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Variable renewable energy droughts in Europe

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KOPERNIKUS PROJEKTE
Ariadne
Die Zukunft unserer Energie

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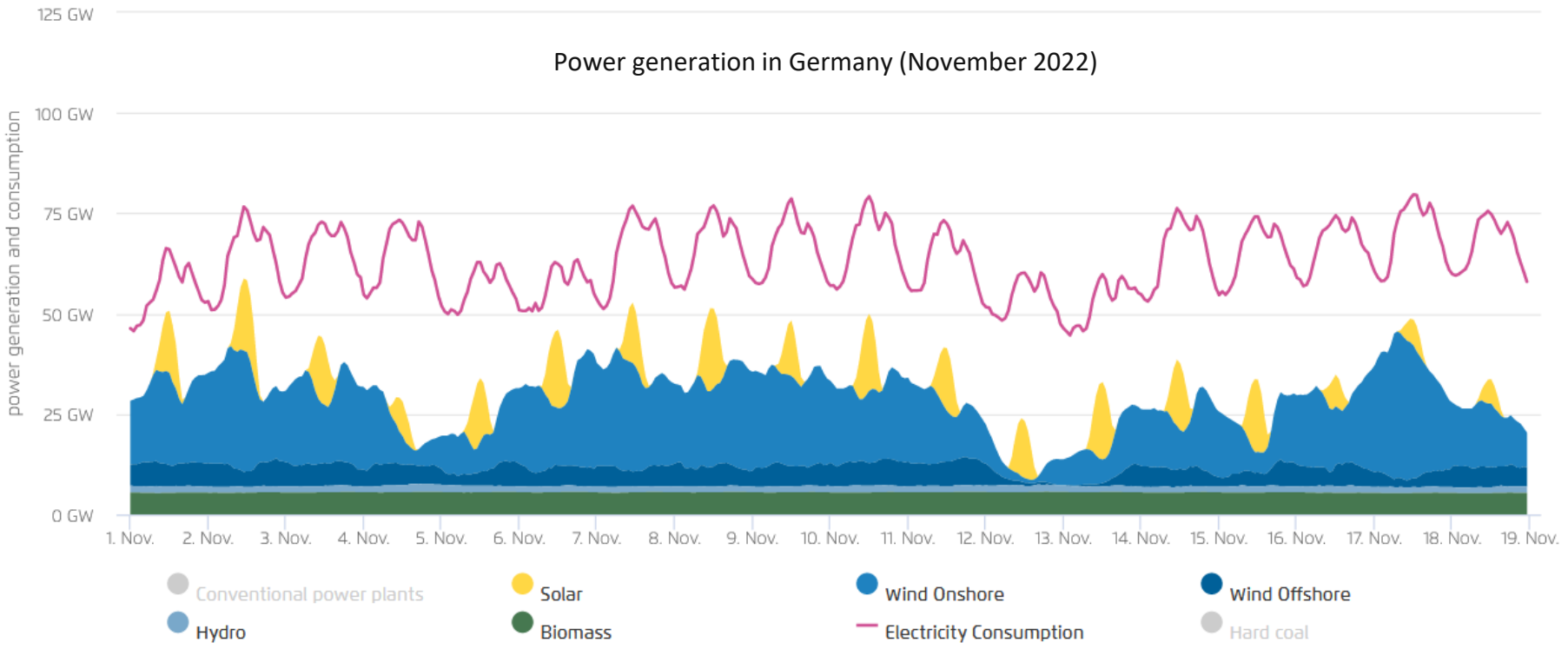
Agenda

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

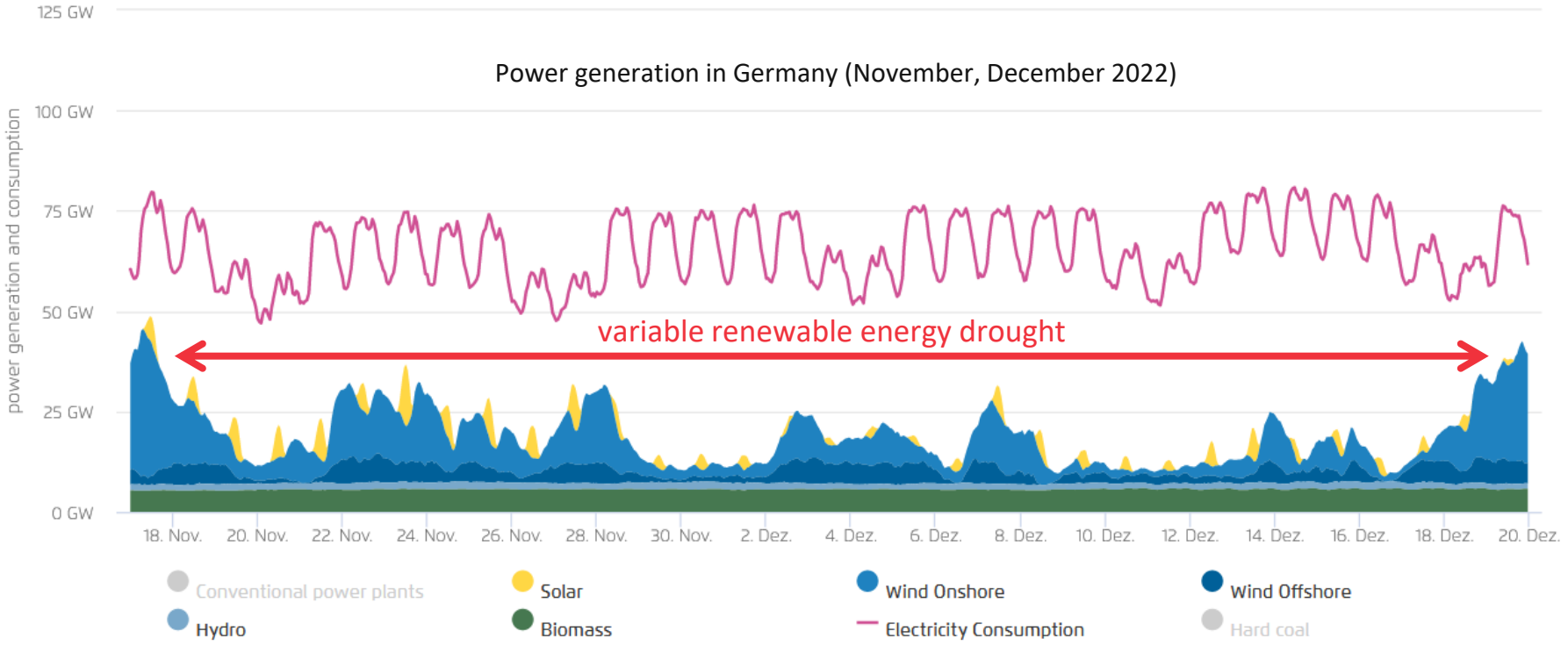
High variability in renewable power sector



