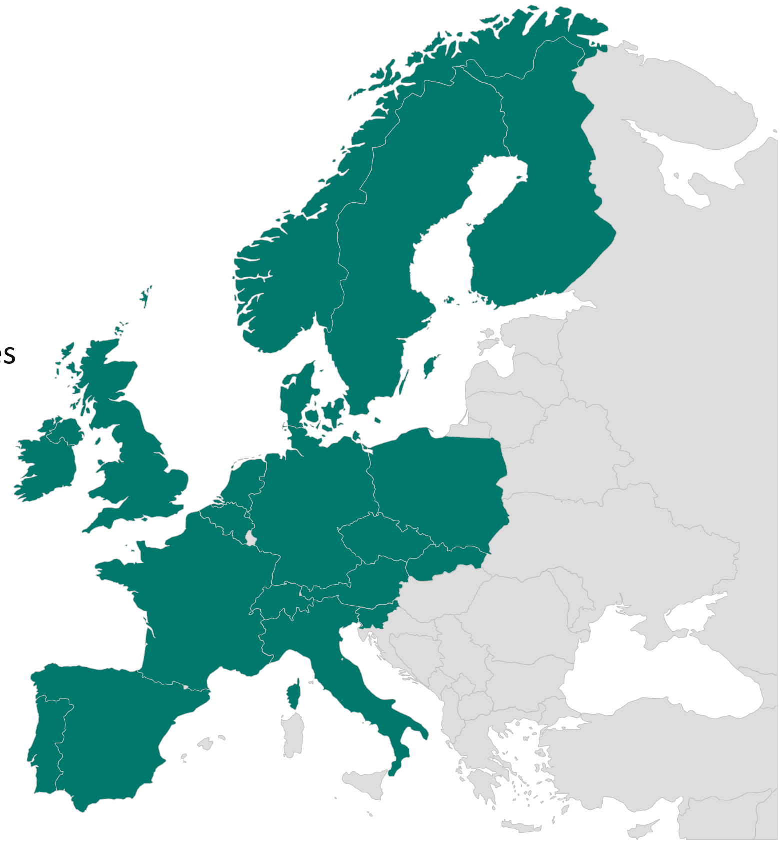
Power flows

2.2

Scenario assumptions

100% renewable European power sector

- 18 European countries
- No fossil fuels or nuclear power (for now)
- NTC from TYNDP 2022, Distributed Energy scenario
- Fixed hydrogen demand (DE 96 TWh, other countries scaled)



