DIW BERLIN

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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 **decarbonized 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 ("*Dunkelflaute*"): periods of low electricity production by wind and solar
- System flexibility: long-duration storage and interconnection

1.1 Motivation (2)

Opinion UK energy

The dreaded 'dunkelflaute' is no reason to slow UK's energy push

Government should be working towards a full-system transformation, not just renewables

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"GHOST POWER"

READ ALOUD

Expert: Power lines and storage systems are missing for the energy transition

from Stephan Kloss, MDR CURRENT

As of February 12, 2023, 05:00

Electricity from renewable sources is to replace climate-damaging coal-fired power in Germany.

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ENERGY TRANSITION

CLIMATE GLOSSARY

Can Europe survive the dreaded dunkelflaute?

Unpacking the German word that threatens Europe's ability to keep the lights on this winter

Motivation (3)

Need for long-duration storage

- Well established by many papers
- Optimal size of storage varies (assumptions, weather years, etc.)
- Spatial flexibility (i.e. interconnection) reduces storage need

Drivers of long-duration storage need underexplored

- Is it a single week in winter?
- What about several events one after the other?
- Interaction between events in different countries?

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
   - Connection between time series and modelling

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

Scenario assumptions

100% renewable European power sector

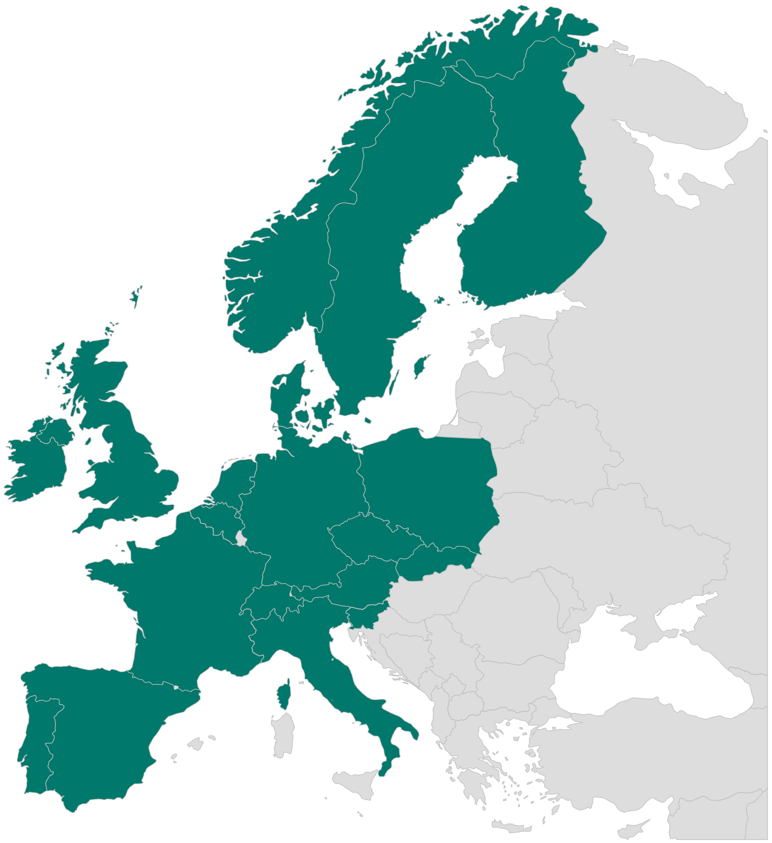
- 18 European countries
- No fossil fuels or nuclear power (for now)
- NTC from TYNDP 2022, Distributed Energy scenario
- Fixed hydrogen demand (DE 96 TWh, other countries scaled)

