

7th International Conference on Energy & Meteorology

Variable renewable energy droughts and the power sector

A model-based analysis and implications in the European
context

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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

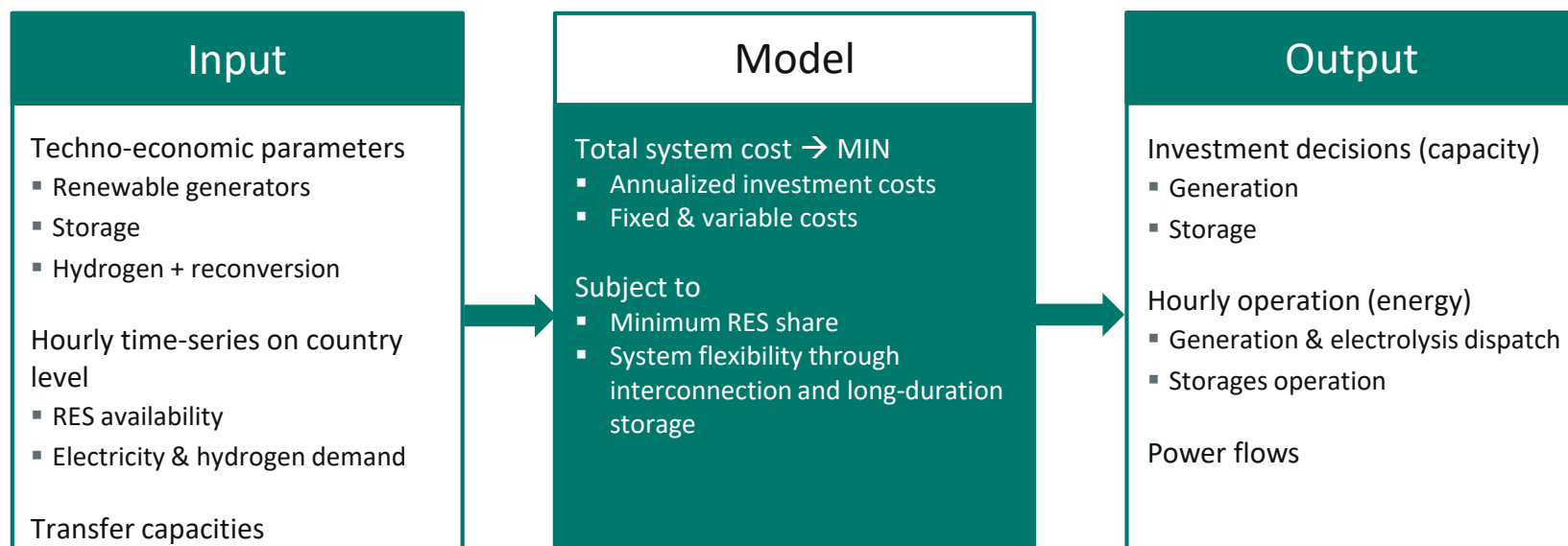
- Weather dependence of VRE → interannual variability & VRE droughts
- System flexibility: long-duration storage and interconnection

1. 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

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”)



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)