Source: www.agora-energiewende.de [22.06.23]

High variability in renewable power sector

- variable renewable energy (VRE) droughts are periods with very low availability of renewable generation
- rising renewable penetration → VRE droughts become increasingly challenging



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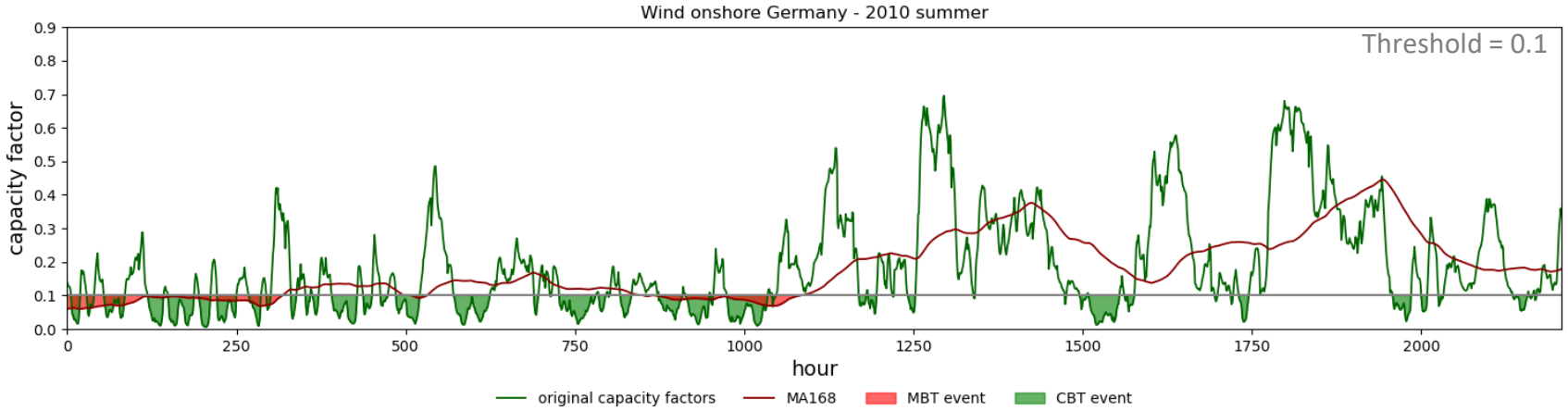
1.3 Research questions

1. How severe are variable renewable energy droughts?
   - duration
   - frequency
2. When do variable renewable energy droughts occur?
   - seasonality
   - most extreme years
3. Are variable renewable energy droughts spatially correlated?
   - across regions
   - across technologies