Spatial scope

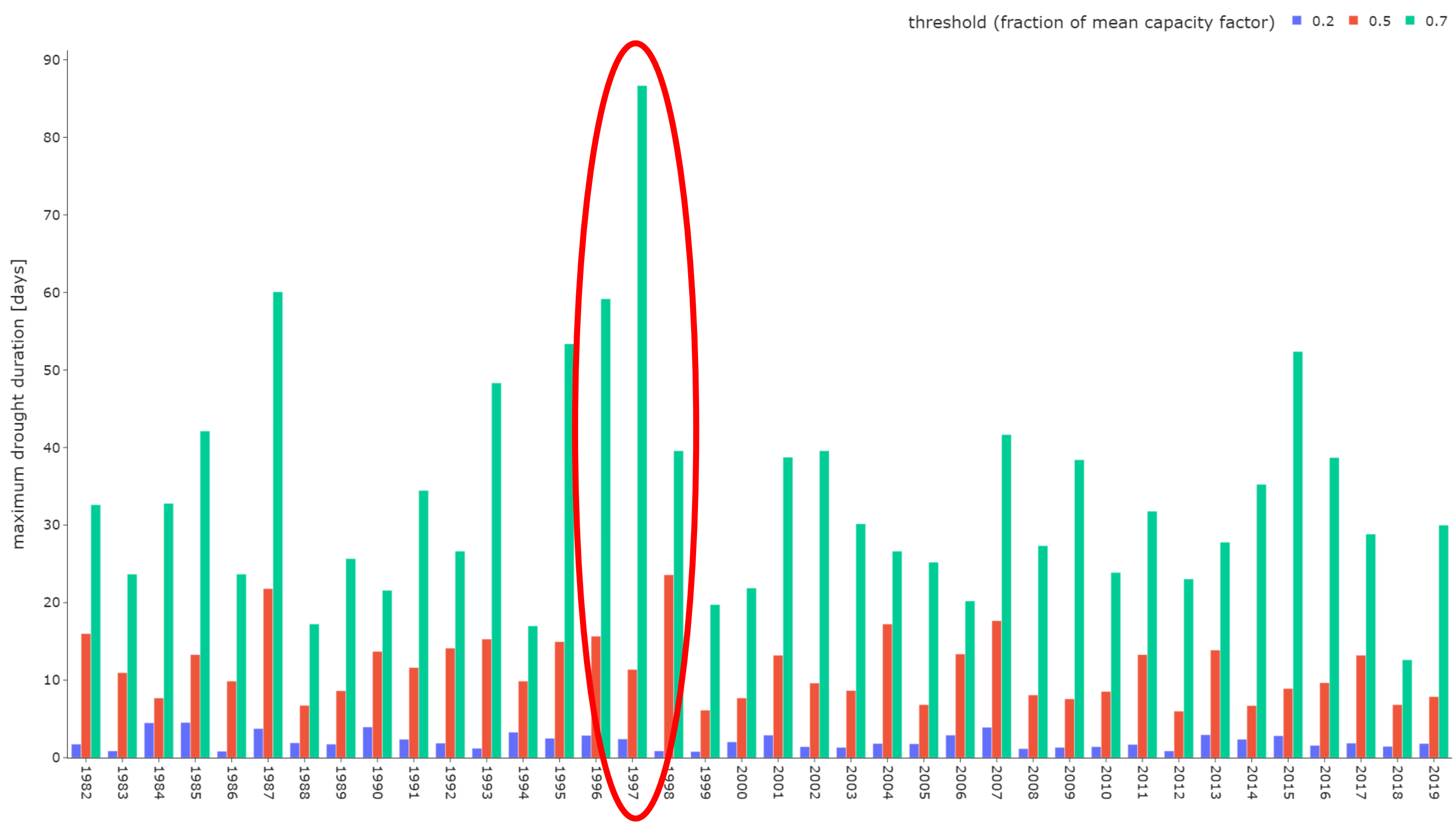
- 20 weather years: 1990-2010 (for now)

Yearly time horizon

- “Calendric”: January – December
- “Academic”: July – June
- (multi-annual optimization planned)



