EMS Annual Meeting 2025 – 12.09.2025

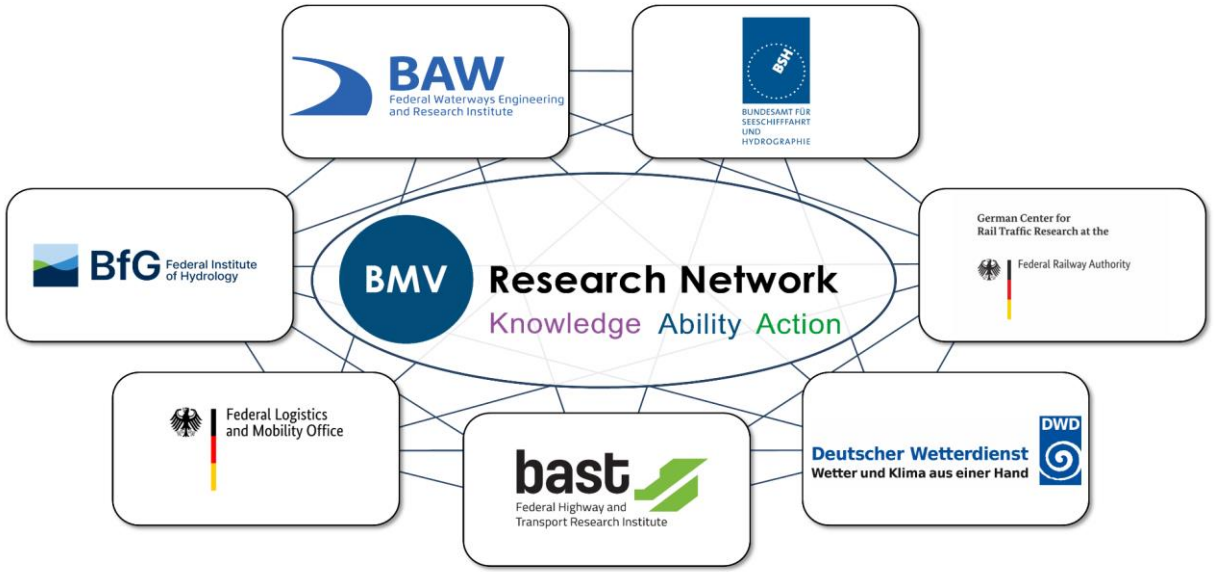
BMV Research Network
Knowledge Ability Action

‘Dunkelflaute’ as an extraordinary weather event for the energy sector in Germany using precise power plant data

Viola Dost (DWD), Franziska Bär (DWD)

SCREEN CAPTURE WELCOME

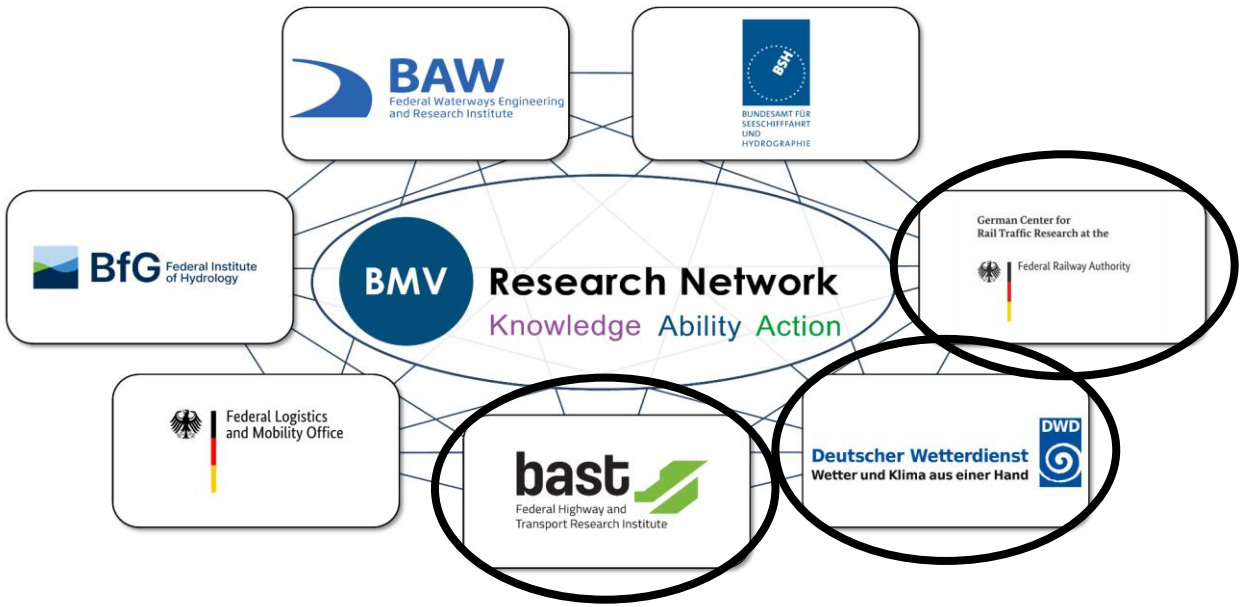
The Project



- Cross-institutional research in the transport sector
- Create basis for a resilient and environmentally compatible transport system