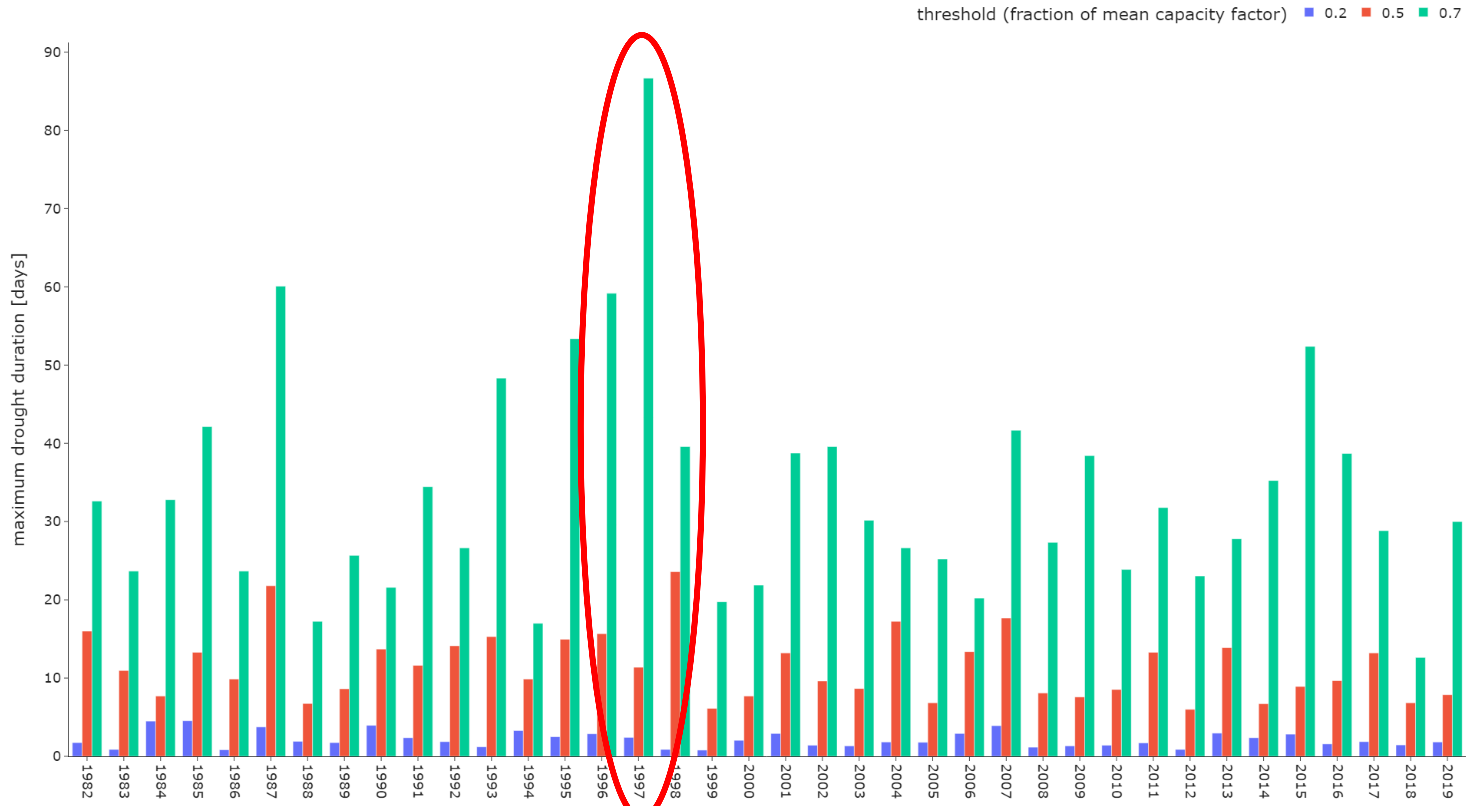
Spatial scope

- 20 weather years: 1990-2010 (for now)

Yearly time horizon

- Academic: July – June → in line with time series analysis
- Calendric: January – December