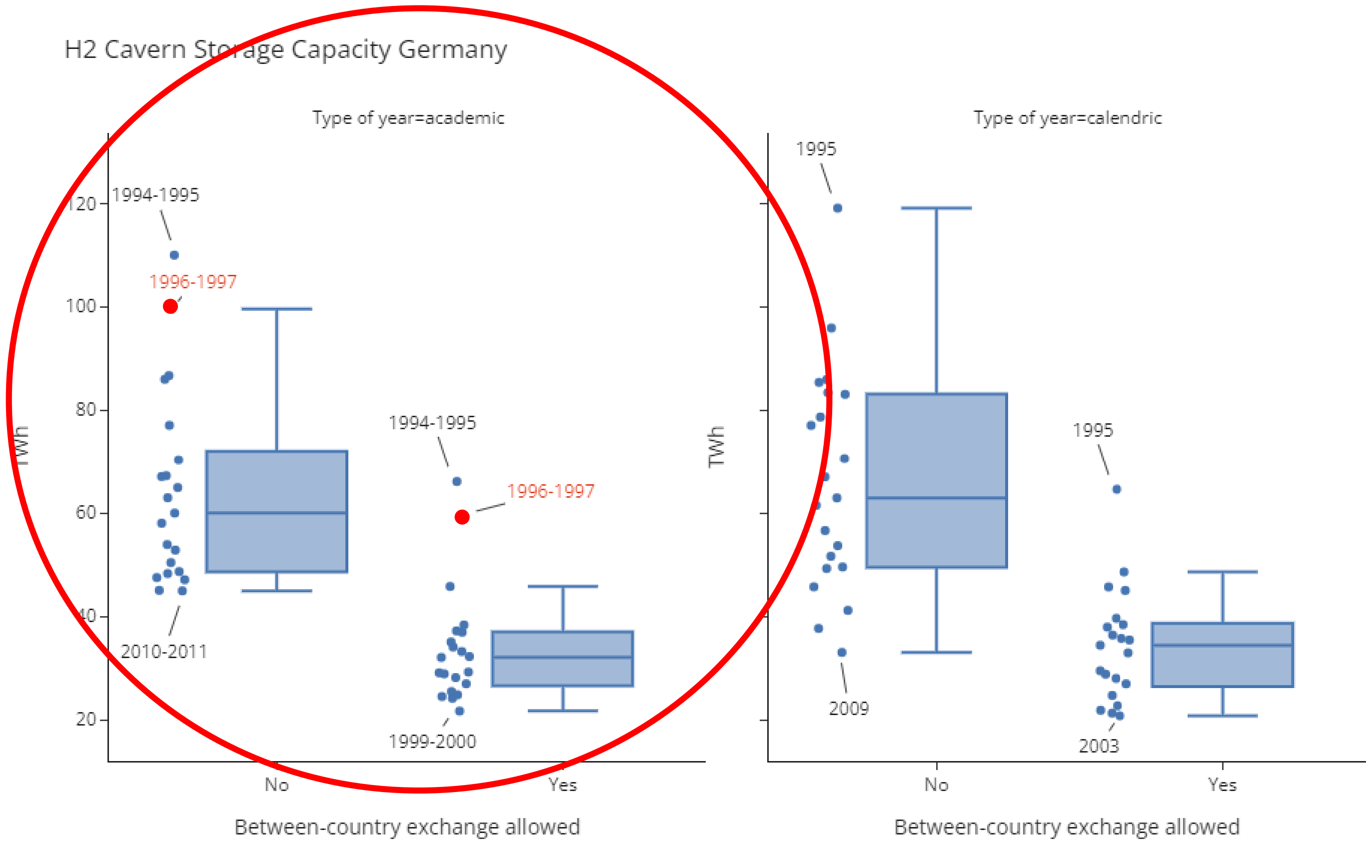
3.1 VRE droughts in Germany: most extreme period duration across years