SCREEN CAPTURE WELCOME

The Project



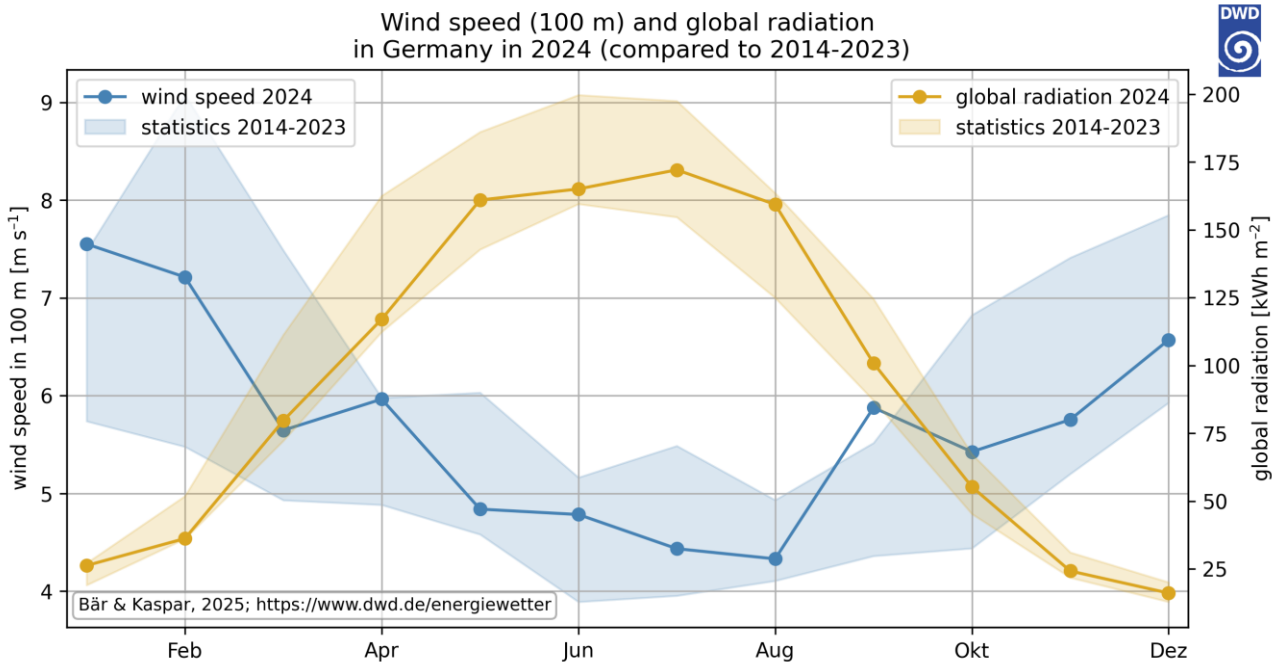
- Cross-institutional research in the transport sector
- Create basis for a resilient and environmentally compatible transport system

- Topic Area: Renewable energies

→ Assessment of renewable energy potential along transport infrastructure

Motivation

- Variability of renewable energies is of importance to asses potential production along transport infrastructure
- Solar radiation and wind speed complement each other over the course of the year [1]



[1]Bär, F., Kaspar, F. (2025). Energiewetter im Jahr 2024: Meteorologischer Jahresrückblick auf energierelevante Wetterelemente. Deutscher Wetterdienst / BMDV-Expertennetzwerk. https://www.dwd.de/energiewetter

Motivation

- Variability of renewable energies is of importance to asses potential production along transport infrastructure
- Solar radiation and wind speed complement each other over the course of the year [1]
- Multiple extraordinary weather events can put stress on the energy system

→ Low production of wind and solar energy, so-called ‘Dunkelflaute’

