# The Average UK Offshore Wind: Testing Array Design

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## Objectives

This work uses freely available data provided by The Crown Estate's marine data exchange to analyse the offshore wind climate around the UK. Using the resulting expected climate values, CFD simulations are employed to compare various farm layout designs. It is expected that this work will emphasize the importance of designing the layout to mitigate turbulence intensity (TI) within a farm rather than maximising the overall power output.

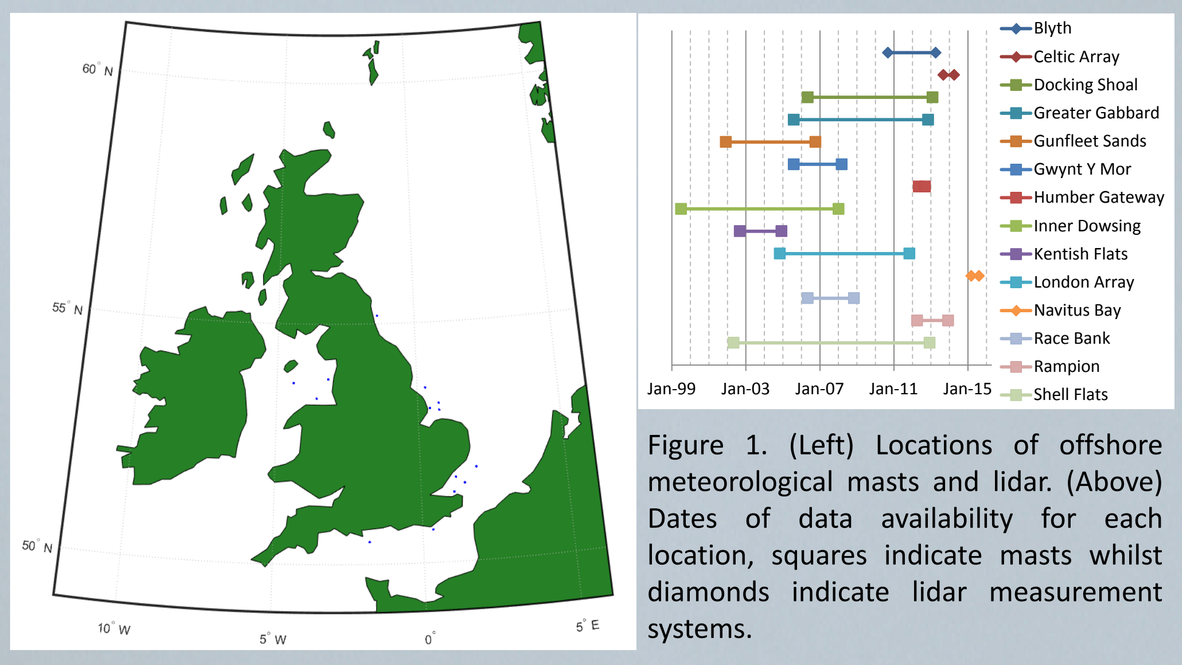


Figure 1. (Left) Locations of offshore meteorological masts and lidar. (Above) Dates of data availability for each location, squares indicate masts whilst diamonds indicate lidar measurement systems.

## Results – Data Analysis

The meteorological data is available without charge from the marine data exchange website and is therefore lacking in any of the normal data cleaning procedures normally applied to commercial datasets. This in part can be mitigated by careful analysis of individual locations, though it is not possible to ensure complications such as mast shadow effects have been fully accounted for in each set. In addition to data quality, variations in age, heights and the parameters measured at each location, values of TI are not always available and all comparisons should be considered with caution.

