Offshore Turbine Wake Power Losses: Is Turbine Separation Significant?

Peter Argyle, Simon Watson

CREST, Loughborough University, UK

Introduction

The UK offshore regions currently being developed into wind farms are much larger than those developed previously, leading to turbines being built further apart. It has long been known that longer distances between turbines enable greater wake recoveries and thus higher farm output power productivity when the wind blows parallel to turbine rows. However the offshore wind rose is not unidirectional, meaning it is important to consider the wake recovery for all directions, especially as turbines spaced further apart are directly affected by wake conditions for fewer flow directions. This work uses Computational Fluid Dynamics (CFD) to simulate a 40 turbine offshore wind farm with 30 turbine separation options and 2 configurations. By weighting the results from 4 wind speeds and 10 degree bins, wind power production in the UK offshore climate is linked to turbine separation.

Analysis

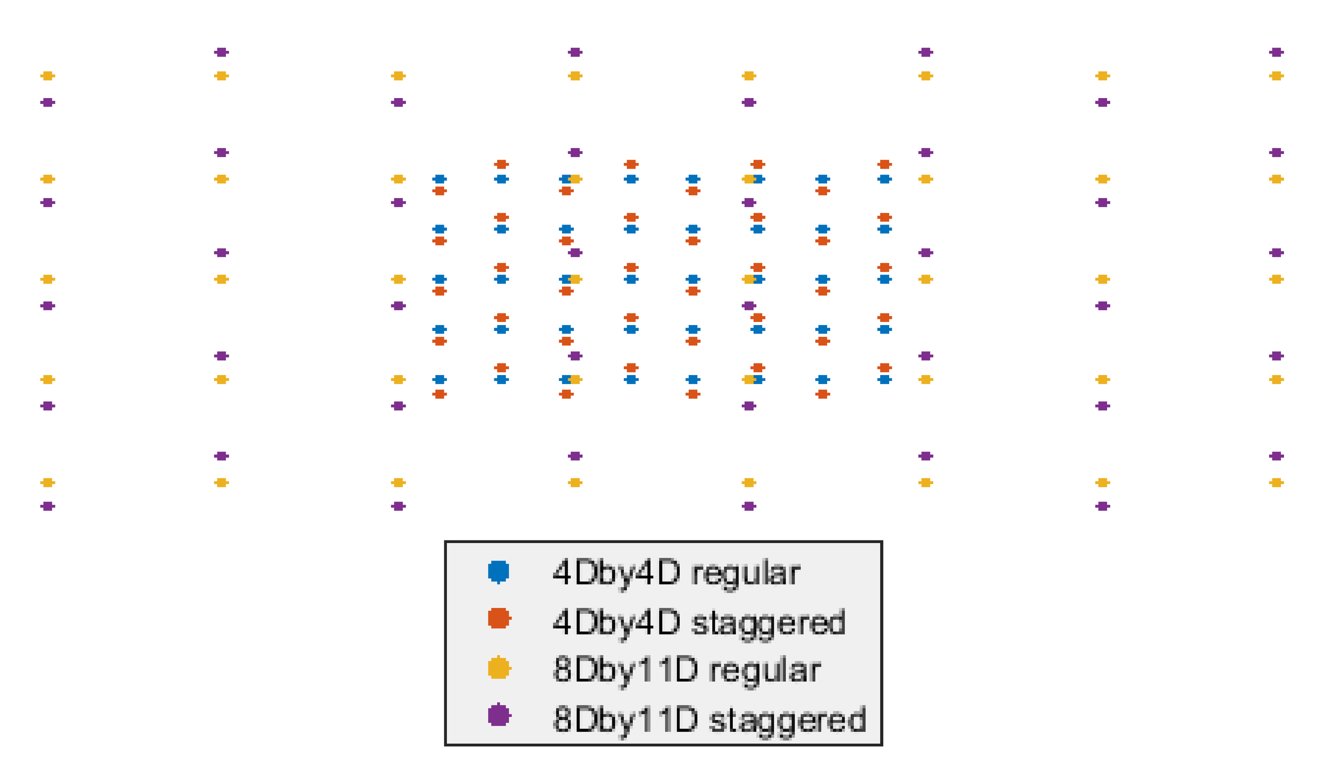

Figure 1. Extreme variation of turbine separation for both layout configurations

Results are presented for 60 farm layouts (30 regular and 30 staggered arrays, examples in Figure 1) conducted with 4 wind speeds at 10° directional intervals using CFD software package Ansys Windmodeller [1]. Expected power production is shown in Figure 2, assuming a uniform wind rose. The most significant differences in power output in relation to turbine layout occur at 10ms^{-1} and 8ms^{-1} whilst variation is less significant at 5ms^{-1} and 15ms^{-1} due to the thrust curve of the Siemens 3.6MW simulated turbine.