3.1 VRE droughts in Germany: most extreme period duration across years

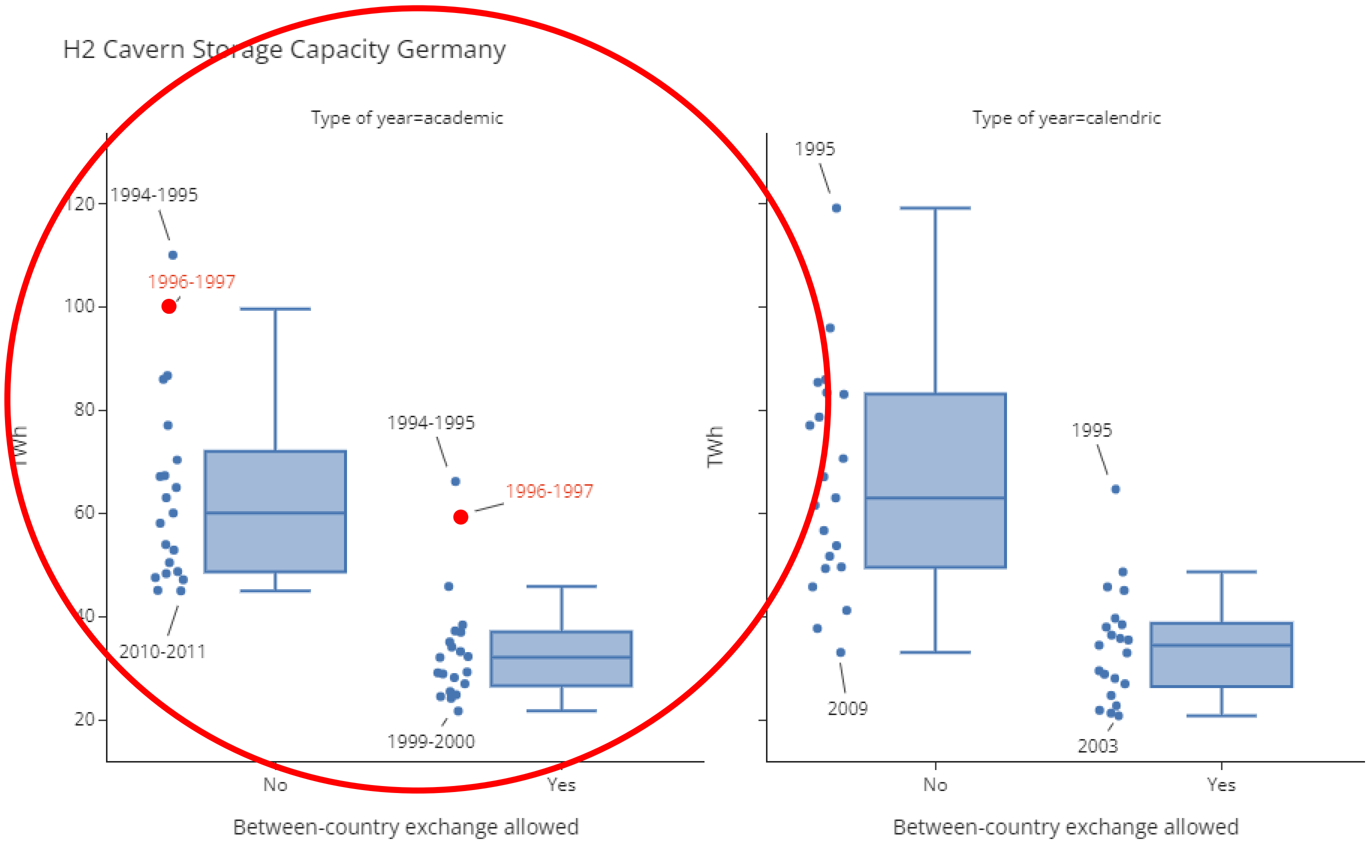


(source: see previous presentation)

- Explorative approach: focus on VRE portfolio extreme year 1997 → implication on power sector?