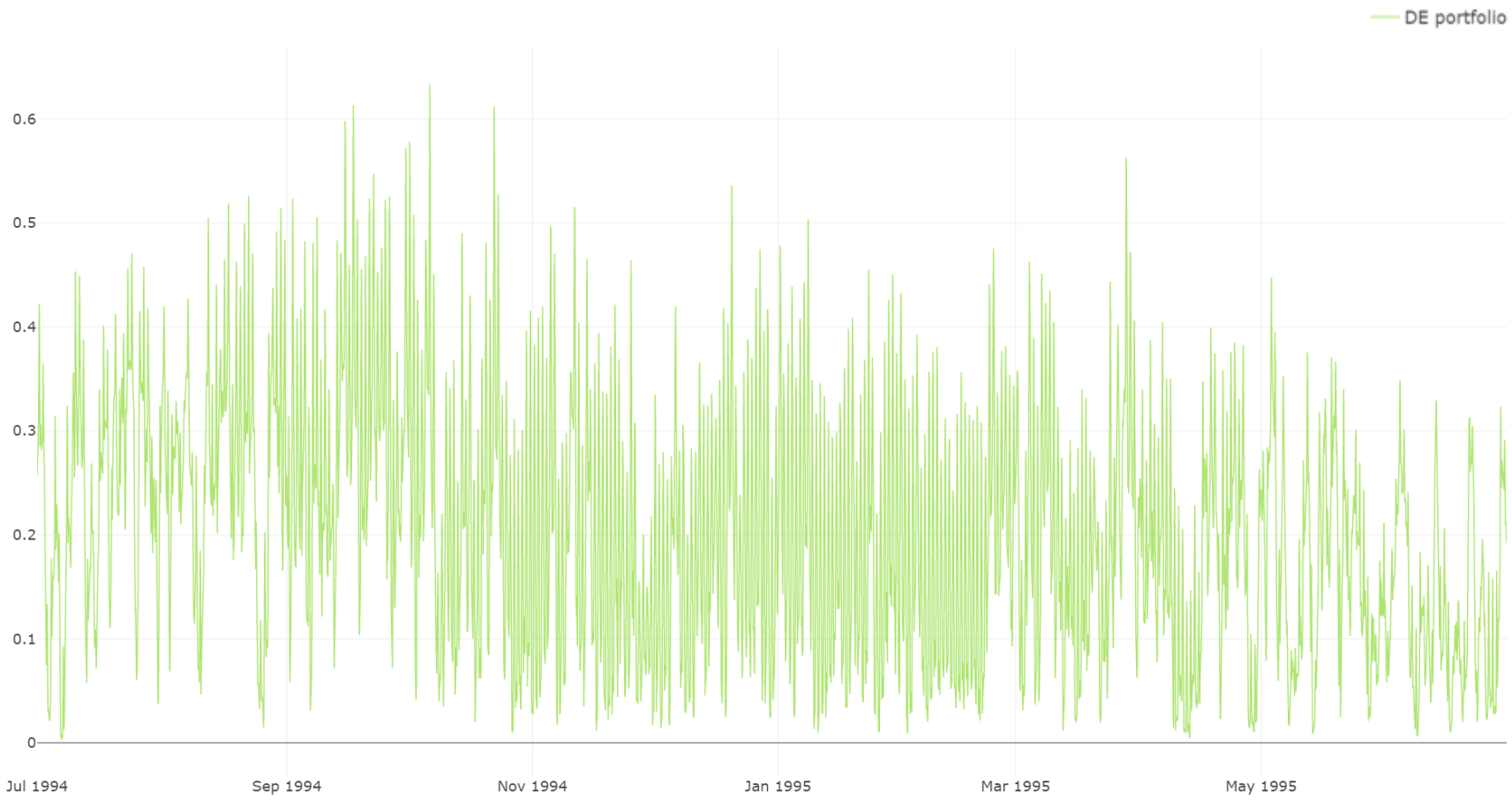
2.1 Methods: drought definition

Constantly Below Threshold (CBT)	Mean Below Threshold (MBT)
▪ consecutive hours below drought threshold	▪ consecutive hours with moving average below drought threshold → incl. brief periods above threshold



- Metric: VRE capacity factors [0, 1], available energy (MWh) normalized by installed capacity (MW)
- Scaling of threshold to enable comparability across regions and technologies
- Drought event:
  - qualified period with variable duration
  - each event counted only once (search in descending order of drought period durations)

2.2 Methods: drought identification



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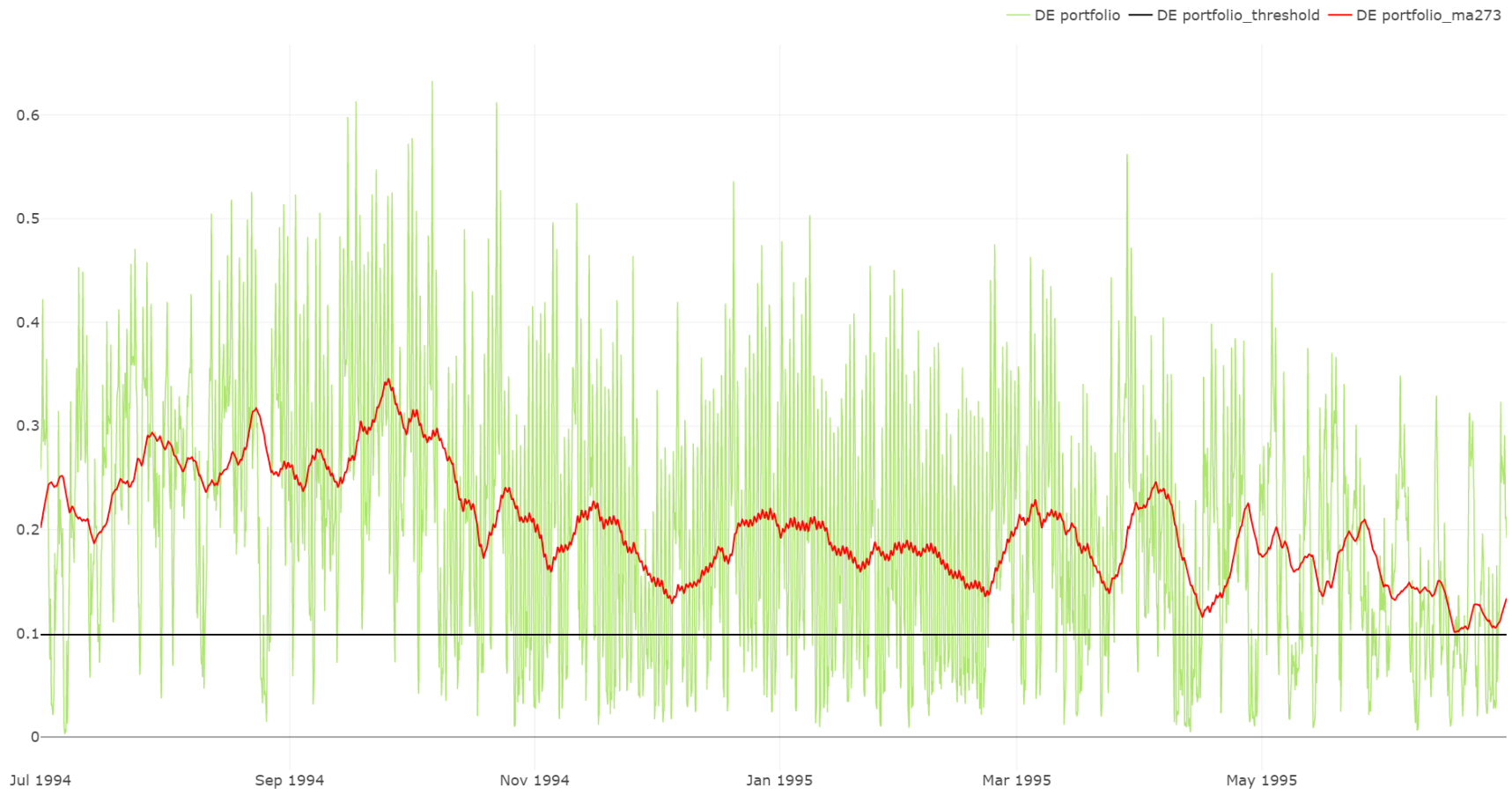

