Variable renewable energy droughts in Europe

Martin Kittel, Wolf-Peter Schill
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Agenda

1. Motivation & research question
2. Methods
3. Results
4. Conclusion & outlook
High variability in renewable power sector

Power generation in Germany (November 2022)

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

Power generation in Germany (November, December 2022)

Source: www.agora-energiewende.de [22.06.23]
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)**
- consecutive hours below drought threshold

**Mean Below Threshold (MBT)**
- 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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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
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
VRE droughts in Germany: most extreme period duration across years

- Selection of relevant weather years matters
- Combination of VRE reduces most extreme durations
Temporal correlation of droughts lasting longer than two weeks across all years (threshold = 0.5 of mean capacity factor)

- Low overlap across technologies \(\rightarrow\) 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

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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
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
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!

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

Martin Kittel
mkittel@diw.de