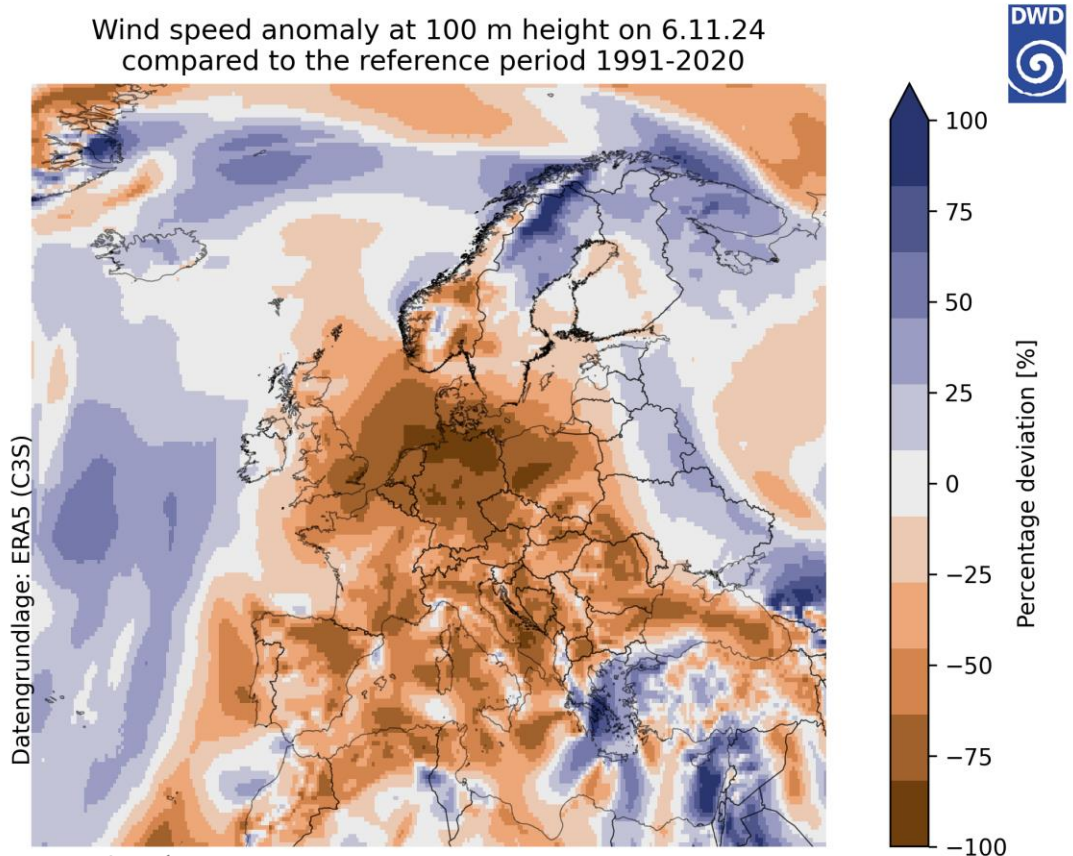
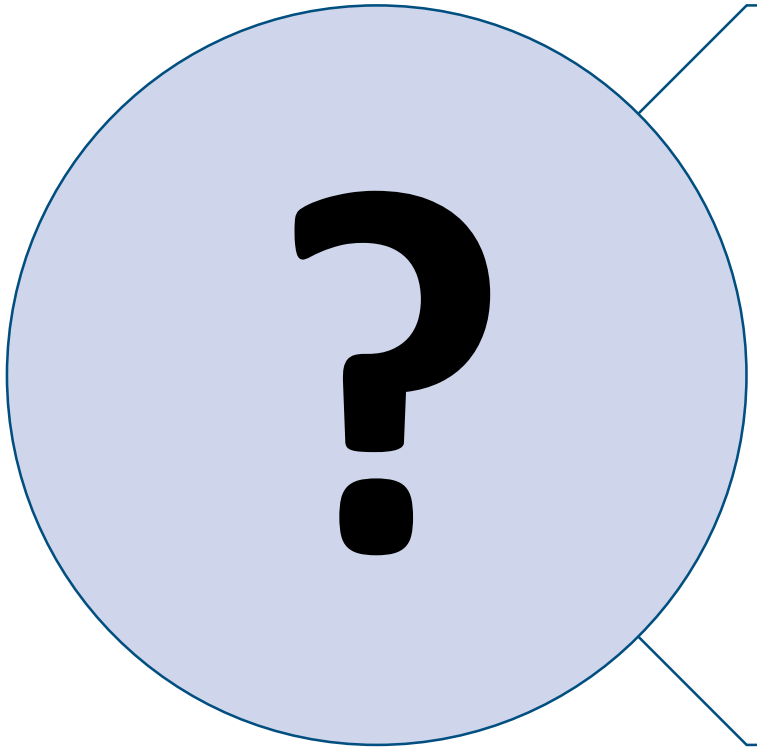


Figure from [1]

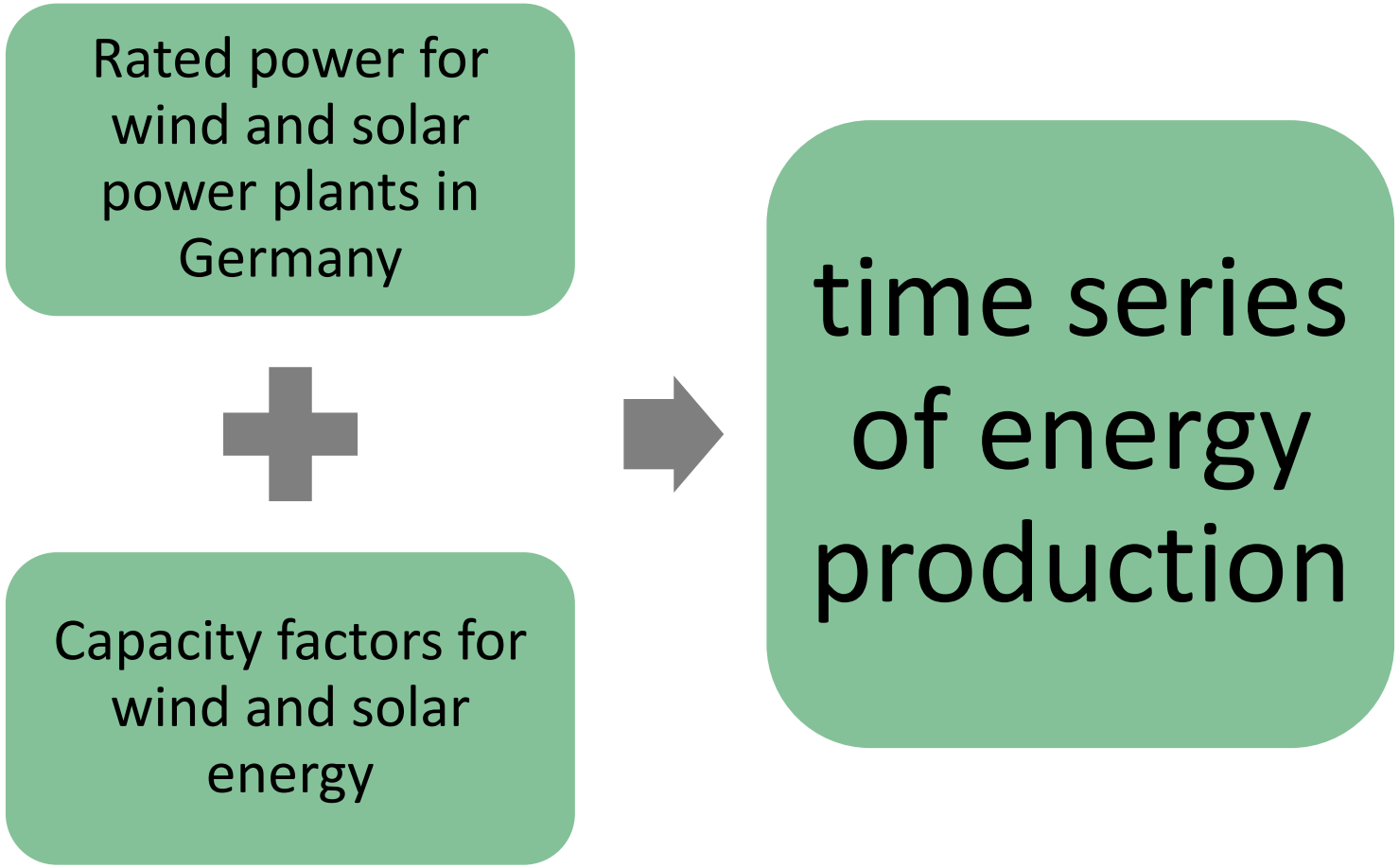
[1]Bär, F., Kaspar, F. (2025). Energiewetter im Jahr 2024: Meteorologischer Jahresrückblick auf energierelevante Wetterelemente. Deutscher Wetterdienst / BMDV-Expertennetzwerk. https://www.dwd.de/energiewetter