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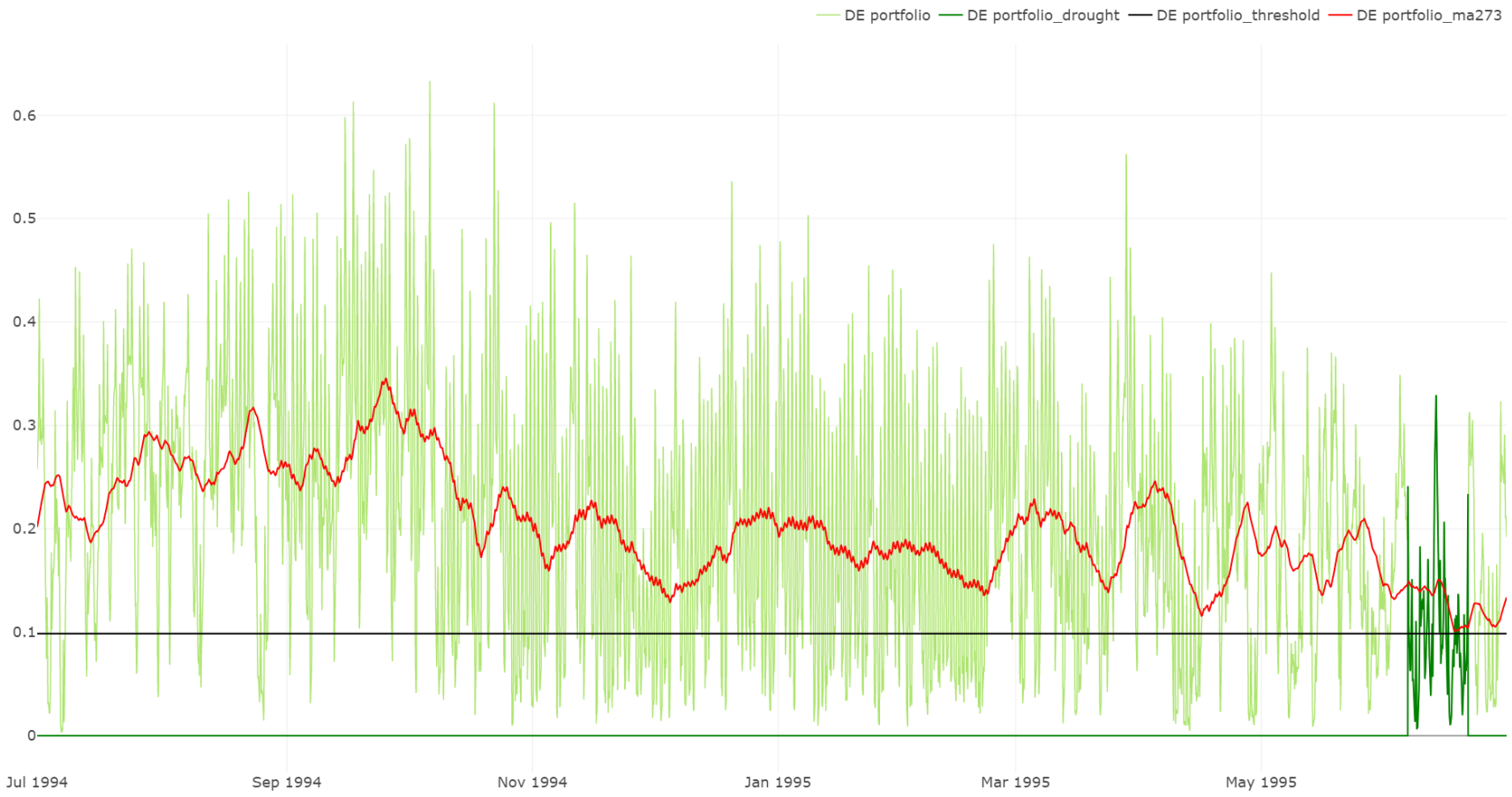


2.2 VREDA: Variable Renewable Energy Drought Analyzer

Analysis of VRE droughts in Europe in 2050

Drought definition

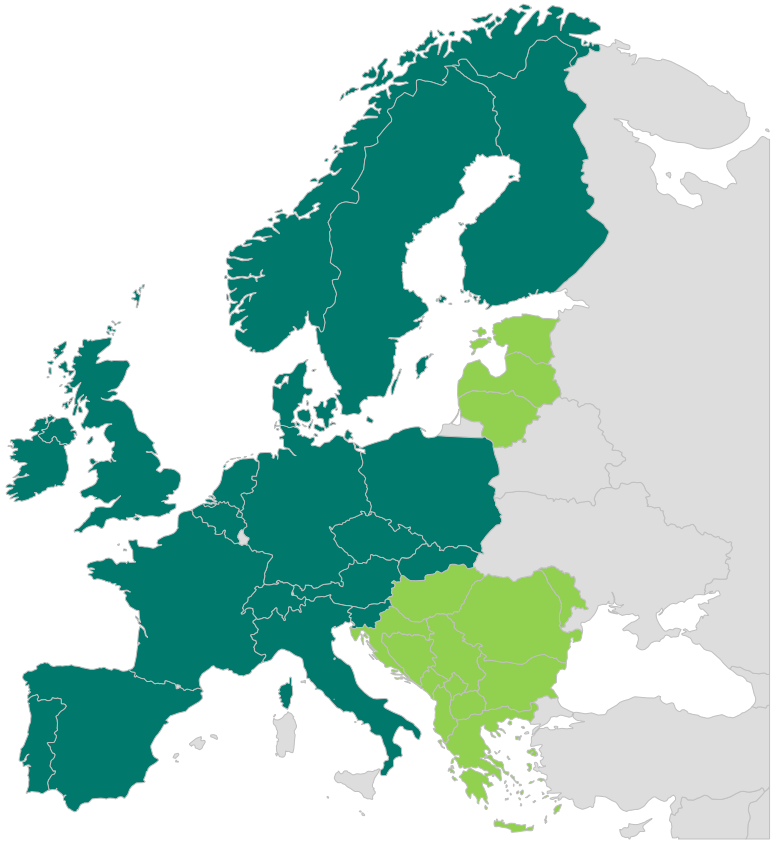
- Threshold: 20%, 50%, 70% of mean capacity factor (enables comparability)
- Drought notion: MBT