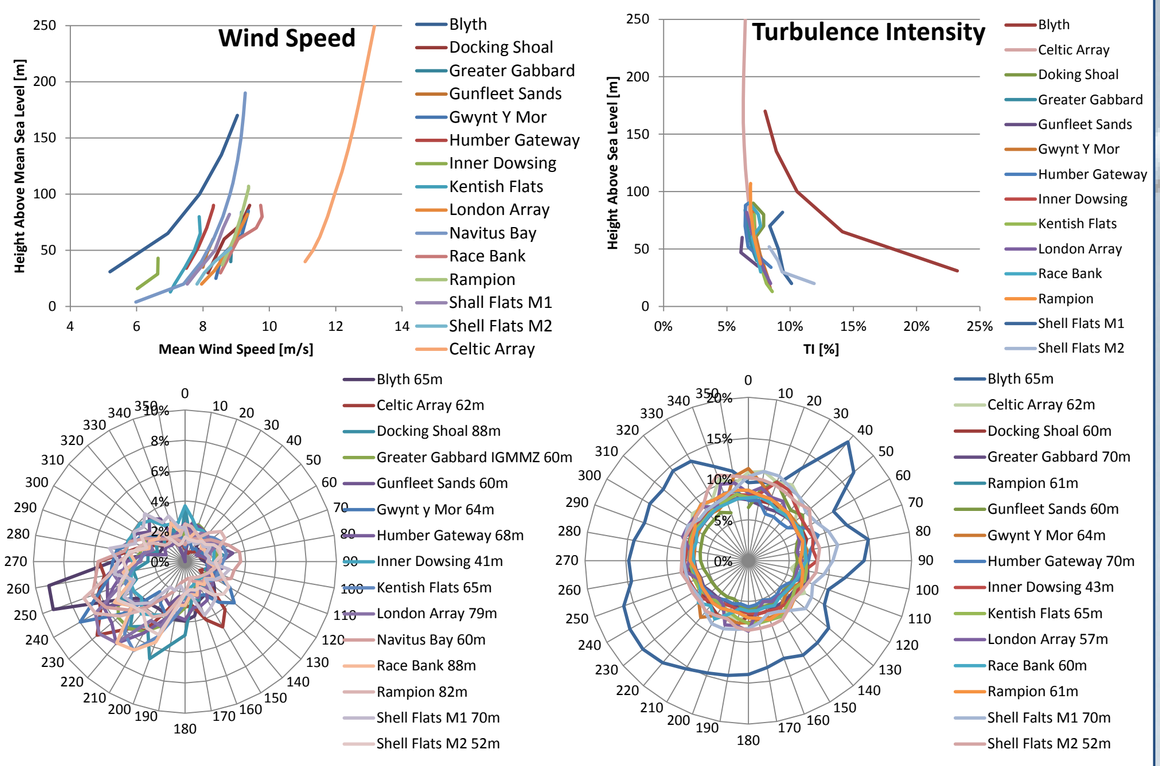


Figure 2: (Top) Vertical profiles of wind speed and TI, (Bottom left) wind rose and (bottom right) average TI value by direction for each location.

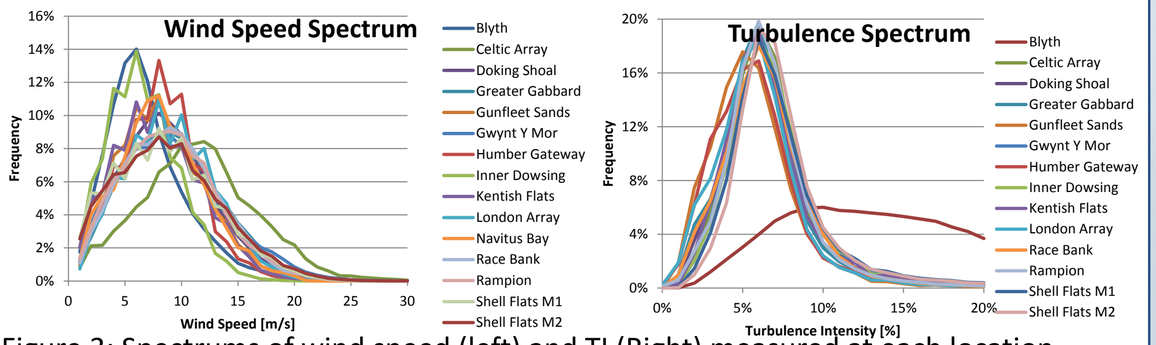


Figure 3: Spectrums of wind speed (left) and TI (Right) measured at each location.