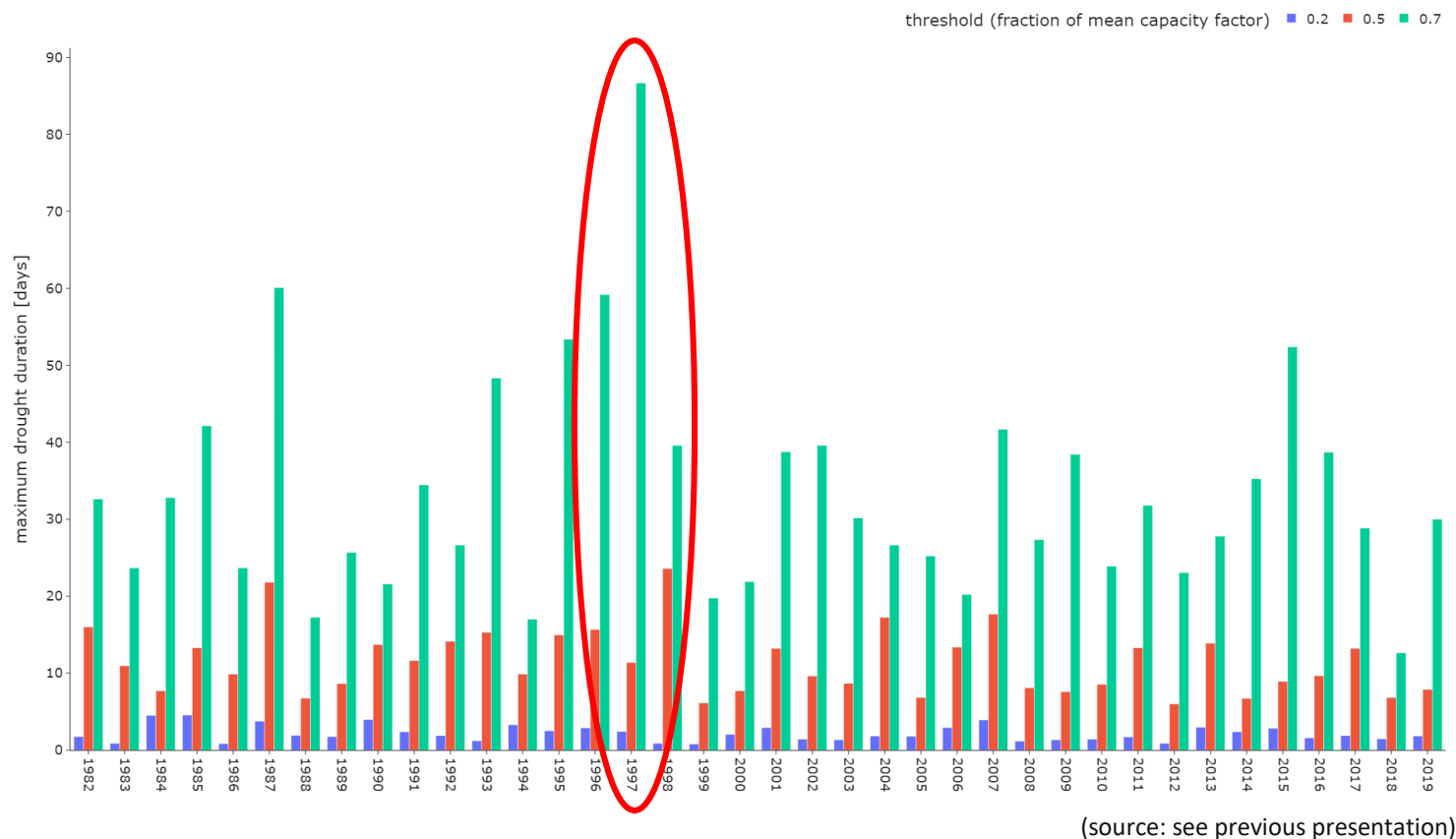
Spatial scope

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