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

Power sector model results: Germany

Preliminary results



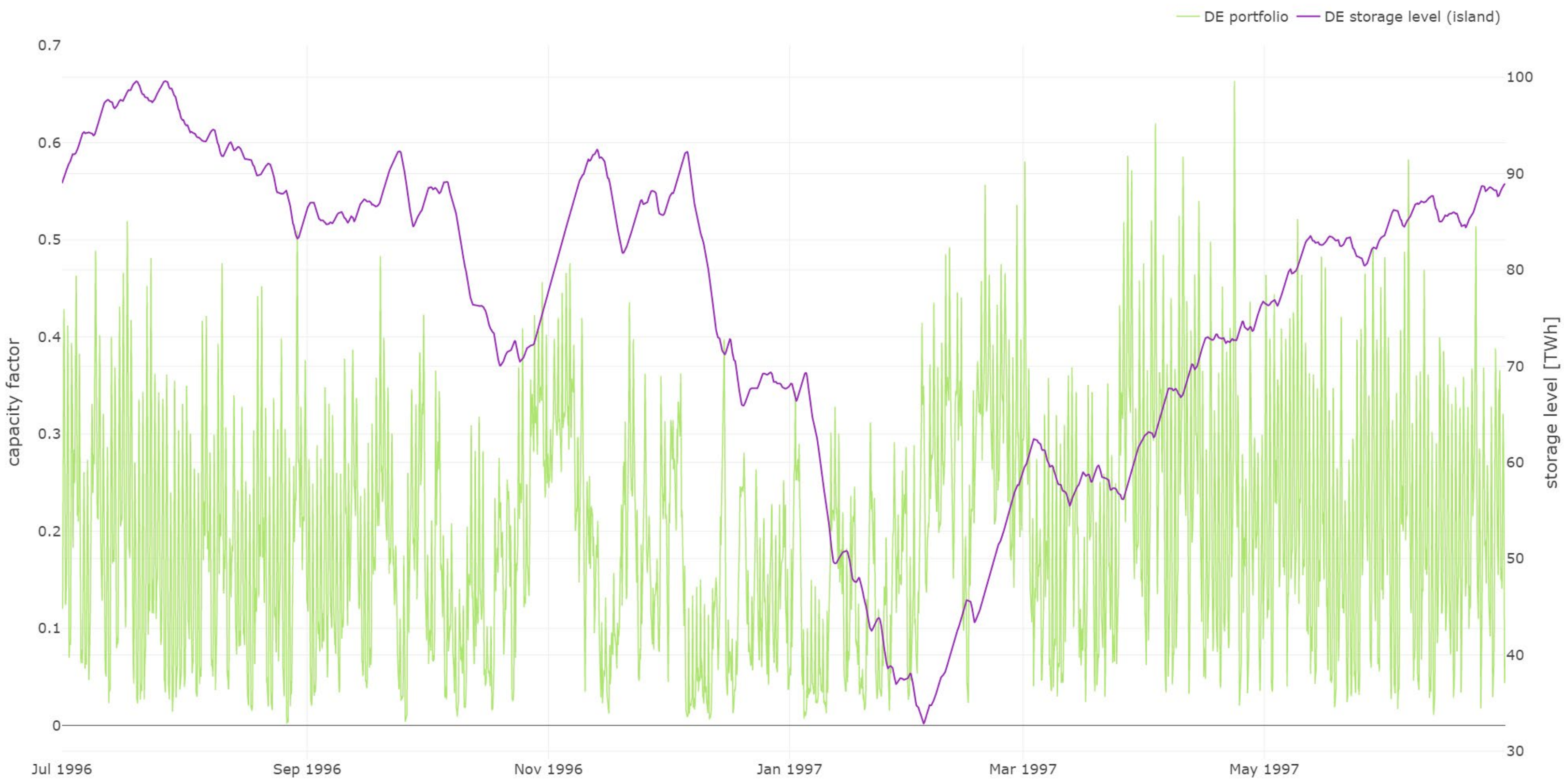
100% renewable power sector

- 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

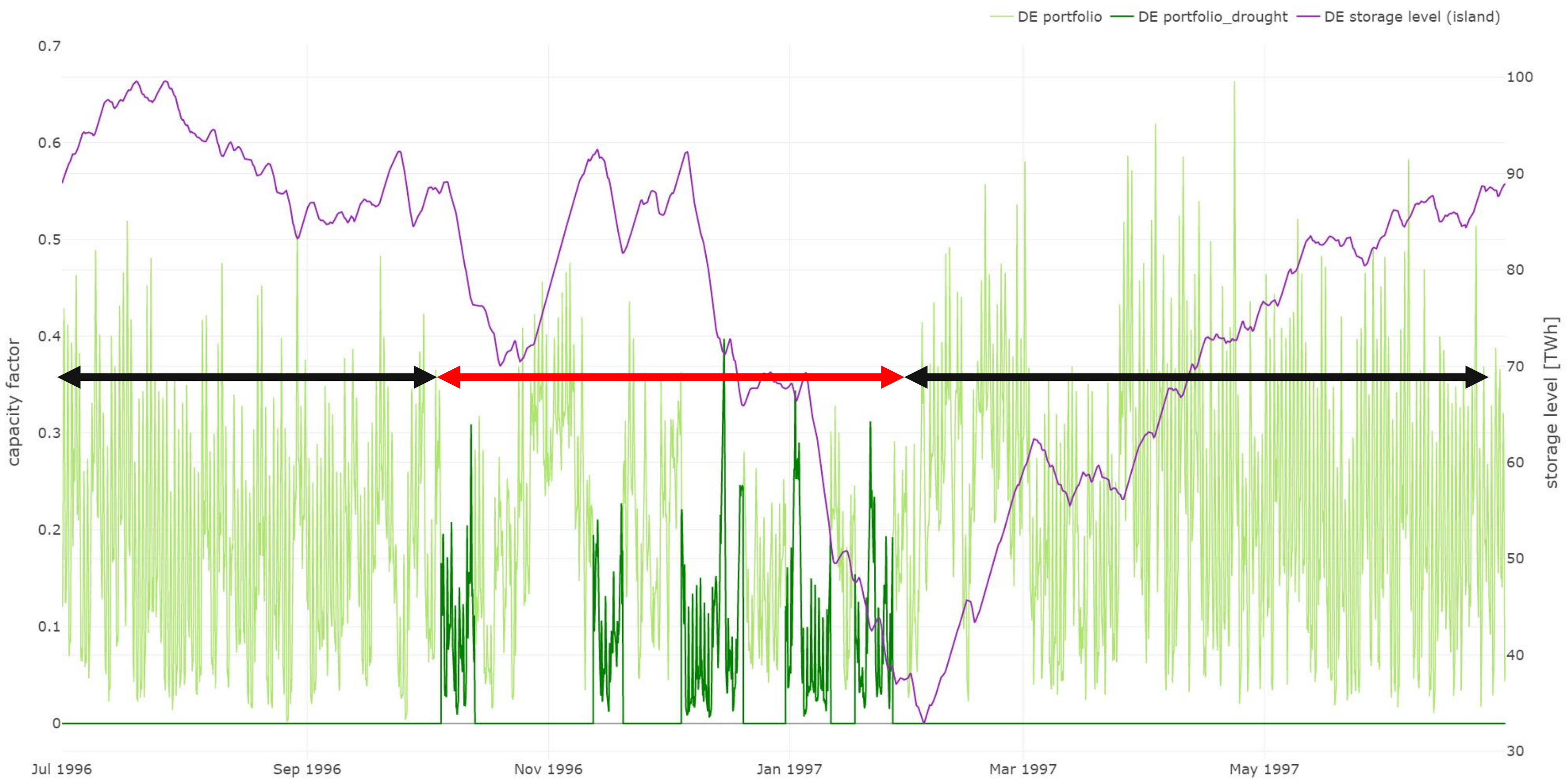


