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Yield Predictions for German Offshore Tenders 2025 – Let's plan an offshore wind farm!

Background: Most offshore wind farm areas are located more than 12 nautical miles away from the coastlines inside exclusive economic zones. The rights to commission, operate and decommission a wind farm are typically provided through yearly public tenders where different developers bid on. The one with the best conditions wins the rights for a fixed term of 20 years plus a potential extension.

Let's assume you have started a job at such a developer/operator and one of your first tasks is to estimate the potential energy yield of a future offshore wind farms on one of the areas that are currently tendered (until late summer 2025) in the cluster N-10 (areas N-10.1 and N-10.2) in the German Bight.

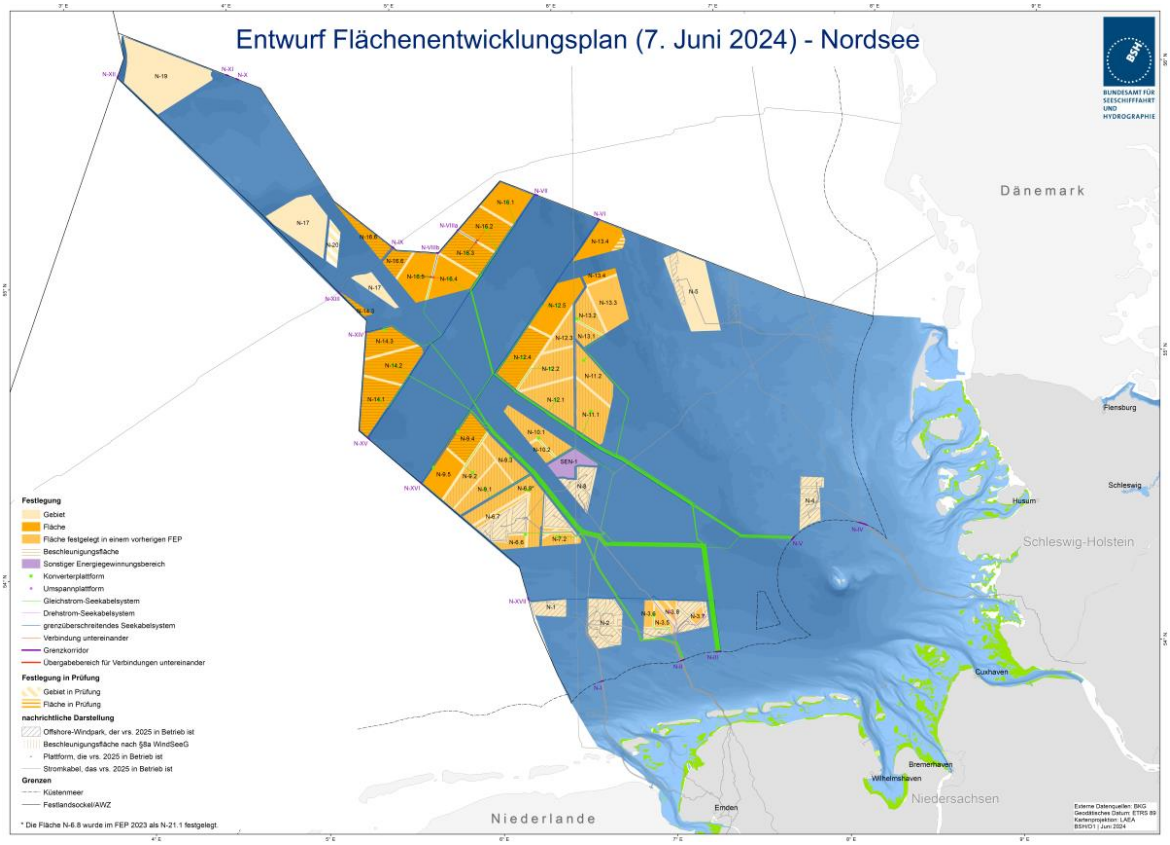

Figure 1: Wind farm clusters in the German Bight. The currently tendered areas are N-10.1 and N-10.2 located in the center, left of the purple area. (source: BSH)

Overall Goal: Estimate the potential long-term yield and its distribution over the turbines for the area N-10.1/N-10.2 (dependent on your group) using various python packages and methods that were presented in the Python Programming and Modelling (last semester) and PPES courses. This should include energy yield (power), internal wake losses and external wake losses.

Due Date: Tuesday 01.07.2025 - upload via stud.ip. This is **the day before the presentations**!

Deliverable: Well documented jupyter notebook including plots of relevant quantities (histograms/windroses/scatterplots/maps etc.). Well documented here means: 1) extensively comment on your clean code and, 2) use markdown cells to explain our methodology and discuss the results, similarly to what you'd normally include in a report.

Data provided:

- Floating lidar measurement data
- Long-term reference model data (ERA5): 1995-2024
- Turbine coordinates of existing and planned wind farms
- Geometric turbine coordinates for the areas of interest N-10.1/N-10.2 (not optimized – see Task 12)
- Shapefiles of wind farm areas, the countries Denmark, Germany and the Netherlands (mainly for nice plots)
- Thrust and power curves (public material only)

Tasks (can also be started in different order):

1. Organize all input data, filter, and read them in in a proper way.
2. Plot relevant quantities (e.g. histograms, windroses, spatial plots or maps, time series, scatterplots, etc.) of the input data and describe potential deficiencies (e.g. data gaps). Compare the lidar with the reanalysis data for the period lidar data is available.
3. Execute a long-term referencing with lidar measurements on model data (ERA5) using multiple (at least 2) MCP methods. Plot the relevant variables to demonstrate the effect of the long-term referencing. Explain the differences with the original reanalysis data (analyzed in task 2).
4. Calculate the yield of the area N-10.1/N-10.2 without external wake effects (no other wind farms) using FOXES. Use the year 2006 from the long-term corrected ERA5 data as input. This year is generally considered to be representative of the last 30 years in terms of wind climate.
5. Use two other FOXES setups (wake models) of your choice to calculate the yield again and plot the differences. Explain your results.
6. Pick one of your three FOXES setups. Next, run a FOXES simulation with existing and future wind farms. To limit computational time, only consider wind farms in a ~50 km radius from areas N-10.1/N-10.2. Calculate the energy yield of N-10.1/N-10.2.
7. Derive the wake losses. This is, in percentage, the yield you lose due to the wake effect, relative to the theoretical situation in which no wakes would occur. Estimate what part can be allocated to external wake effects (other wind farms), and what part can be allocated to internal wake effects (the wind farm itself).

8. Plot the total yield of the individual turbines inside the areas of interest in a spatial plot for both the FOXES simulation with and without other wind farms. Analyze the result and explain the patterns.
9. Bonus: Optimize the wind farm layout based on the actual wind conditions using FOXES and iwopy and re-calculate the yield of tasks 4, 6-8.

Notes:

- The project is to be carried out in groups. You are free to choose your partners but not to change the groups later on.
- This is supposed to be a fun and dynamic project. We expect that you likely can't solve this completely on your own. Please attend Wednesday's tutorial to ask questions. We will help you and are also happy to discuss intermediate results there. Please also feel free to ask questions via studIP.
- You are encouraged to use all potential python libraries that might help you. The usage of AI like Gemini or Chat-GPT is not forbidden. However, we encourage you to also try to learn to solve the exercise yourself.
- On Wednesday 04.06 we will all ask you for a short update on your progress. No additional preparation needed, just show up with your group and show us what you did so far.
- There are many details that can be done differently; therefore, it is expected that every group will end up with different results! Too similar results will be investigated for plagiarism!