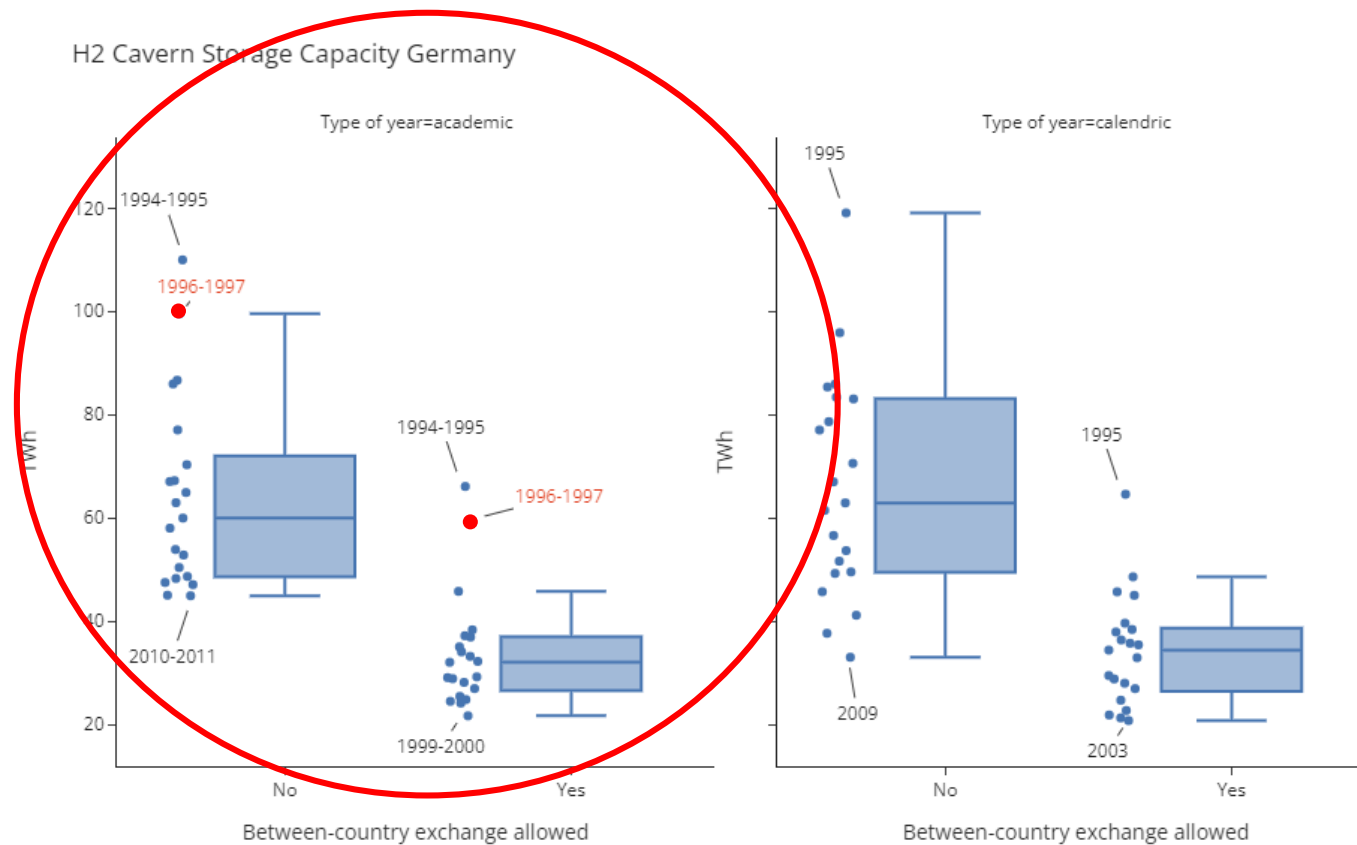
Yearly time horizon

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