Power sector model results: Germany (island)

Preliminary results

100% renewable power sector (academic time horizon)

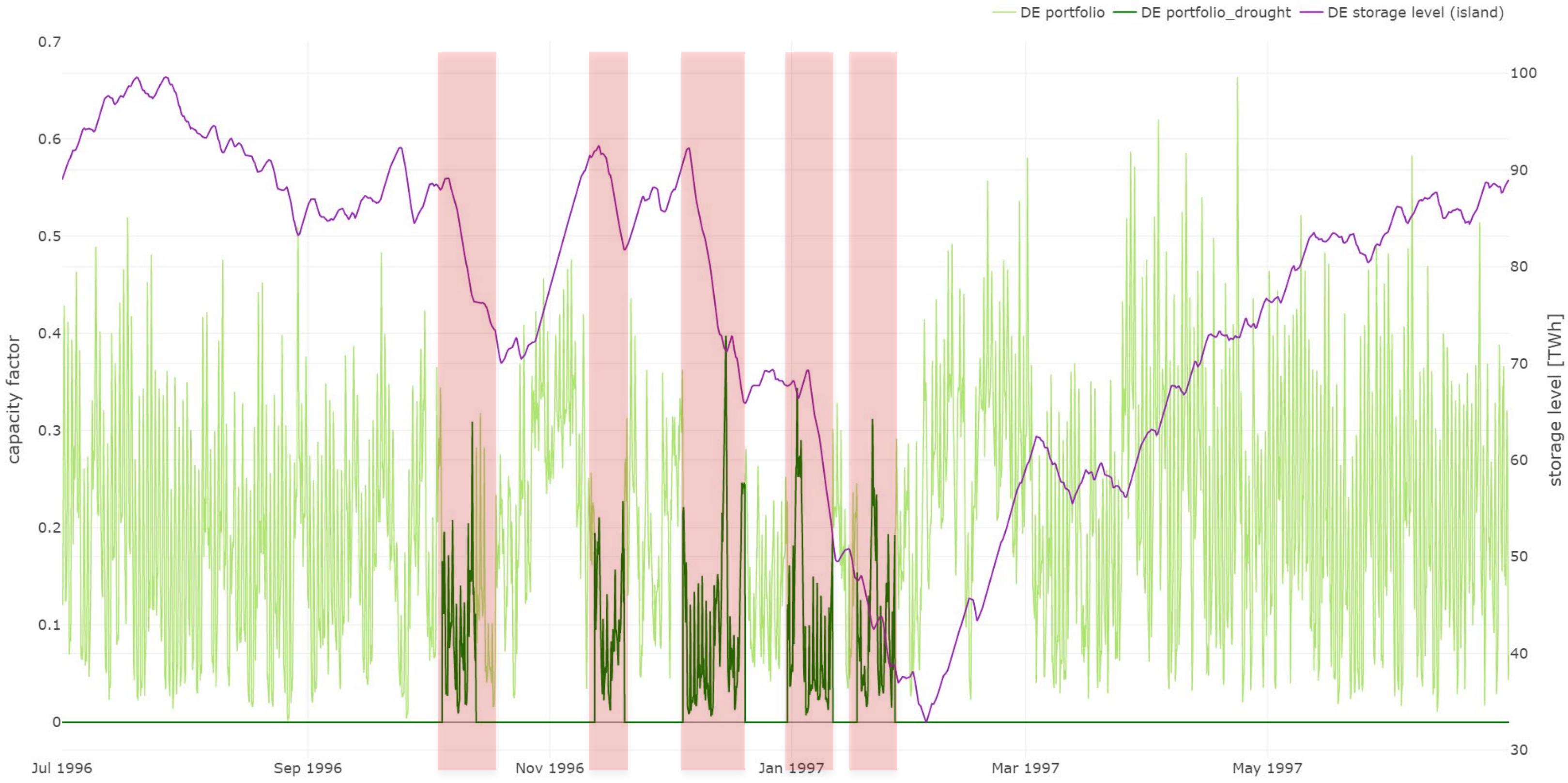
- Drought threshold: 0.5 fraction of mean capacity factor, droughts longer than one week