Data from ENTSO-e

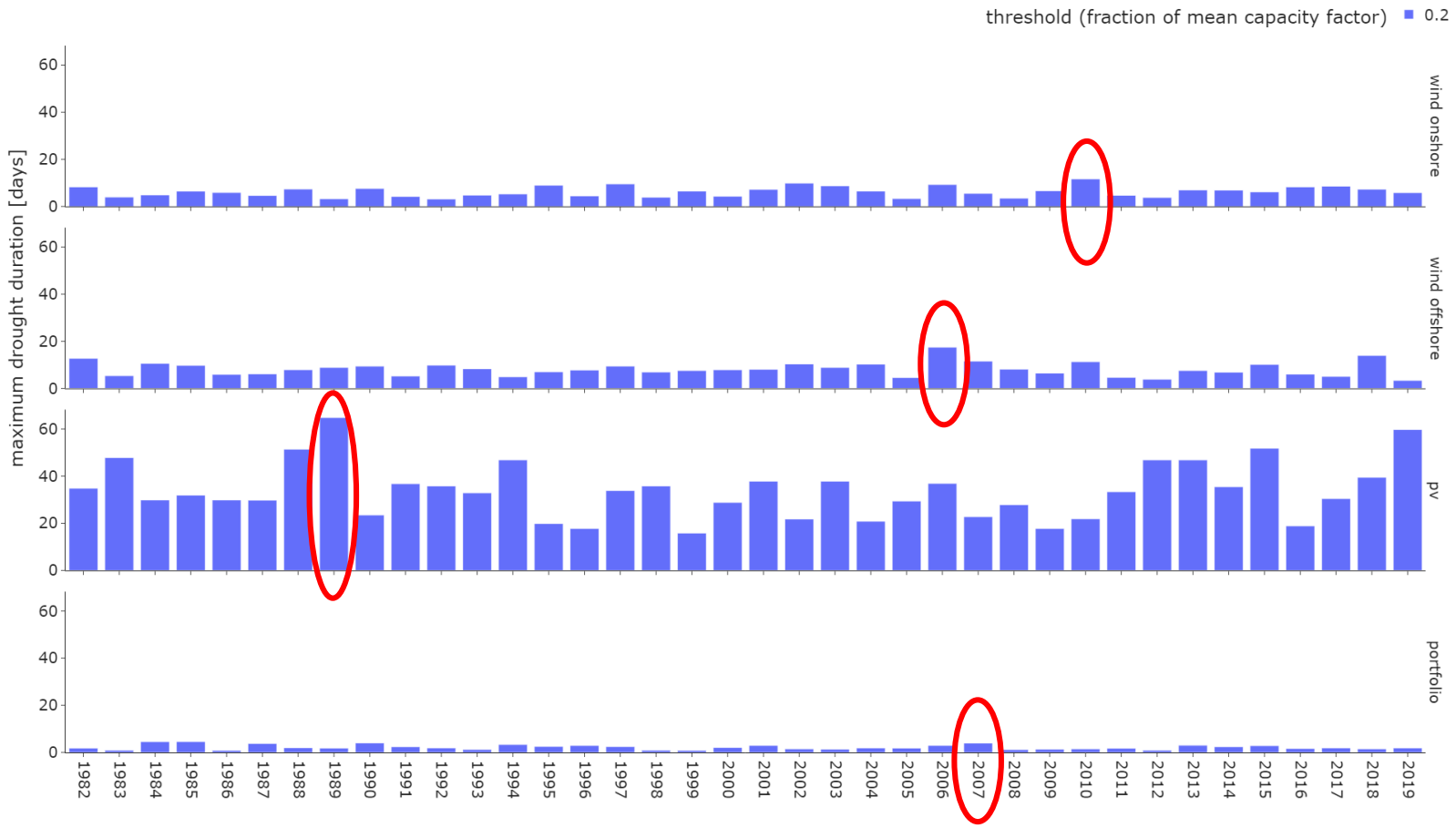
- VRE hourly capacity factors for 2030 (39 years) from Pan-European Climate Database 2021.3
- VRE capacity for 2050 from ENTSO-e Ten-Year-Network-Development Plan 2022, Scenario DE

Scope

- Each VRE technology individually → universal insights
- VRE portfolio (60% wind onshore, 10% wind offshore, 30% PV) → insights specific to TYNDP scenario