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

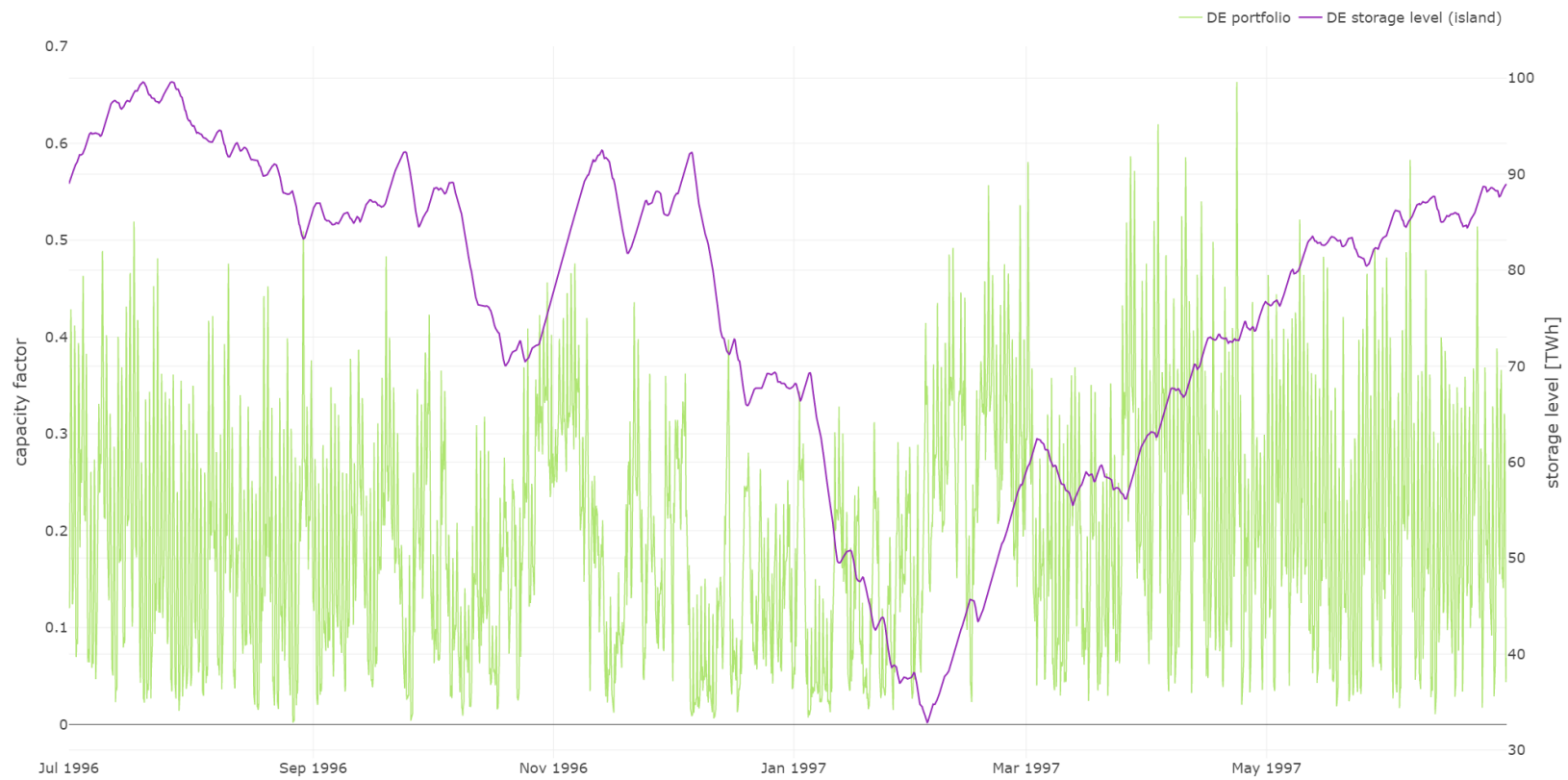


100% renewable power sector