Power sector model results: Germany

Preliminary results



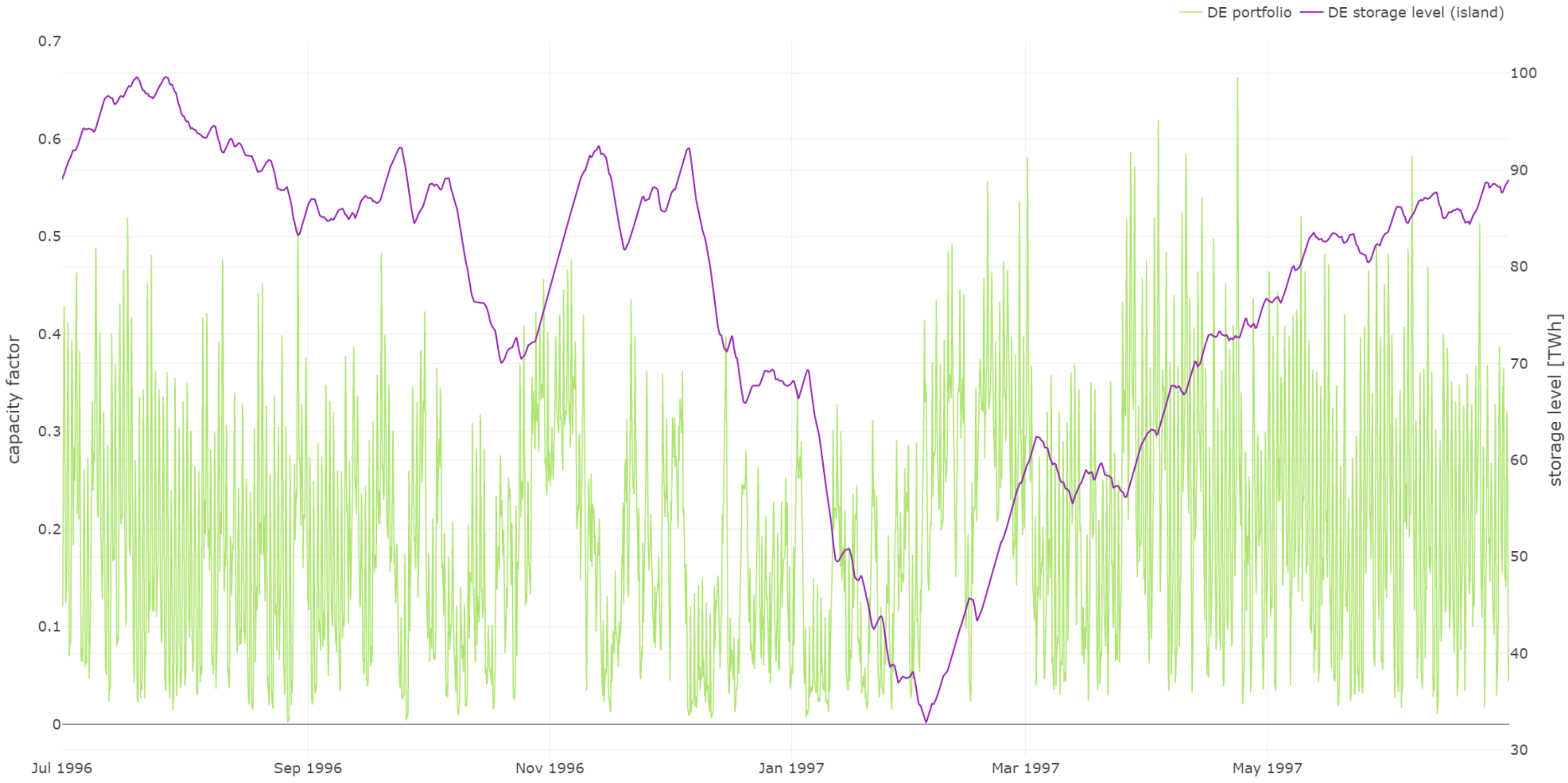
100% renewable power sector

- Academic time horizon: 1994-95 highest storage need (VRE droughts in many countries)
- Calendric time horizon: 1995 highest storage need

Preliminary results

100% renewable power sector (academic time horizon)