Research Question



How often do situations like the 6th of November occur?

Basis of analysis



Rated power

- Taken from MaStR (Core Energy Market Data Register)

→ Database including all power producing units in Germany

→ Owners fill in data themselves 

- Using version from 1st of January 2025

Processing:

✓ Remove power plant not in service

✓ Remove power plants with coordinates outside of Germany

✓ Check position of solar power plants with rated power > 10 MW

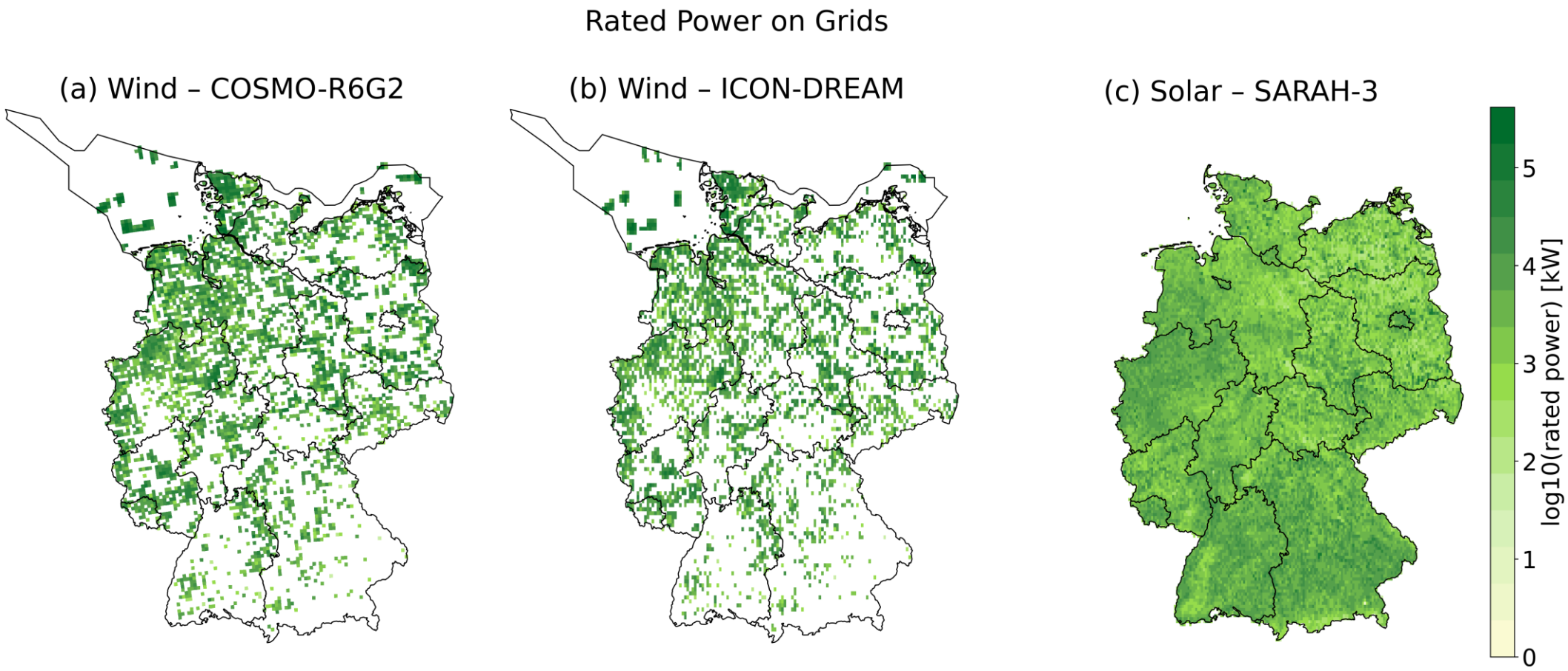
✓ Remove very small wind power plants and when coordinates or rotor diameter are missing [1]