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

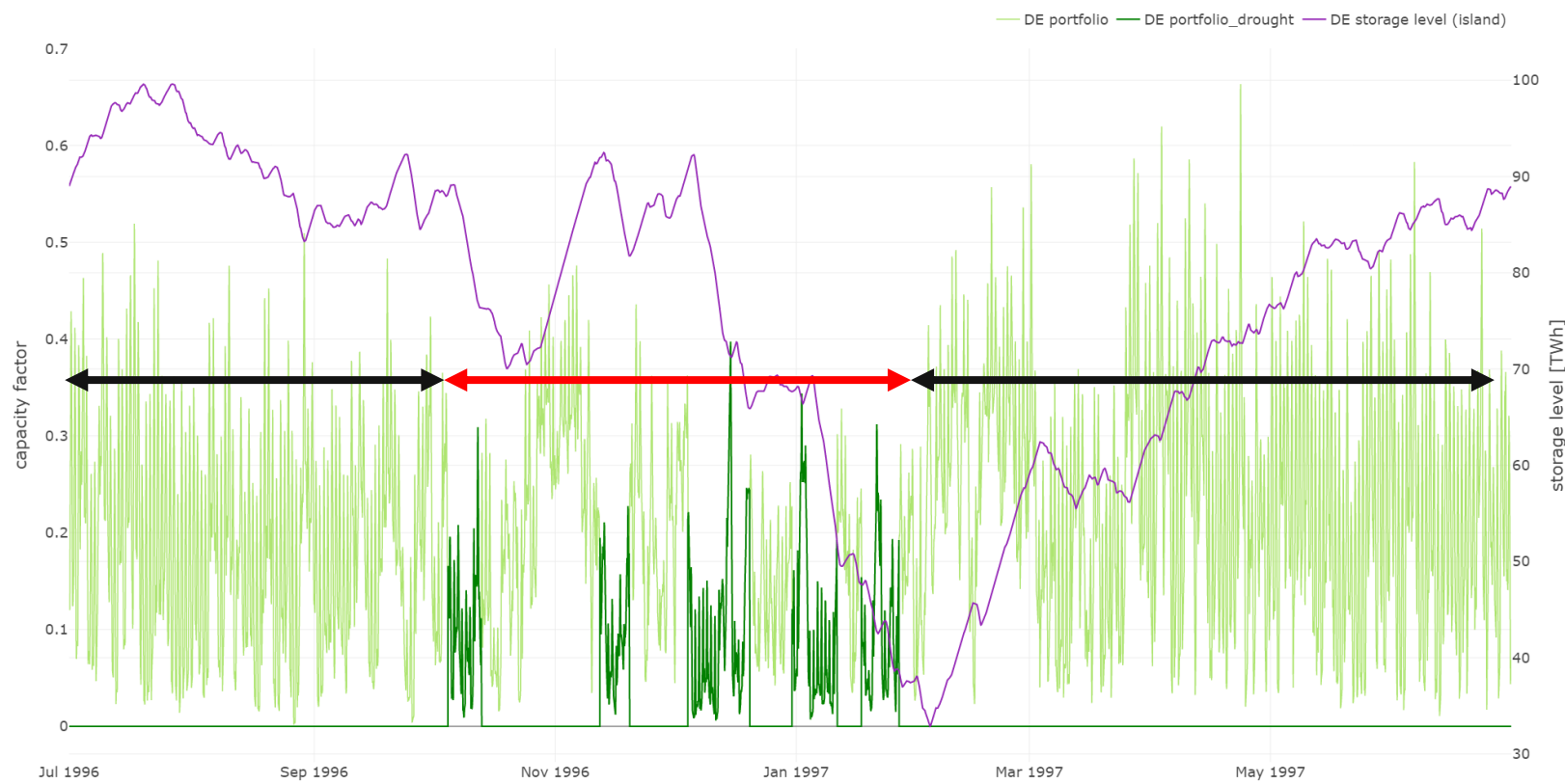
100% renewable power sector (academic time horizon)