Preliminary results

100% renewable power sector (academic time horizon)

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



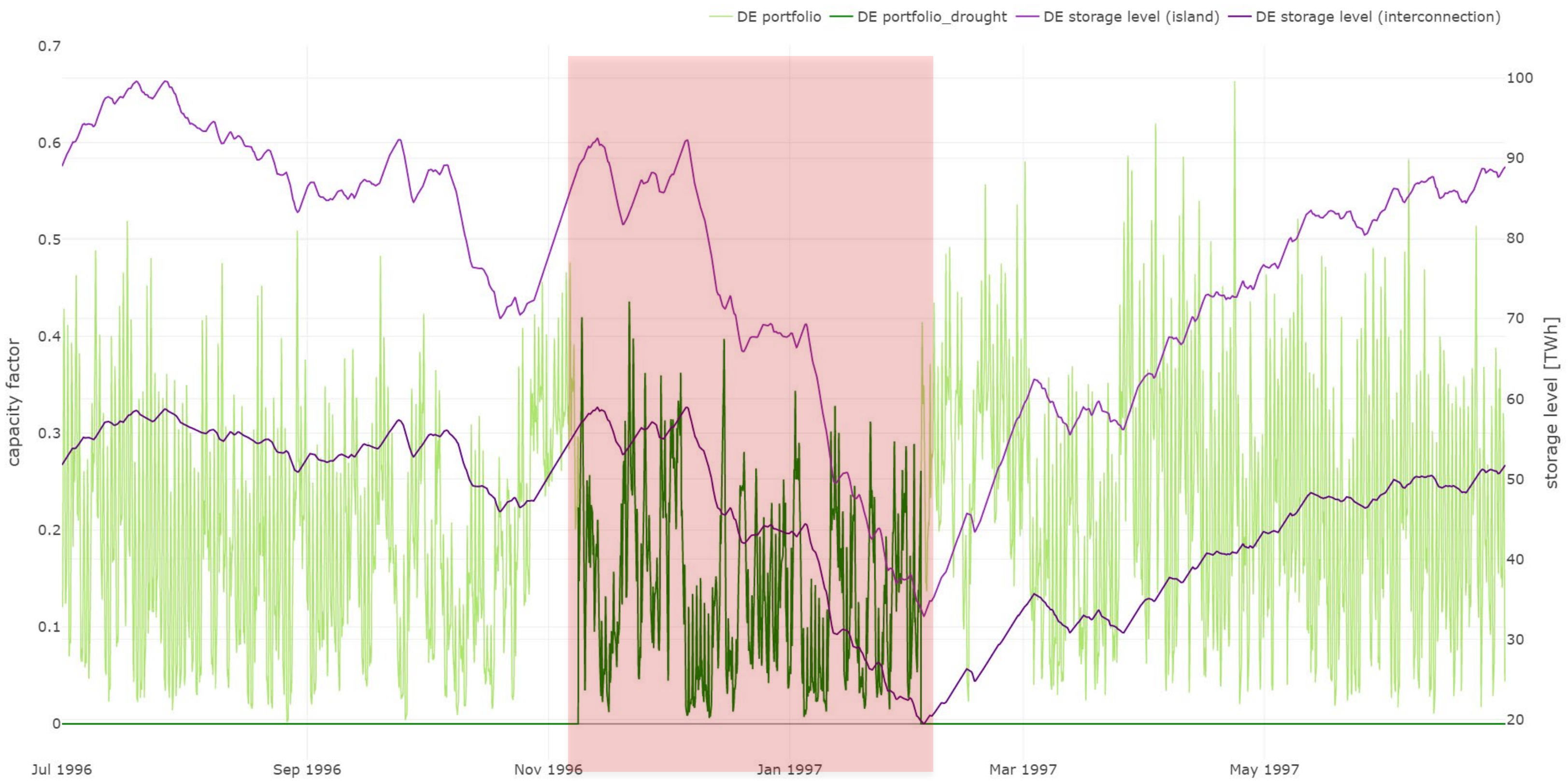
Preliminary results

100% renewable power sector (academic time horizon)