With the exception of the Blyth lidar, which is located very close to shore, the wind conditions measured around the UK across many years is remarkably consistent in its distribution. This is likely due to the UK weather being mainly governed by synoptic-scale systems which track across the whole country. Notable variations such as at the Celtic Array are mostly due to measurement campaigns shorter than a complete year.

## Results – CFD Simulations

The second part consists of a series of RANS CFD simulations using the Windmodeller package of tools combined with actuator disks to represent 40 Siemens 3.6MW turbines with a 78m hub height and 107m diameter (D). The turbines were arranged in 5 rows of 8 turbines aligned East-West in a regular array. 16 different configurations were simulated with column and row separations varying between 8-11D and 5-8D respectively, covering between 12-28km$^2$. An additional 16 staggered layout configurations were also simulated with similar separations. 10m/s hub height wind speeds were simulated for each of the 32 arrays from each direction at 10° intervals.

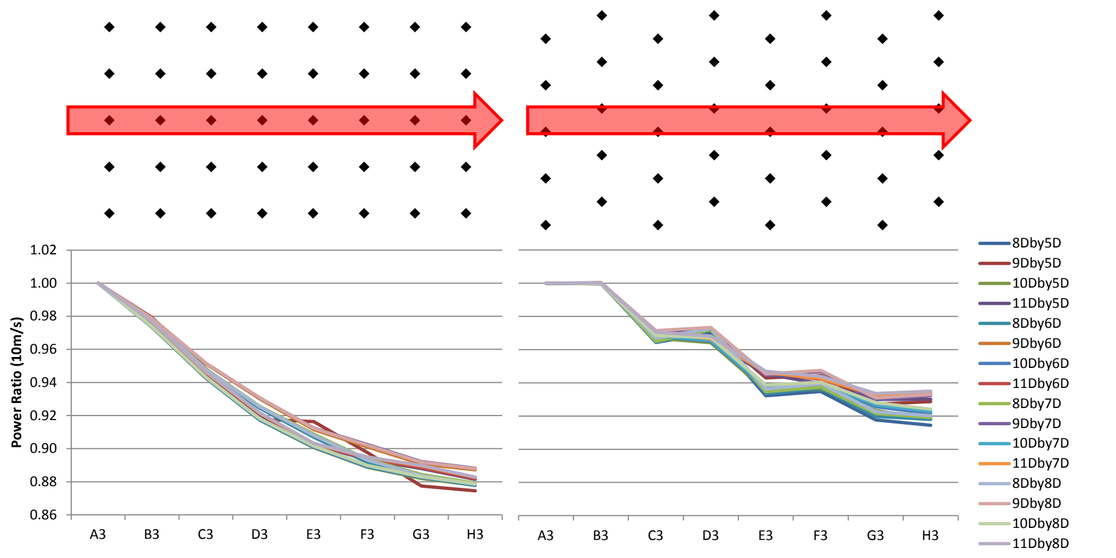


Figure 4. Example of results showing how power losses due to wake effects change with turbine layouts.