- storage discharged during winter



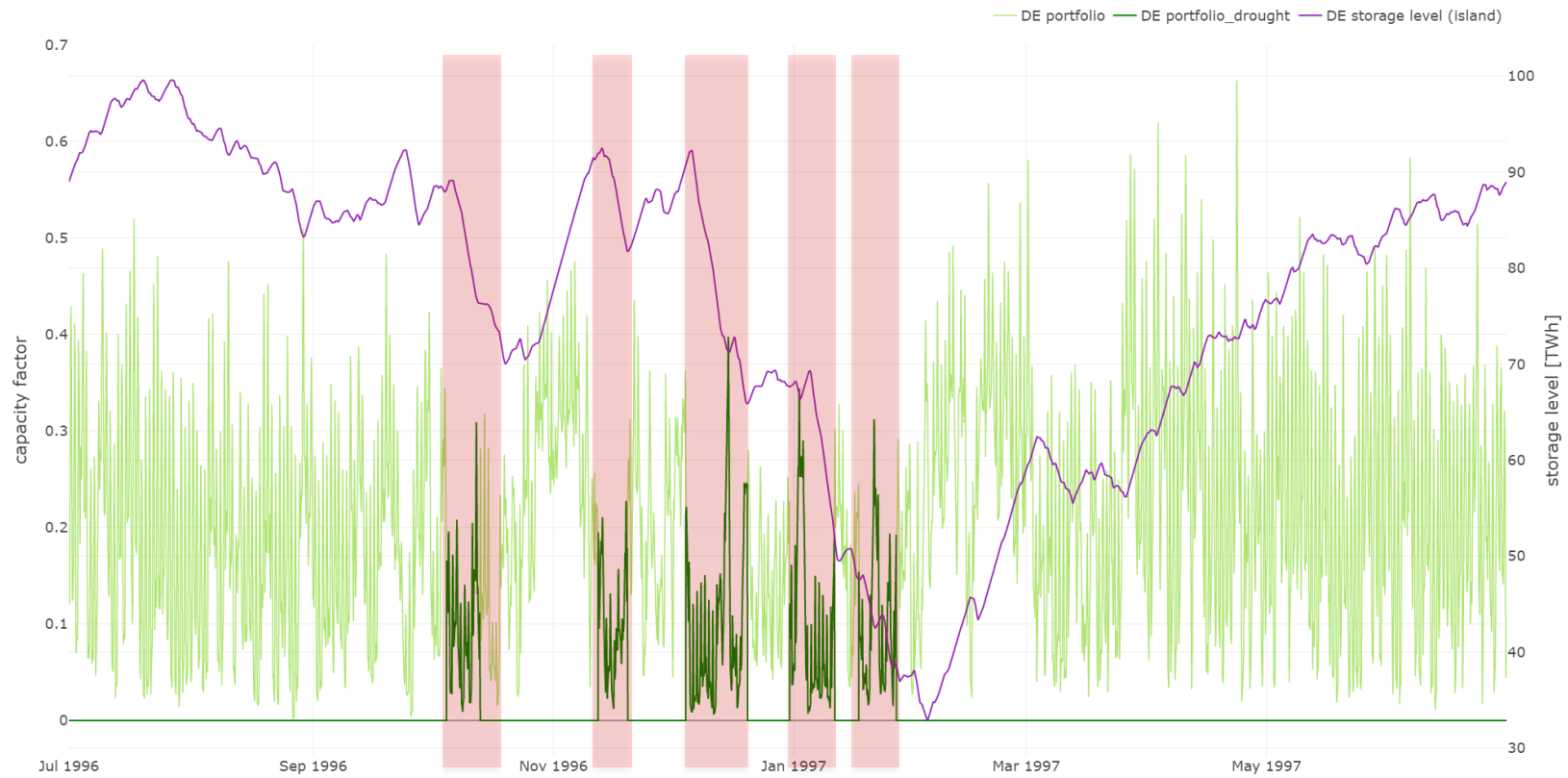
100% renewable power sector (academic time horizon)

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



100% renewable power sector (academic time horizon)

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



100% renewable power sector (academic time horizon)