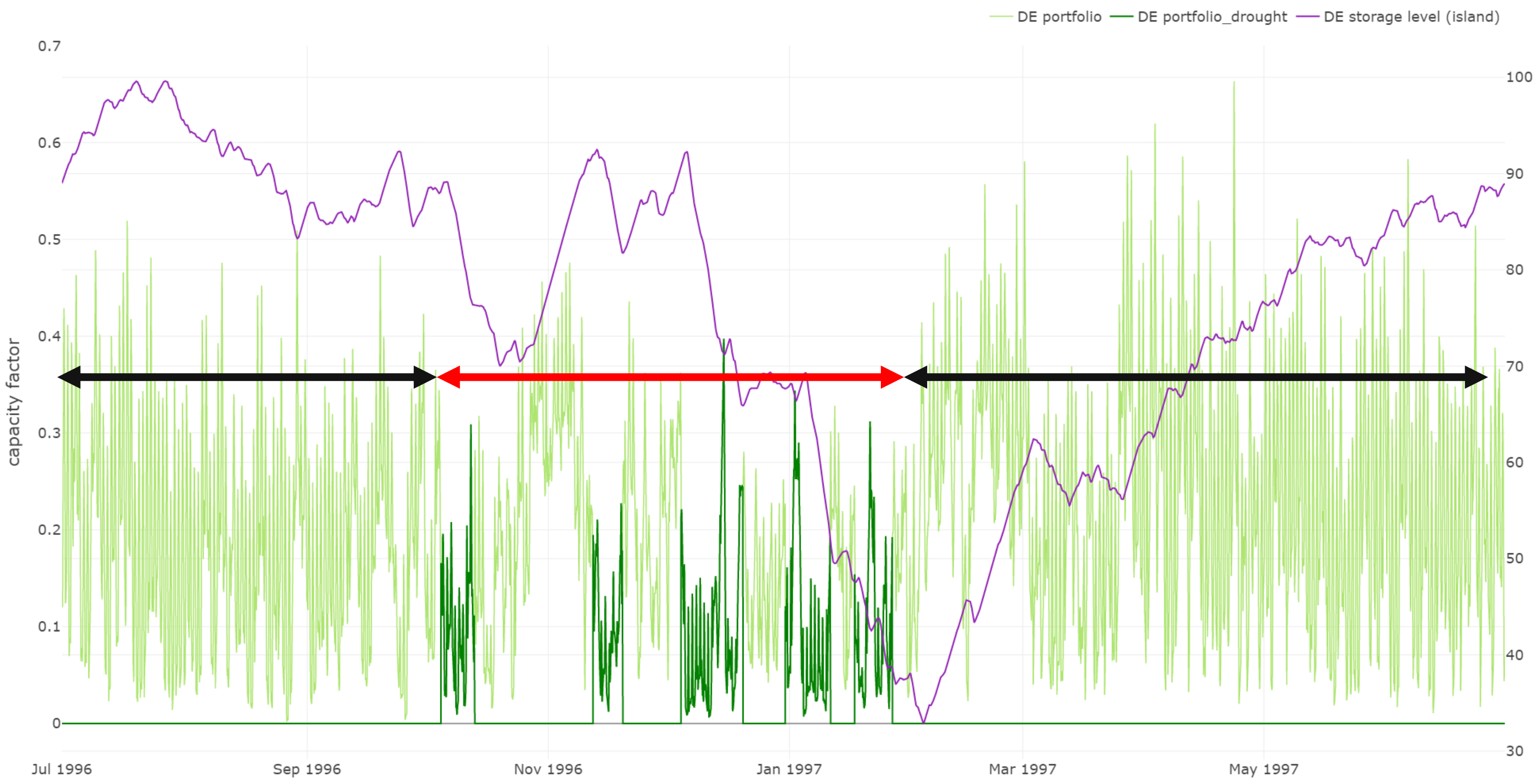
- storage discharged during winter



Preliminary results

100% renewable power sector (academic time horizon)