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

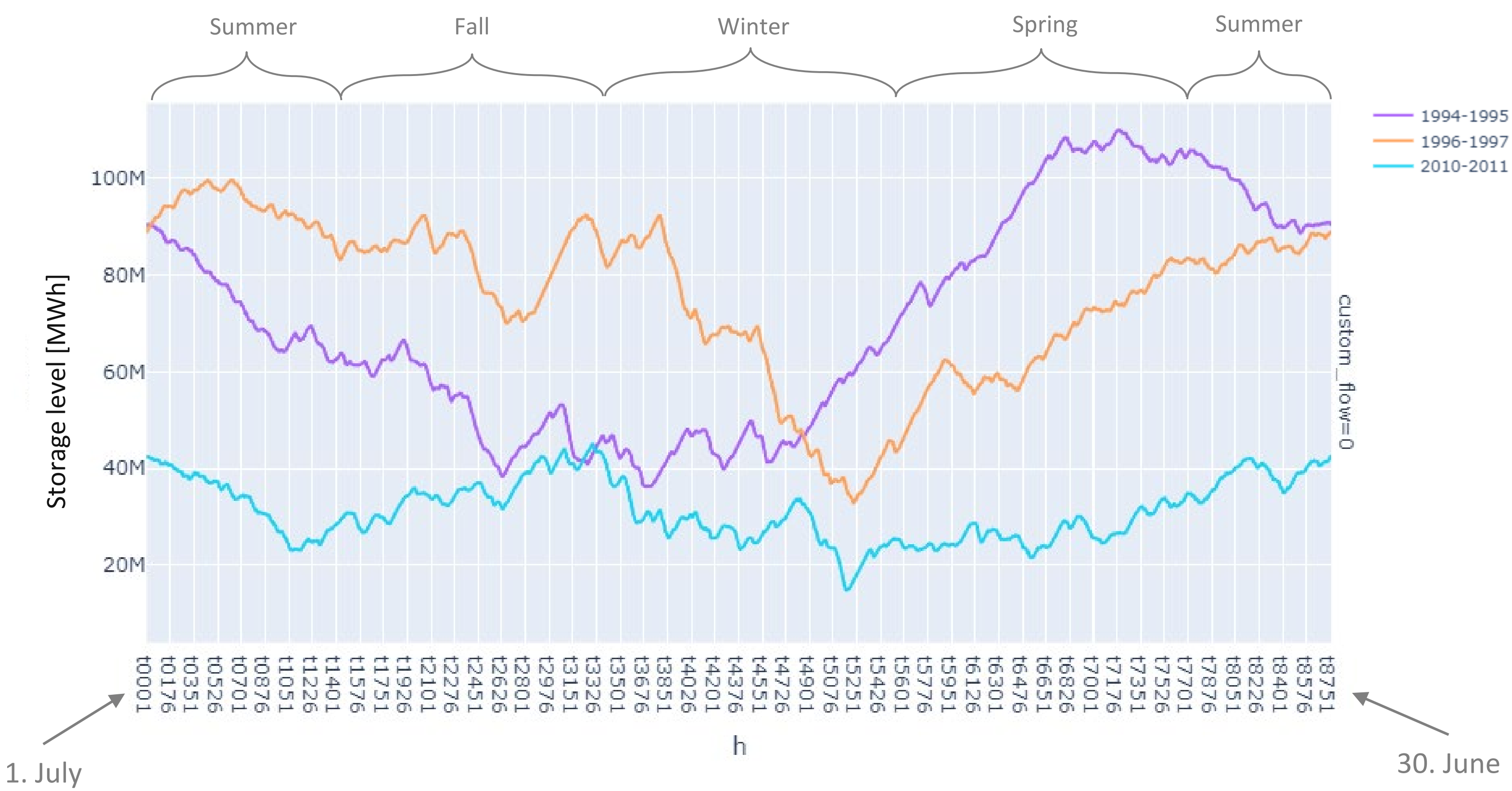
100% renewable power sector (academic time horizon)