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

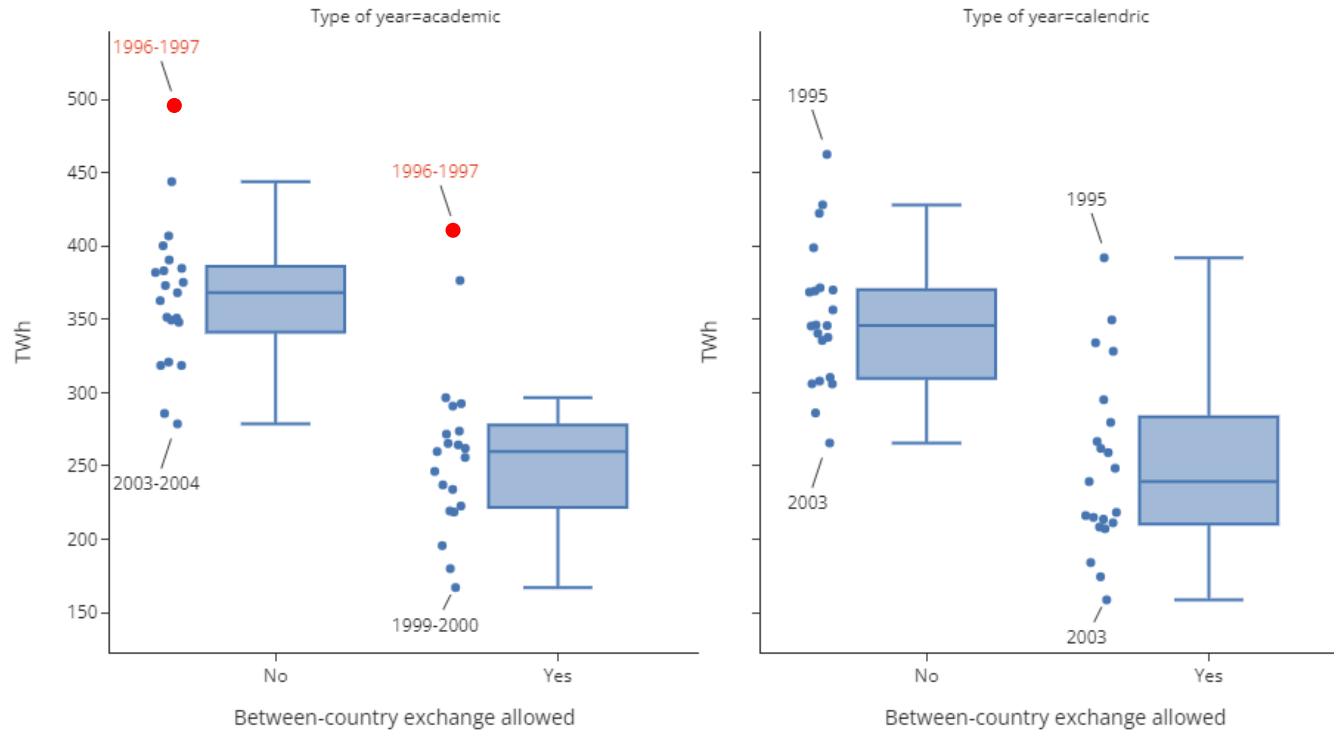


100% renewable power sector (academic time horizon)

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



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

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

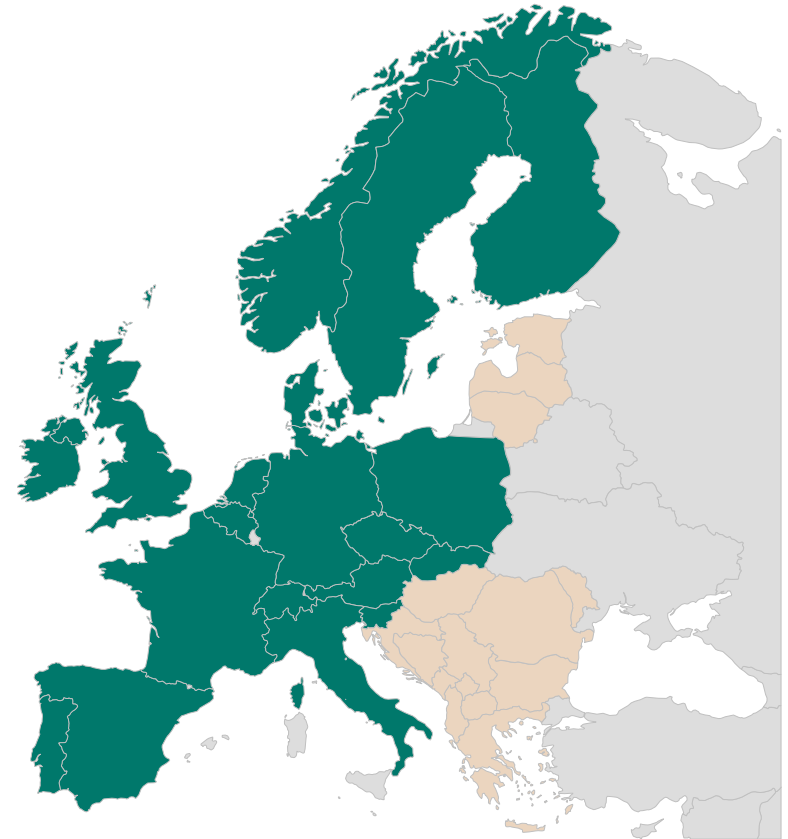
- Time horizon: variation across academic and calendric resolution
- “Worst” and “best” year varies:
 - Spatial scope (EU / DE)
 - Time scope (calendar vs „academic“ year)

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!



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