✓ Remove wind power plants when rotor-generator ratio* is outside of plausible range [1]

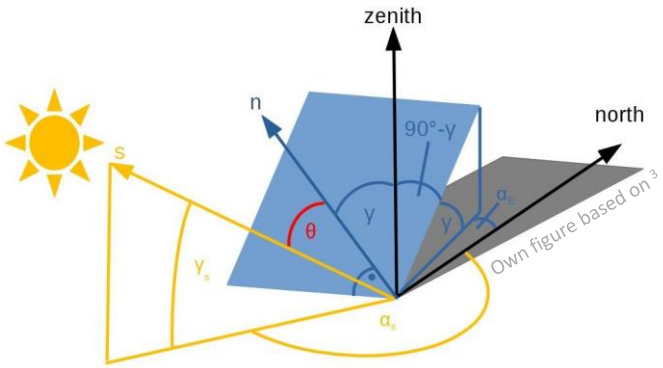
*rotor-generator ratio = rated power divided by the circle area swept by rotor blades

[1]Geiger, D., et al. (2025). Assessing the performance of reanalysis and meso-scale model datasets for onshore wind power modelling in Germany. [Manuscript submitted for publication in Advances in Science and Research].

Rated power



Capacity factors



- capacity factor = $\frac{\text{real power output}}{\text{maximum power output}}$
- Solar capacity factor (CF)
  - Radiation input from CM-SAF SARAH-3 [1]
  - Surface wind and temperature from COSMO-R6G2 the follow-up of COSMO-REA6 [2]
  - 9 module set-ups weighted based on the MaStR → equal for all grid points
  - 0.05° (~5 km) grid spacing
- Wind CF
  - Wind speed, density and temperature input from COSMO-R6G2 or ICON-DREAM
  - Representative wind power plants weighted based on the MaStR → separate for on-shore and off-shore
  - 6 km or 0.065° (~6.5 km) grid spacing
- Using data from 2012–2023

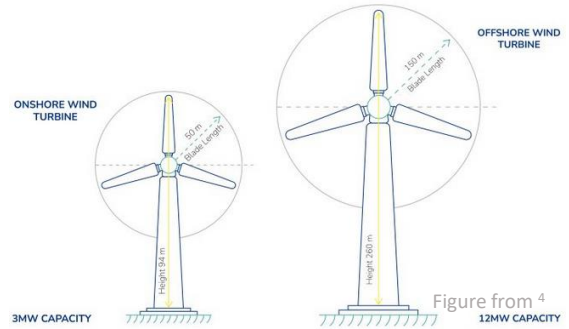
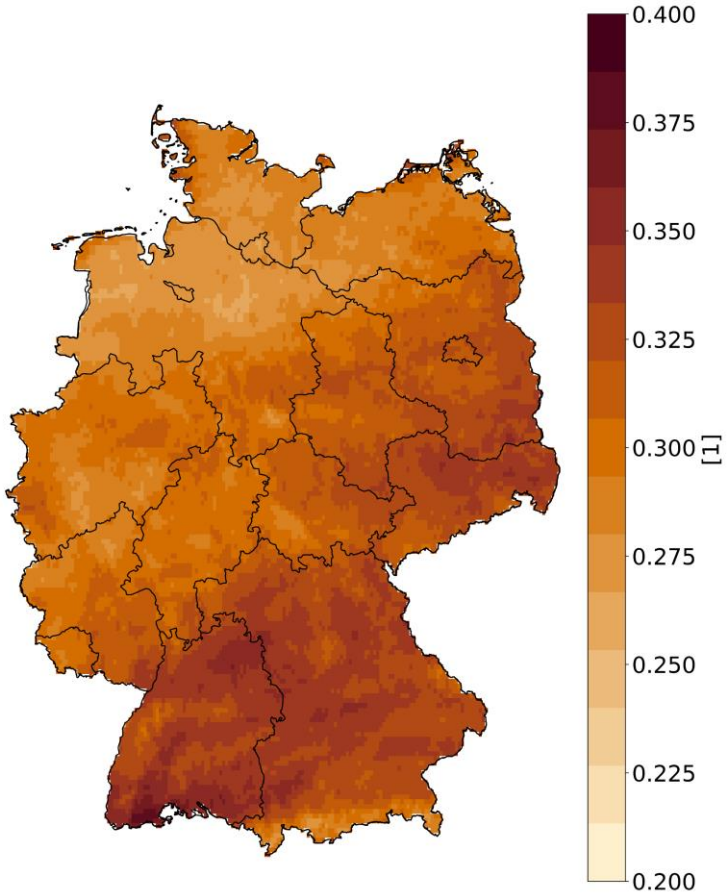


Figure from [4]

