Lecturers: Balthazar Sengers, Hassan Kassem, Jonas Schulte, Lukas Vollmer, Martin Dörenkämper, Sandra Schwegmann

Yield Predictions for German Offshore Tenders 2024 – Let's plan an offshore wind farm!

Initial Position: Most offshore wind farm areas are located more than 12 nautical miles away from the coastlines of the countries and thus inside the exclusive economic zones. The rights to commission, operate and decommission a wind farm are typically provided via 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.

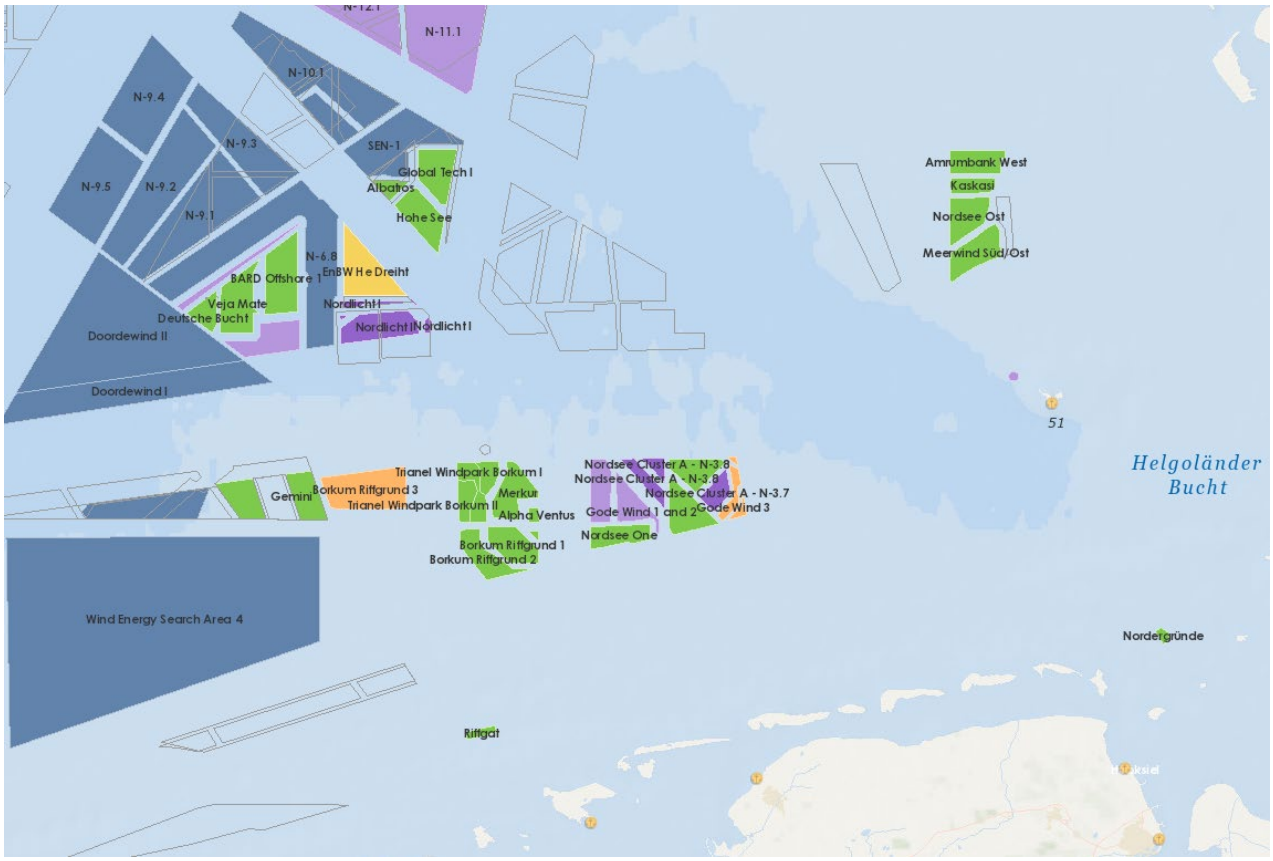

Figure 1: Wind farm clusters in the German Bight. The currently tendered areas are N-9.1/N-9.2 and N-9.3 located in the top left (source: 4coffshore.com.

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 2024) in the cluster N-9 (areas N-9.1/N-9.2 and N-9.3) in the German Bight.

Overall Goal: Estimate the potential long-term yield and its distribution over the turbines for the areas N-9.1/N-9.2/N-9.3 using various python packages and methods that were presented in the PPES course in winter and summer term. This should include yield, internal wake losses and external wake losses.

Due Date: Tuesday 25.06.2024 – noon - 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.

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Data provided:

- Floating lidar measurement data from two positions (netCDF-Files)
- Long-term reference model data (ERA5): 1990-2023 (csv-Files)
- Turbine coordinates of existing and planned wind farms (csv-files)
- Geometric turbine coordinates for the areas of interest N-9.1/N-9.2/N-9.3 (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 a 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).
3. Do a long-term referencing with lidar measurements and model data (ERA5) using different MCP methods
4. Plot the relevant quantities after long-term referencing
5. Find a geometrically optimized wind farm layout for the areas N-9.1, N-9.2 and N-9.3 using FOXES (you can use the provided material for reference but we want to see the code).
6. Calculate the yield of the areas N-9.1, N-9.2, N-9.3 without external effects. Use the long-term corrected ERA5 data as input.
7. Use three other FOXES setups of your choice (wake models) to calculate the yield again and plot the differences. Explain your results.
8. Pick one of your four FOXES setups. Next, run a FOXES simulation for all existing and future wind farms. Calculate the energy yield of your wind farm under the influence of both internal and external wakes.
9. 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).
10. Analyze the three areas separately in terms of the yield, total wake losses, internal wake losses and external wake losses.
11. Plot the yield of the individual turbines inside the areas of interest.
12. Bonus: Optimize the wind farm layout based on the actual wind conditions using FOXES and iwopy and re-calculate the yield of steps 6-11.

Notes:

- The project is to be carried out in groups students. You are free to choose your partners but don't 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. There might be even traps that we don't know yet. Please attend the Wednesday's class dates to ask questions. We will help you and 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 05.06 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 got.
- 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!