Dunkelflaute and long-term electric energy shortage events in Europe

Yvonne Scholz[1], Lueder von Bremen[1], Gerald Lohmann[1], Wenxuan Hu[1], Marion Schroedter-Homscheidt[1]
[1]*German Aerospace Center (DLR), Institute of Networked Energy Systems, Oldenburg, Germany*
yvonne.scholz@dlr.de

In central Europe, slowly moving low-pressure systems in winter can cause prolonged periods of low wind and solar power generation with simultaneously increased demand for electricity for heating. Information about such electric energy shortage events is important for long term planning of storage capacities and other flexibility options in energy supply systems with high shares of variable renewable energy (VRE) sources. Furthermore, multi-annual remaining residual loads may cause additional needs of VRE generators.
We use the *TYNDP Distributed Energy*[1] scenario and 30 years of *ERA5* reanalysis data[2] to investigate shortage events of different duration that, given the installed capacities from the scenario, would have happened in Europe between 1990 and 2020. The information helps assessing the amount of energy required for balancing or generator extension. We also identify the calendar dates when the events would have occurred. The identified most critical calendar periods can be used as input to specify the set-up of further energy systems analysis studies.

Data

- ERA5 reanalysis data[2]: SSRD, T_2M, U_100M, V100M
- European supply scenario based on TYNDP Distributed Energy[1]
  - Interpolated year 2035
  - Capacity: 648 GW PV, 687 GW Wind onshore, 206 GW Wind offshore
  - Power demand: 4365 TWh/a
- ENTSO-E energy demand data[3]

Methods

- Power generation time series with EnDAT[4] (Energy Data Analysis Tool)
- Residual load: daily power demand minus daily VRE power generation
- Residual load anomalies: residual load minus mean residual load
- Rolling averages of residual load anomalies with different durations:
  - Dunkelflaute: several days
  - Seasonal electric energy shortages: one to several months
  - Long term electric energy shortages: one to several years

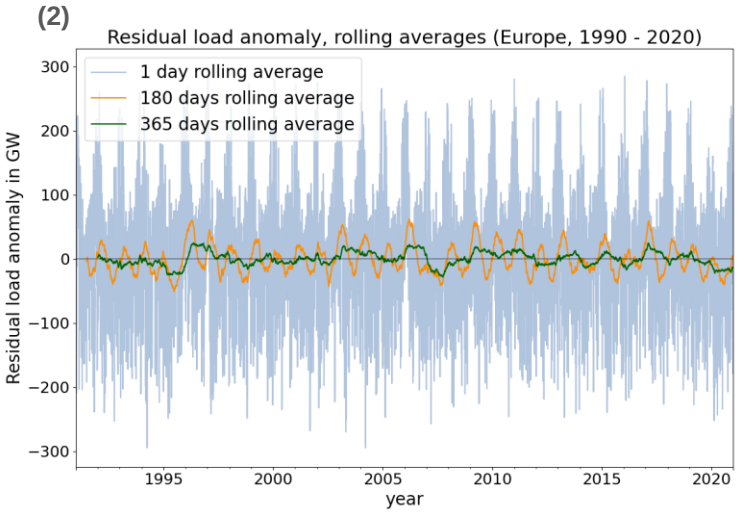
Results

(1)

- Mean load: 410 GW
- Mean residual load: 84 GW
- → 79.5 % VRE
- → 20.5 % non-VRE

Subtracting the mean residual load from the residual load sets the mean residual load as a reference. The result is a time series of residual load anomalies