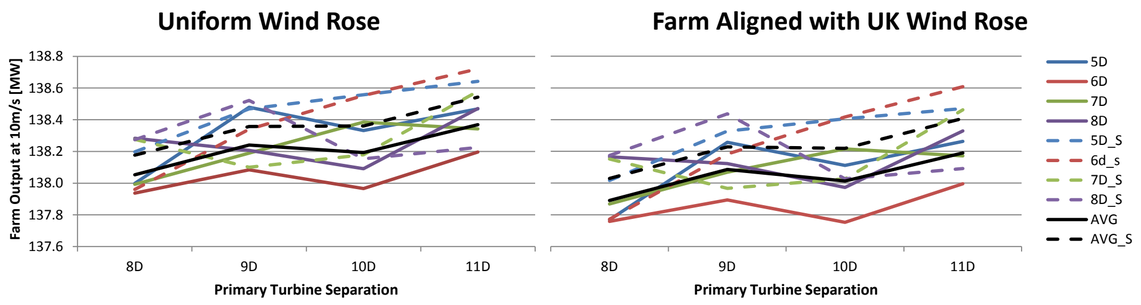


Figure 5. Simulated farm power generation by turbine separation for 10m/s wind speeds. Solid and dashed lines represent the regular and staggered arrays respectively.

Since it was expected that the farm alignment with the wind rose would influence the farm's output, the effect of rotating the farm was investigated and shown below.

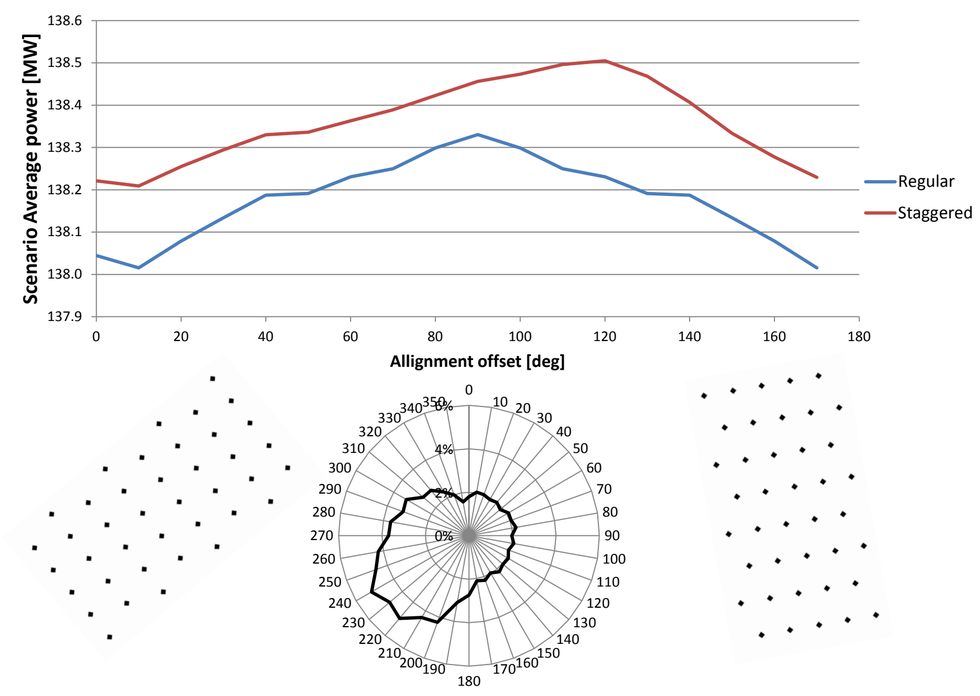


Figure 6. Anti-clockwise from top: Power output from farm with average turbine spacing against the angle offset between the prevailing wind and main farm axis, layout of staggered array aligned with prevailing wind, Averaged UK offshore wind rose from data available, layout of staggered array aligned for maximum power output.

## Conclusion

There is a strong correlation of wind speeds and directions between measurements taken at different offshore sites around the UK. There is even greater consistency between sites when considering TI. Data from the Celtic Array highlights the importance of running measurement campaigns throughout the year rather than just the winter months whilst the Blyth dataset shows the effects of being near to shore.

The lack of significant variability between simulated farm output despite a range of layouts suggest future farms could be more compact, though tests would first need to confirm that this would have no significant effect on fatigue through wake induced TI.

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