EGU21-4888
https://doi.org/10.5194/egusphere-egu21-4888
EGU General Assembly 2021

A kinetic energy budget perspective to understand efficiency reductions of offshore wind generation in the German Bight in the North Sea

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The European Commission's net zero decarbonization scenarios estimate that up to 450GW of offshore wind capacity could be installed in Europe by 2050. German energy scenarios estimate that 50 to 70 GW of this could be installed in the German Bight in the North Sea and yield about 4000 full load hours (FLH) per year of power. However, these assume that wind speeds and yields are not reduced by the increased extraction of kinetic energy from the regional atmospheric flow by large wind farms. Our initial assessment of these assumptions, using two different approaches - the simple Kinetic Energy Budget of the Atmosphere model (KEBA) and the Weather Research and Forecasting model with Explicit Wake Parameterization (WRF-EWP), showed that emplacing such a large turbine capacity within the German Bight may lower expected yield down to 3300-3000 FLH. Here, we identify the major factors leading to this reduction. We use the two models to evaluate the role of atmospheric variables like wind directions, atmospheric stability, boundary layer height and surface friction in constraining large scale offshore wind energy generation. We test the KEBA model concept of limited kinetic energy fluxes through the boundary layer determining generation potential, and investigate deviations between the models to identify limitations of the simpler approach.The WRF model sets our "best guess" of energy yield from regional wind turbine deployments (at scales of $10^4 km^2$) since the scale of deployments that we assess are not in operation yet. Our analysis will provide insights about key atmospheric variables that shape regional offshorewind energy potential of the German Bight. We propose that estimating regional wind energy potential should account for atmospheric response.