Multi-decadal offshore wind power variability can be mitigated through optimized European allocation

Charlotte Neubacher\textsuperscript{1,2}, Jan Wohland\textsuperscript{3}, and Dirk Witthaut\textsuperscript{1,4}

\textsuperscript{1}Institute for Theoretical Physics, University of Cologne, 50937 Köln, Germany
\textsuperscript{2}Forschungszentrum Jülich, Institute for Energy and Climate Research - Troposphere (IEK-8), 52428 Jülich, Germany
\textsuperscript{3}Climate Policy Group, Department of Environmental Systems Science, ETH Zürich, 8092 Zürich, Switzerland
\textsuperscript{4}Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK-STE), 52428 Jülich, Germany

Wind power generation is a promising technology to reduce greenhouse gas emissions in line with the Paris Agreement. In the recent years, the global offshore wind market grew around 30\% per year but the full potential of this technology is still not fully exploited. In fact, offshore wind power has the potential to generate more than the worldwide energy demand of today. The high variability of wind on many different timescales does, however, pose serious technical challenges for system integration and system security. With a few exceptions, little focus has been given to multi-decadal variability. Our research therefore focuses on timescales exceeding ten years.

Based on detrended wind data from the coupled centennial reanalysis CERA-20C, we calculate long-term offshore wind power generation time series across Europe and analyze their variability with a focus on the North Sea, the Mediterranean Sea and the Atlantic Ocean. Our approach is based on two independent spectral analysis methods, namely power spectral density and singular spectrum analysis. The latter is particularly well suited for relatively short and noisy time series. In both methods an AR(1)-process is considered as a realistic model for the noisy background. The analysis is complemented by computing the 20yr running mean to also gain insight into long term developments and quantify benefits of large-scale balancing.

We find strong indications for two significant multidecadal modes, which appear consistently independent of the statistical method and at all locations subject to our investigation. Moreover, we reveal potential to mitigate multidecadal offshore wind power generation variability via spatial balancing in Europe. In particular, optimized allocations off the Portuguese coast and in the North Sea allow for considerably more stable wind power generation on multi-decadal time scales.