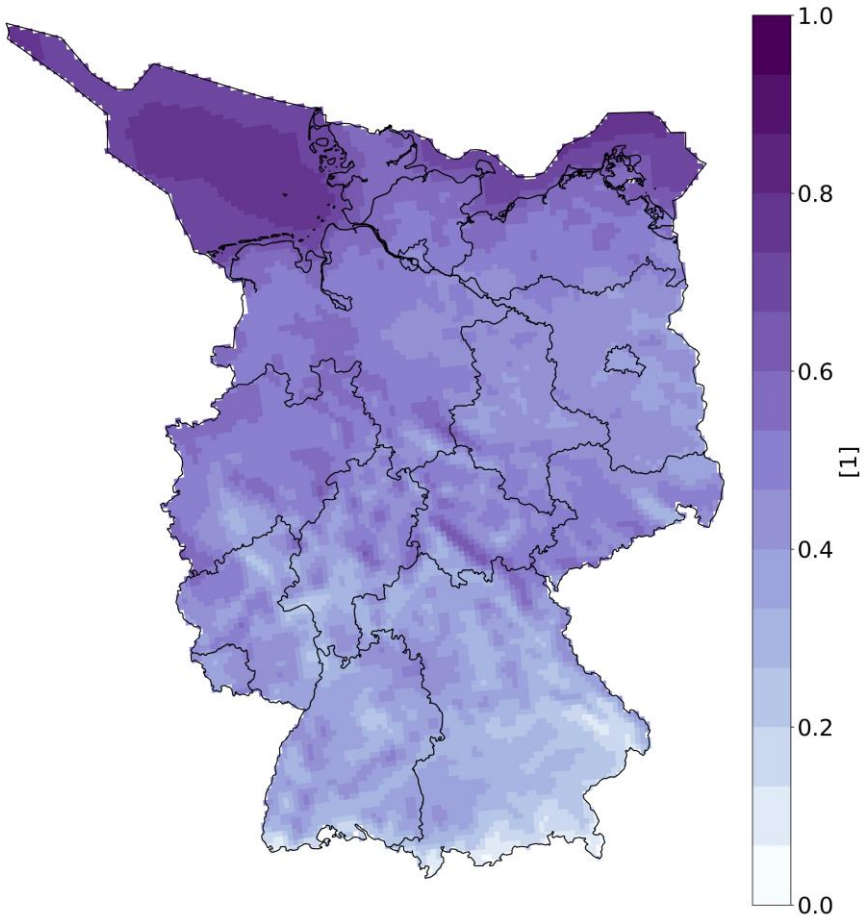
[1]Pfeifroth U., et al (2023). Surface Radiation Data Set - Heliosat (SARAH) - Edition 3, Satellite Application Facility on Climate Monitoring.
[2]Bollmeyer, et al. (2015). Towards a high-resolution regional reanalysis for the European CORDEX domain. Quarterly Journal of the Royal Meteorological Society 141.686: 1-15.
[3]Quaschning, V. (2021). Regenerative Energiesysteme: Technologie - Berechnung - Klimaschutz. Hanser.
[4]https://lumifyenergy.com/blog/different-types-of-wind-turbines/

Capacity factors

Solar CF



Wind CF



Energy time series

Multiplying capacity factors with rated power to get energy

Using factors of 14% [1] for solar and 16% [2,3] for wind to include losses

Calculating area sums

[1]European Commission (2024). PHOTOVOLTSIC GEOGRAPHICAL INFORMATION SYSTEM. https://re.jrc.ec.europa.eu/pvg_tools/en/
[2]Lee and Fields (2021). An overview of wind-energy-production prediction bias, losses, and uncertainties. Wind Energ. Sci. 6(2), 311–365. DOI:10.5194/wes-6-311-2021
[3]Lehneis et al. (2021). Modeling of the German Wind Power Production with High Spatiotemporal Resolution. Resolution. ISPRS International Journal of Geo-Information 10(2), 104. https://www.mdpi.com/2220-9964/10/2/104

Threshold analysis

24 h sum

- only 10% of mean daily November solar and wind energy production generated on 6th of November 2024
- similar sums are not found for 2012–2023