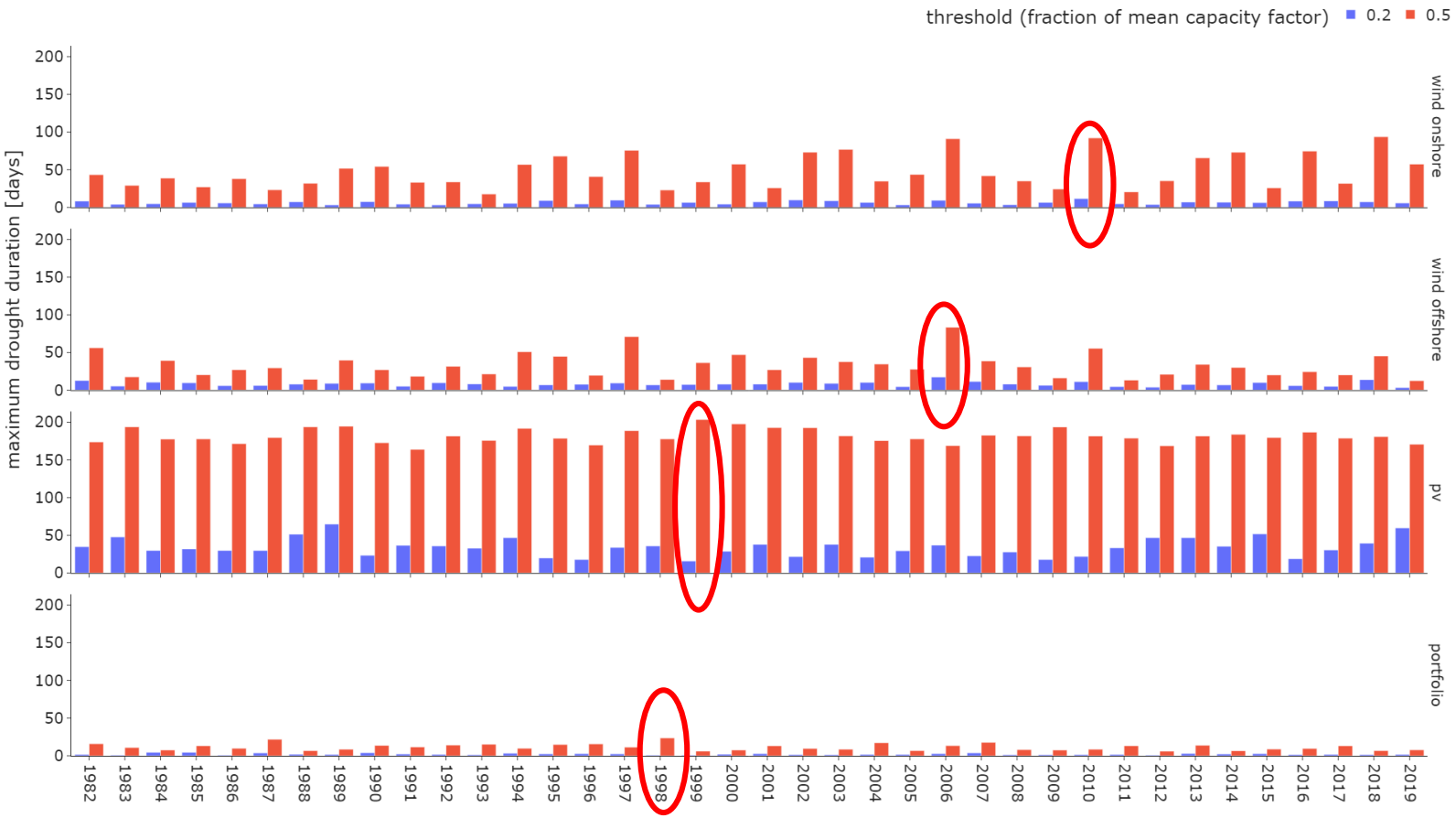


3.1 VRE droughts in Germany: most extreme period duration across years



- Most extreme year differs across technologies
- Combination of VRE reduces most extreme durations

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



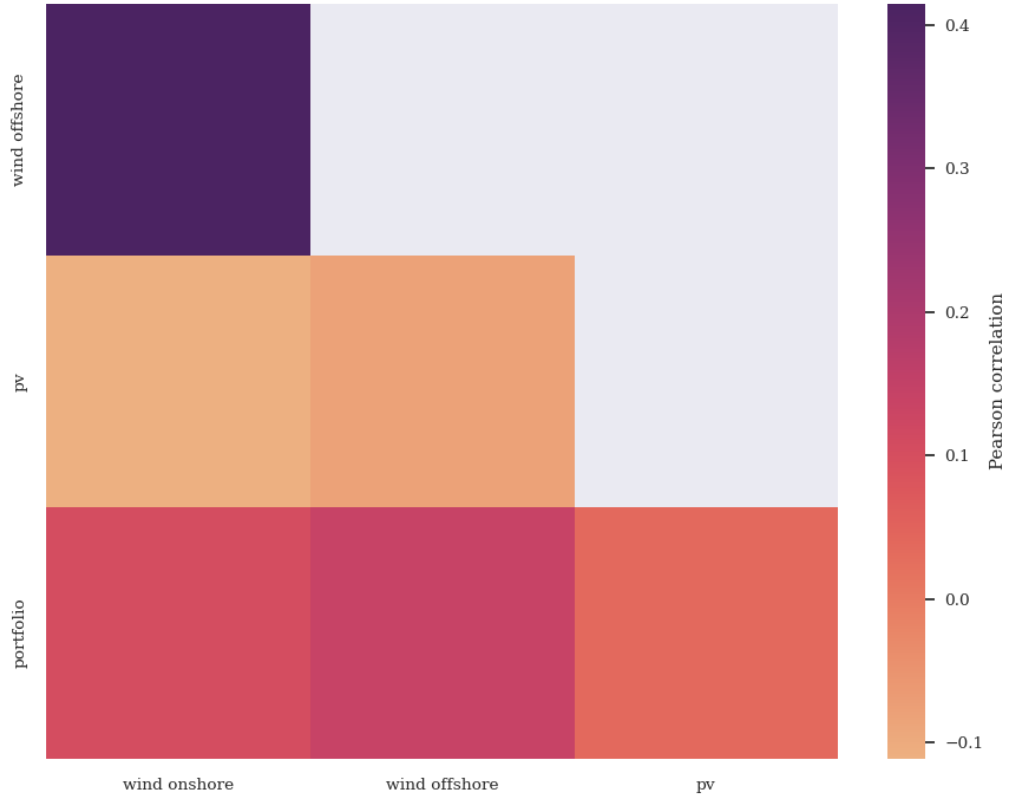
- Extremes differ across years and grow exponentially with threshold
- Combination of VRE reduces most extreme durations

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

- Selection of relevant weather years matters
- Combination of VRE reduces most extreme durations