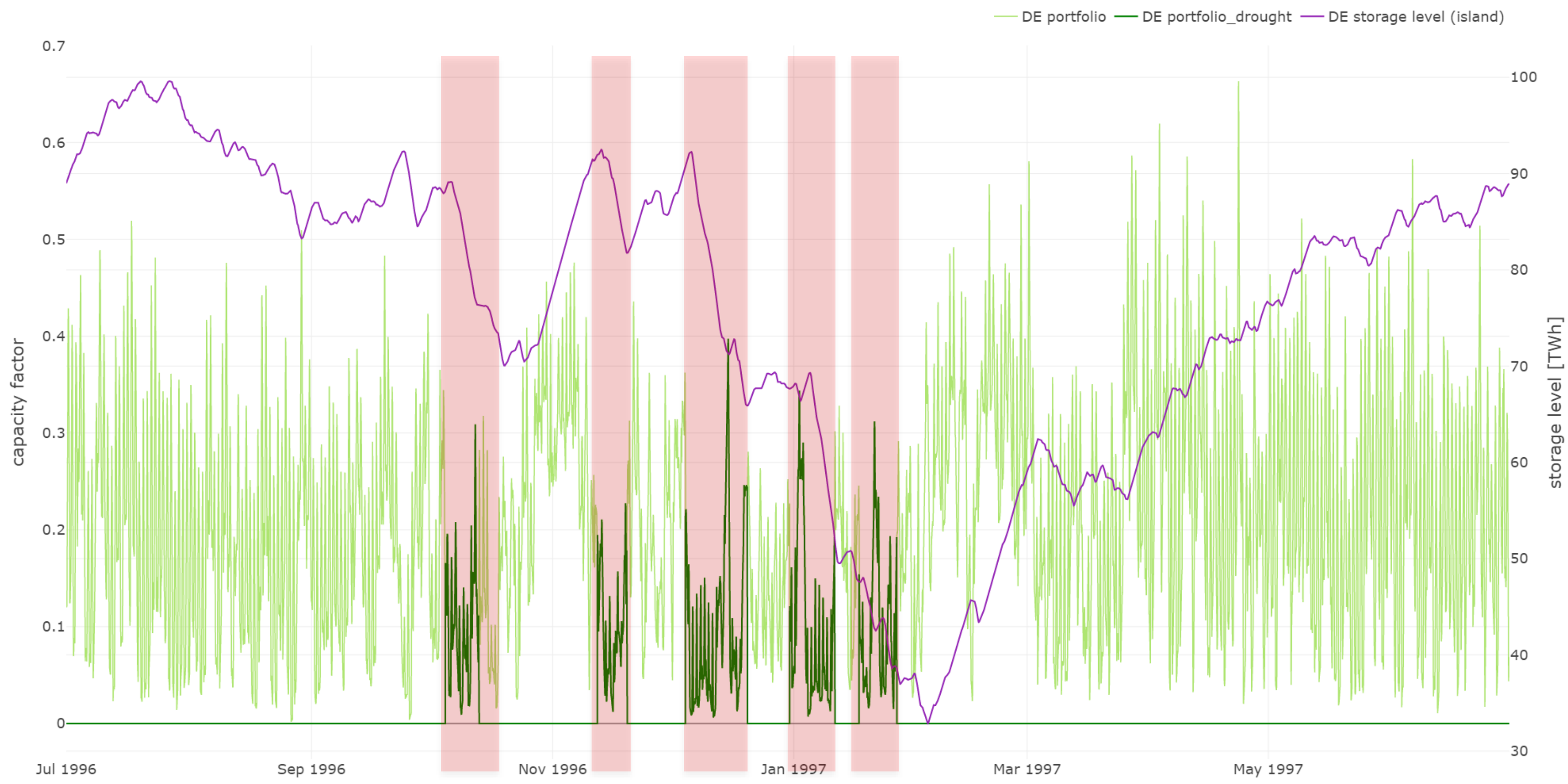
- Drought threshold: 0.5 fraction of mean capacity factor, droughts longer than one week