144 h sum

- whole event from 2nd – 7th of November
- No comparable low sums are found

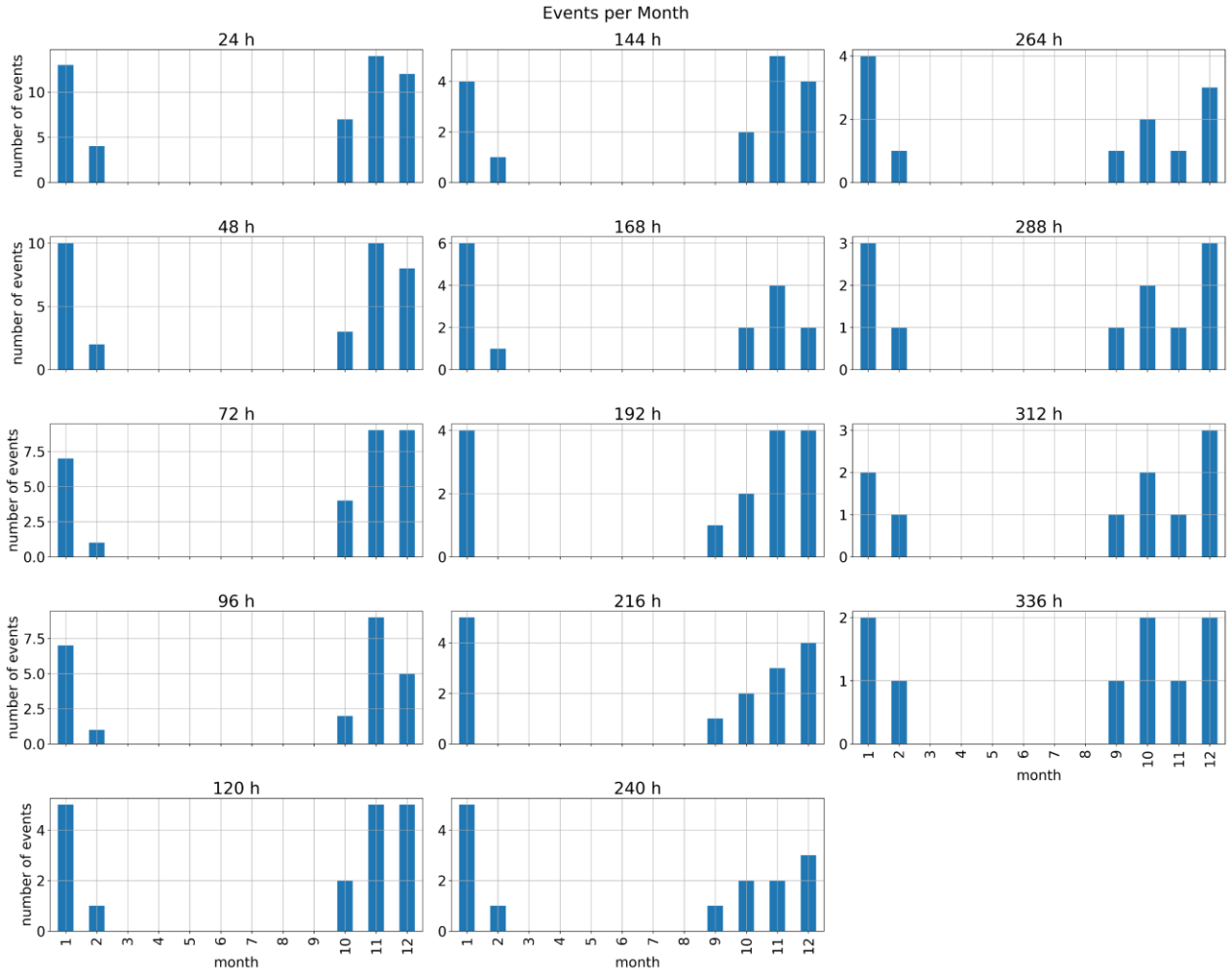
Quantile-based analysis

- Used to assess the occurrence of low wind and solar energy production
- Moving sums for different time windows (1–14 days)
- 1% of time steps with lowest total energy analyzed
- Consecutive timesteps are seen as one event