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



Variation between years

Preliminary results

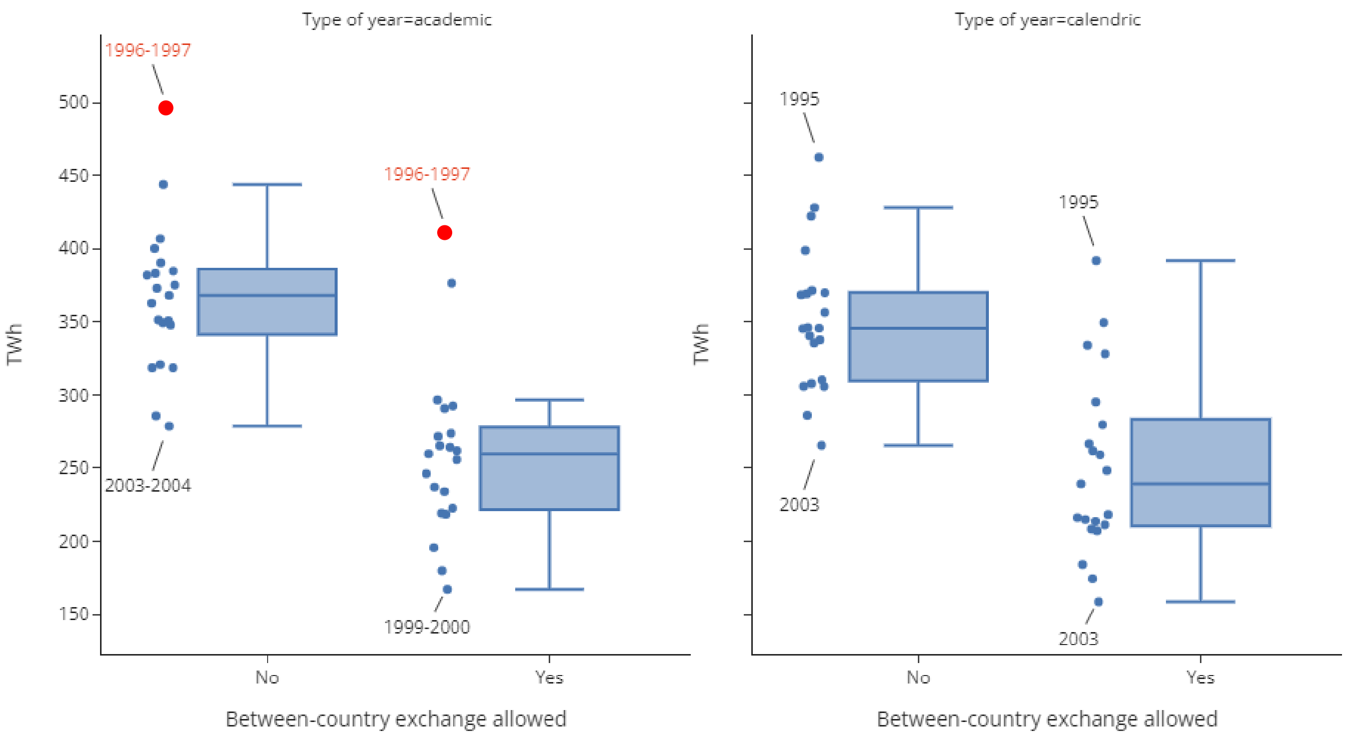


- Storage level patterns differ between years
- Maximum levels not always driven by “one bad week”

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

European power sector

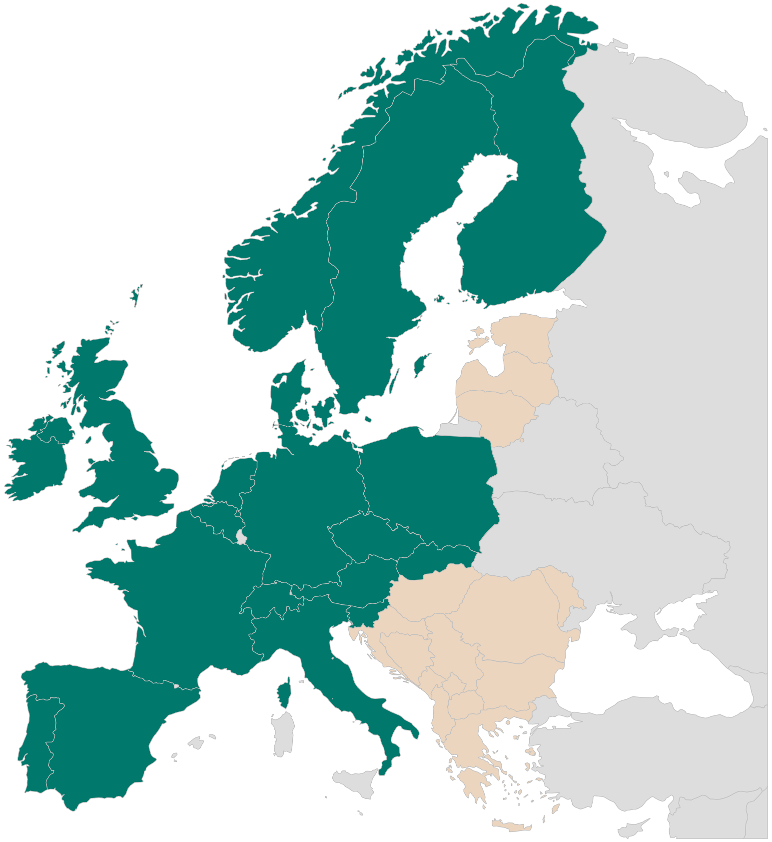
- Large variation across weather years → VRE droughts have system resilience implications
- VRE droughts drive long-duration storage investment & operation
  - Not necessarily one "bad week in winter"
  - Possible are also multiple droughts in different periods of the year
- Interconnection reduces impact 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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