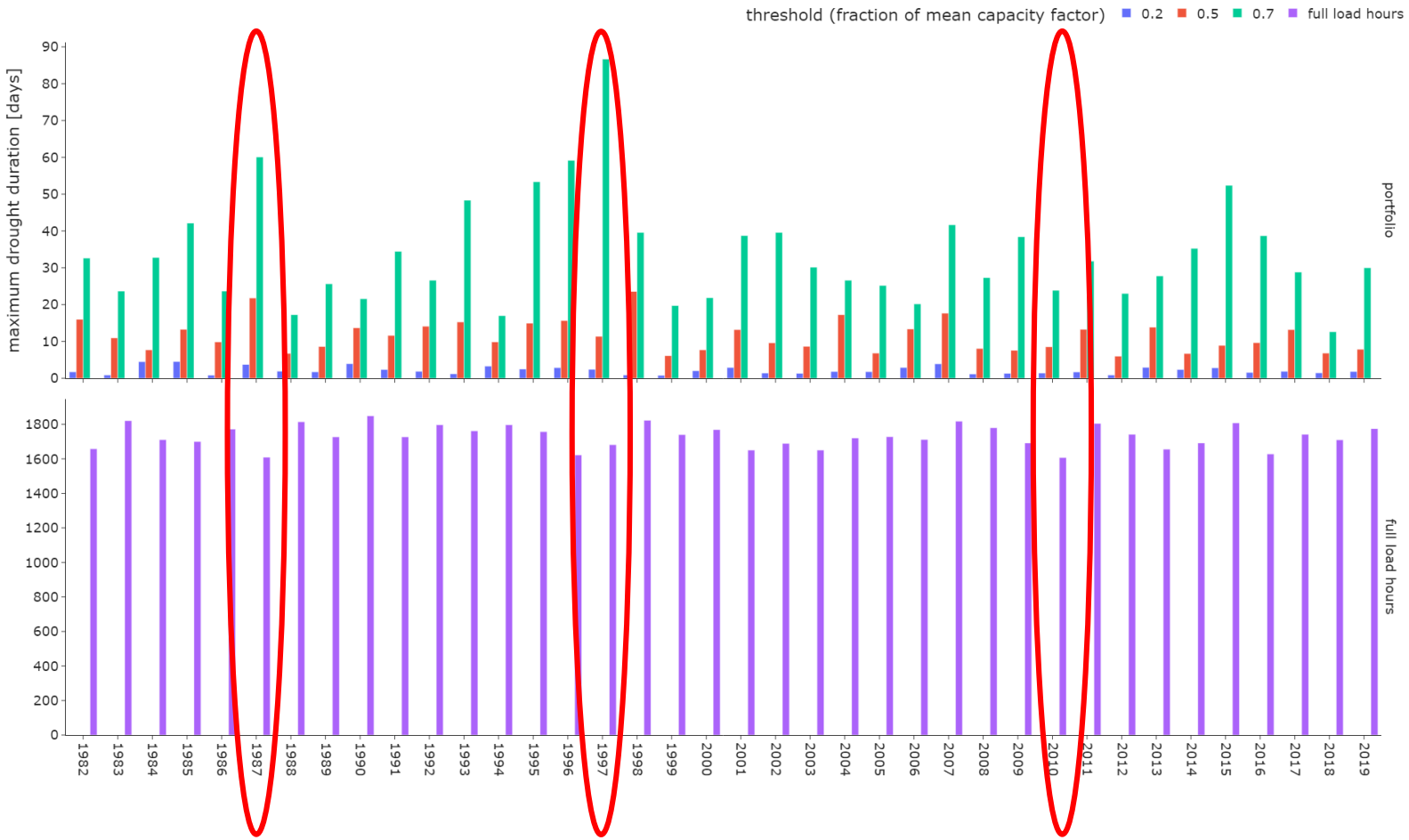
3.2 VRE droughts in Germany: correlation of most extreme periods

Temporal correlation of droughts lasting longer than two weeks across all years (threshold = 0.5 of mean capacity factor)



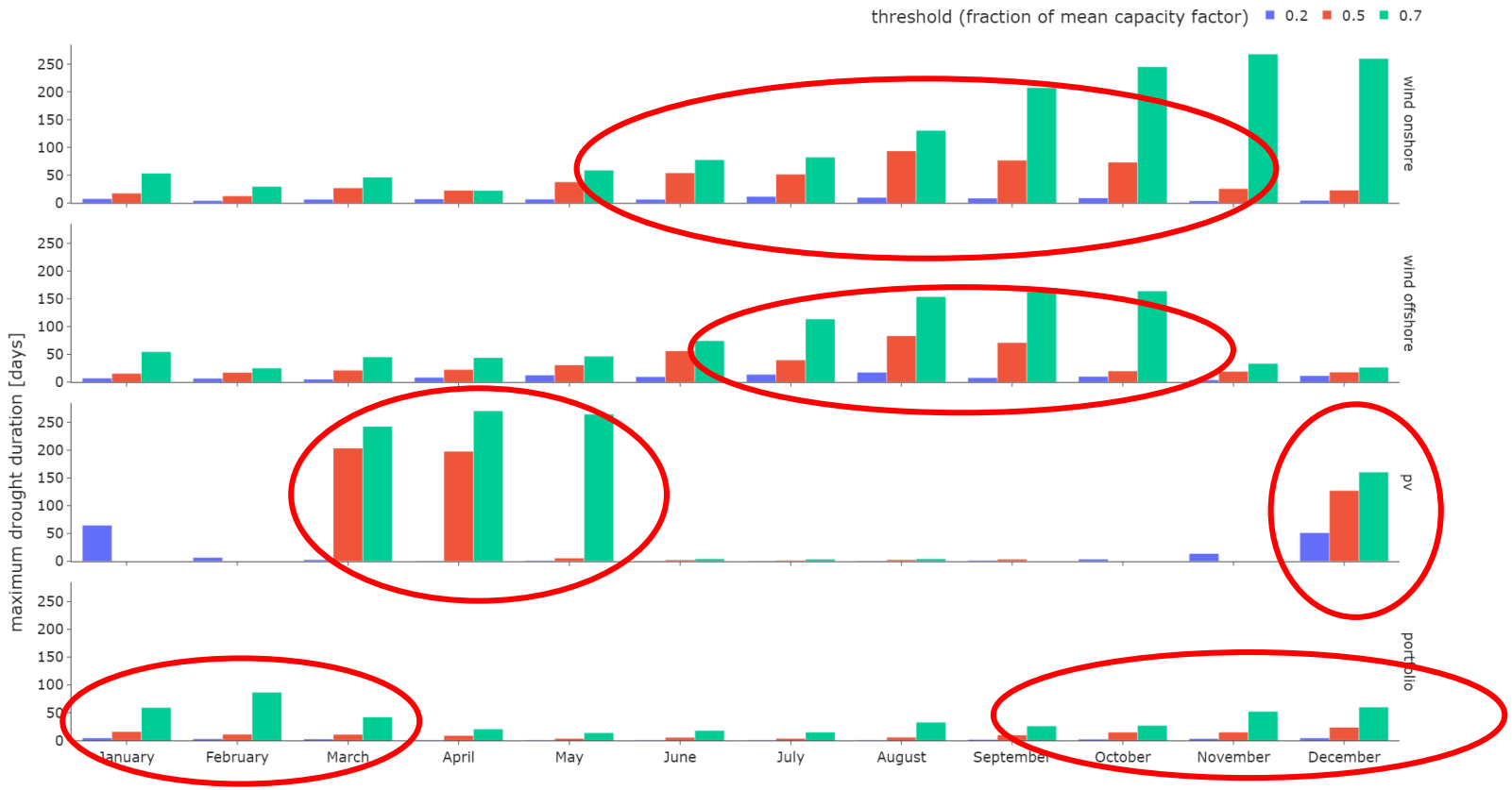
- Low overlap across technologies → combination of VRE reduces most extreme durations