→ Events with longer durations are rarer than shorter ones

→ we find 1–5 events per year

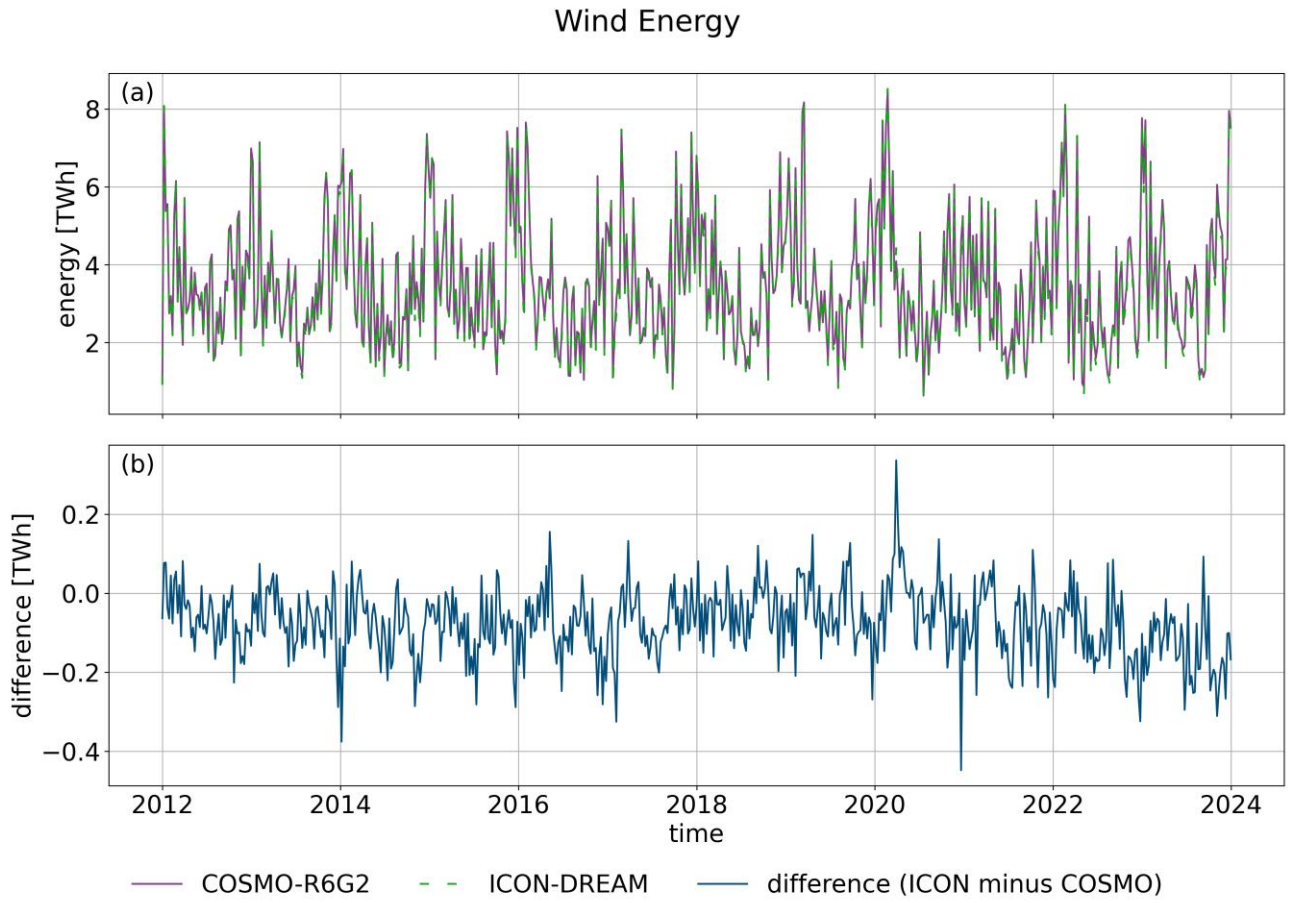
Quantile-based analysis



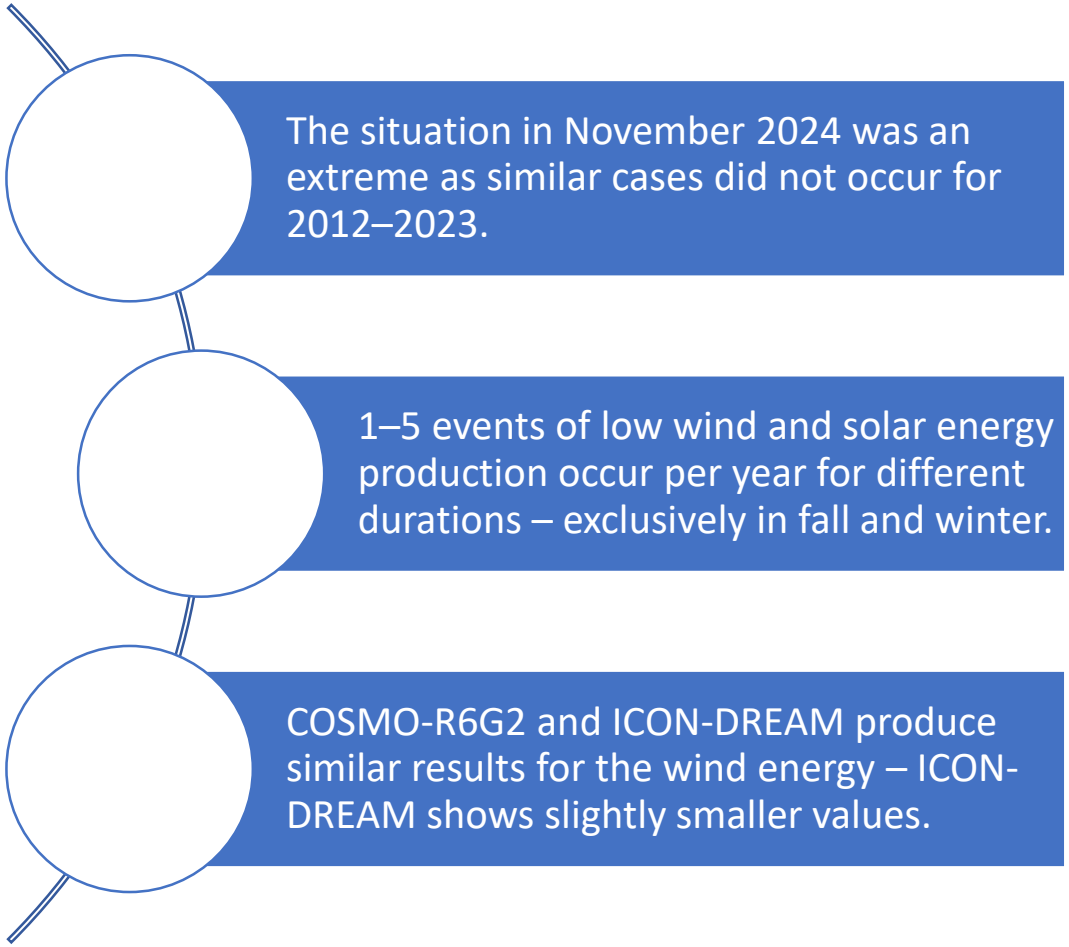
- Occurrence is limited to fall and winter
- Usage of ICON-DREAM as input for the wind CF gives slightly different events but overall similar results

Comparing wind energy

- General agreement between wind energy based on COSMO-R6G2 and based on ICON-DREAM
- Use of ICON-DREAM results in slightly smaller values



Take away



- The report on this is going to be released shortly.

→ Find at

https://www.bmv-forschungsnetzwerk.bund.de/

- Contact me for further questions: viola.dost@dwd.de