Preliminary results

100% renewable power sector (academic time horizon)

- Drought threshold: 0.5 fraction of mean capacity factor, droughts longer than one week

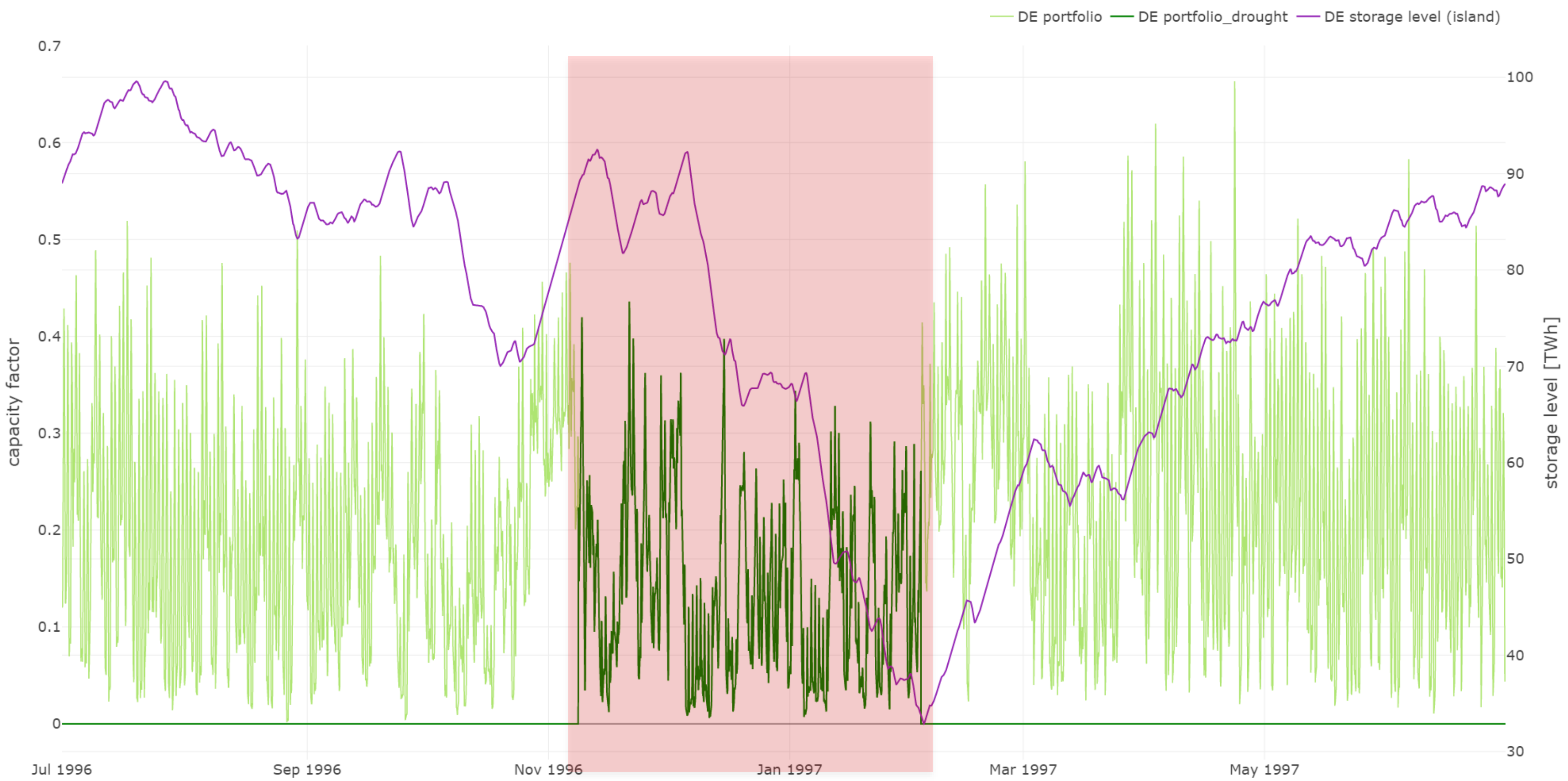


Power sector model results: Germany (island)

Preliminary results

100% renewable power sector (academic time horizon)

- Drought threshold: 0.7 fraction of mean capacity factor → optimal threshold for system resilience



100% renewable power sector (academic time horizon)

- Interconnection reduces impact of VRE droughts (i.e., storage investment)

Power sector model results: all countries

Preliminary results

H2 Cavern Storage Capacity Aggregated

100% renewable power sector

- Academic time horizon: 1996-97 highest storage need (driven by VRE drought in Germany)
- Calendric time horizon: 1995 highest storage need

Conclusion

European power sector

- Large variation across weather years → VRE droughts have system resilience implications
- VRE droughts drive long-duration storage investment & operation
- Interconnection reduces impact of VRE droughts

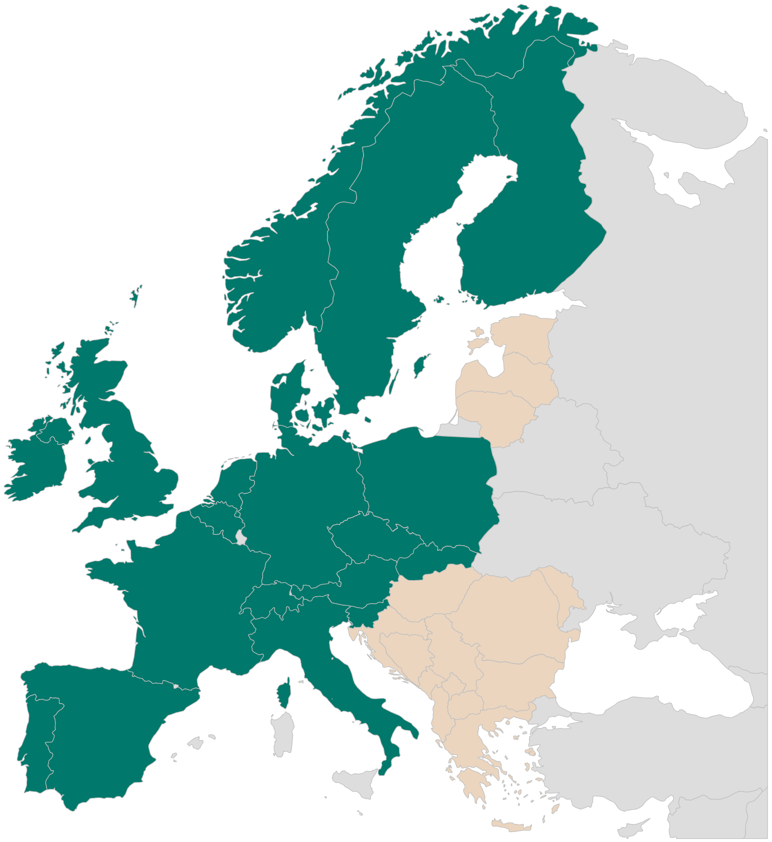
Energy modeling implication

- Time horizon: variation across academic and calendric resolution
- “Worst” and “best” year varies:
  - Spatial scope (EU / DE)
  - Time scope (calendar vs „academic“ year)

Outlook

Future analysis

- Extension spatial scope to all of Europe
- Deep-dive “best” and “worst” years
- Robustness checks
  - Capacity expansion limits
  - Interconnections
  - Level of sector coupling



Method enhancement

- Extension academic time horizon to two years
- Prohibition of unintended energy losses in system

Thank you for your attention!

DIW Berlin — German Institute
For Economic Research e.V.
Mohrenstraße 58, 10117 Berlin
www.diw.de

Martin Kittel
mkittel@diw.de