3.3 VRE droughts in Germany: most extreme period duration and full load hours across years



- Low correlation of full load hours and maximum drought duration → single period might not be driving optimal energy system configuration

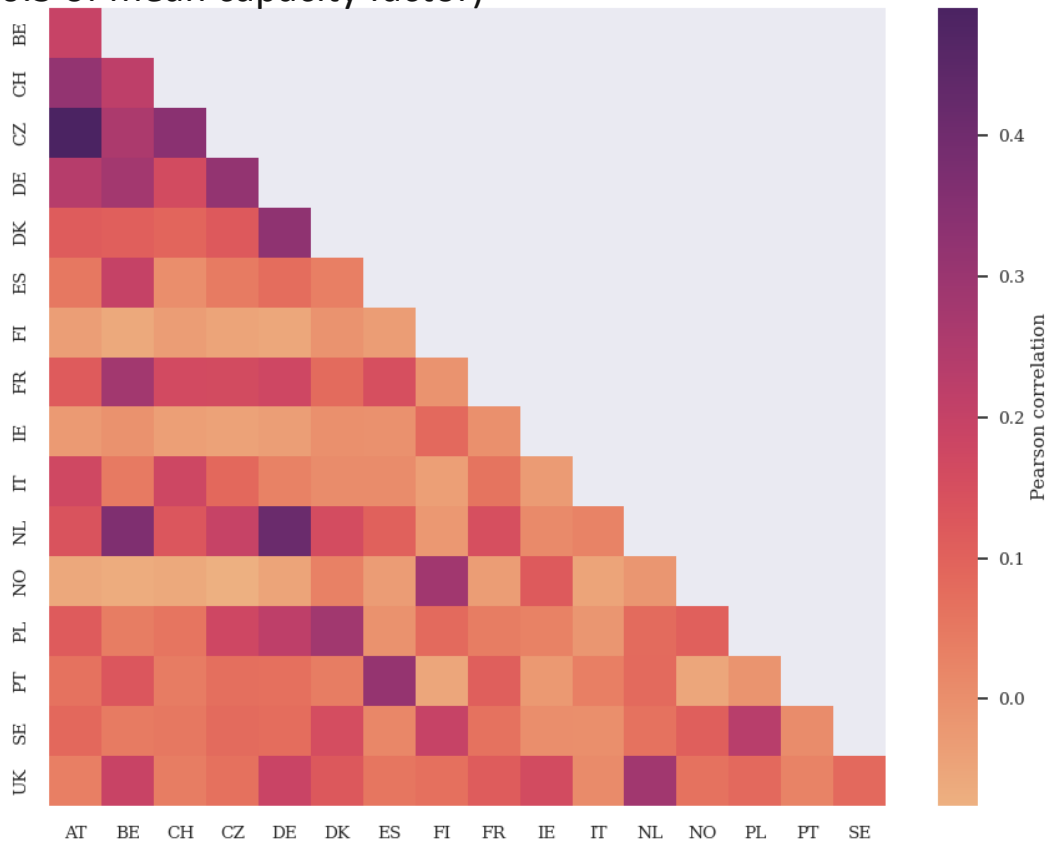
3.4 VRE droughts in Germany: most extreme period duration across seasons



- Most extreme months differs across technologies
- Low overlap across seasons → combination of VRE reduces most extreme durations
- Very high thresholds only relevant for evaluation of VRE portfolio

3.5 VRE droughts in Europe: correlation of most extreme periods across regions

Temporal correlation of droughts lasting longer than one week across all regions (threshold = 0.5 of mean capacity factor)



- Strong variation across Europe → implication for regional balancing

4.1 Conclusion

VRE drought patterns

- Regional variation across Europe
- Technological variation: combined VRE portfolio reduces extremes
- Seasonality variation: depends on technology (mix)
- Spatio-temporal correlation → implications for long-term system planning, esp. flexibility options

Energy modeling implication

- Scenarios with high renewable shares → multiple weather years imperative (TYNDP22: 3 years)
- Hypothesis: not only most extreme period relevant for flexibility need

4.2 Outlook

Tool development

- Compound events: VRE generation net of load (Pandora's box)
- Open access & open source

Future analysis

- Other technologies, e.g., hydro power in Norway
- Climate sensitivity → PECD v4.0
- energy system model applications

Thank you for your attention!

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