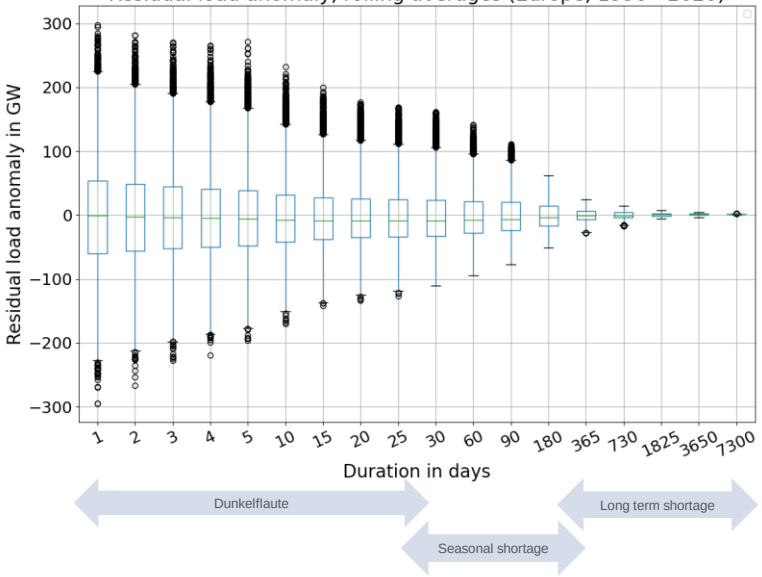
(2)



- Maximum one day rolling average of residual load anomaly: 298 GW ≙ 355 % of mean residual load
- 180-day rolling average: distinct seasonal pattern with winter peaks
- One-Year (365-day) rolling average can be above the mean residual load for more than one year in a row

Plotting distributions of residual load anomalies with different rolling average windows = durations

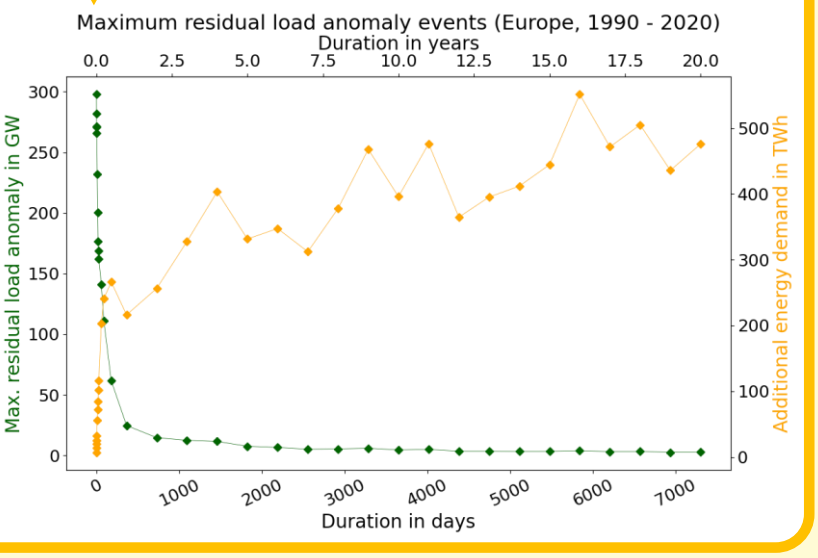
(3)



- Averaging a “classical Dunkelflaute” period of 14 days leads to variations of the residual load anomalies between 207 GW and -144 GW ≙ 246 % and -171 % of mean residual load
- Less than 4 years averaging is associated with maximum residual load anomaly values of more than 10 % of medium residual load
- 10 year residual load anomaly is still up to +5 % of mean residual load

Focusing on the maxima and considering the resulting additional energy demand

(4)



The figure shows *maximum* residual load anomalies and the corresponding additional energy demand for different rolling averaging durations. The additional energy demand must be balanced using storage, imports or additional generators. In a 10 year period, it can be as high as ~400 TWh ≙ 5% above average and in a 20 year period, it can still amount to around 480 TWh ≙ 3 % above average.

Key take aways and outlook

- Energy shortage events of one day to several years duration can be important for energy system modelling,
- The residual load and with it the energy demand can be elevated by up to 246 % compared to the mean residual demand in a 14 day period, by up to 29% in one year and 5% in ten years,
- If a year with average residual load is chosen for energy systems modelling, the long term storage requirement can therefore be underestimated,
- The identified time periods and the corresponding VRE and demand time series can be used in energy system models for further investigation,
- The identified time periods may also be chosen or used to generate synthetic weather years that reflect extremes of residual load for energy systems modelling.

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References

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