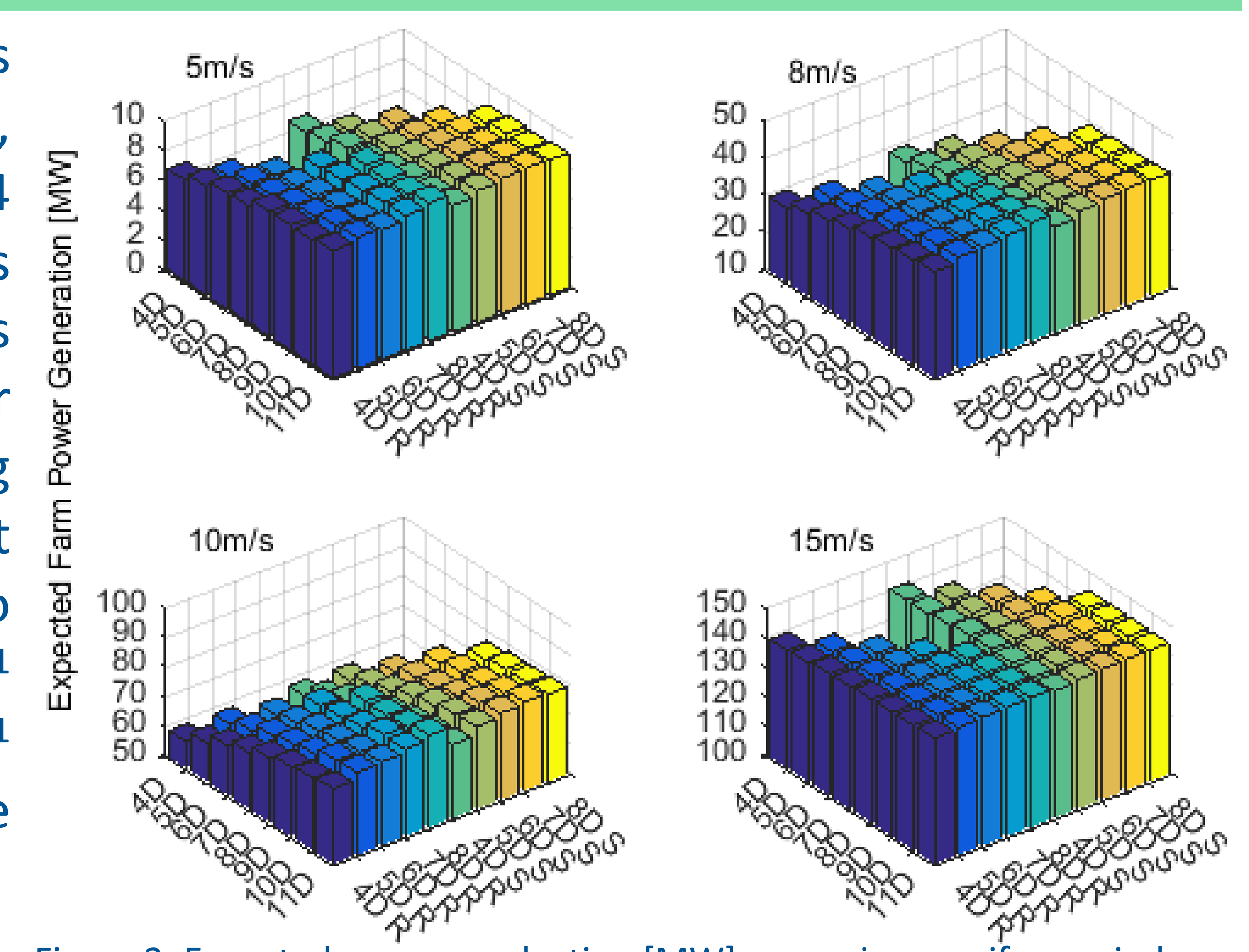

Figure 2. Expected power production [MW], assuming a uniform wind rose

As the uniform wind rose may be contributing to the limited variation in productivity, simulations were weighted according to the UK offshore wind rose [2] with the farm orientation changed to observe any effect of prevailing wind direction (Figure 3). Using the optimal farm alignment, Figure 4 displays the expected farm power output for each turbine layout. Increasing turbine separation in either direction leads to greater productivity most significantly below rated wind speeds and for distances less than 8D, though staggering the array may have a greater effect above rated power.

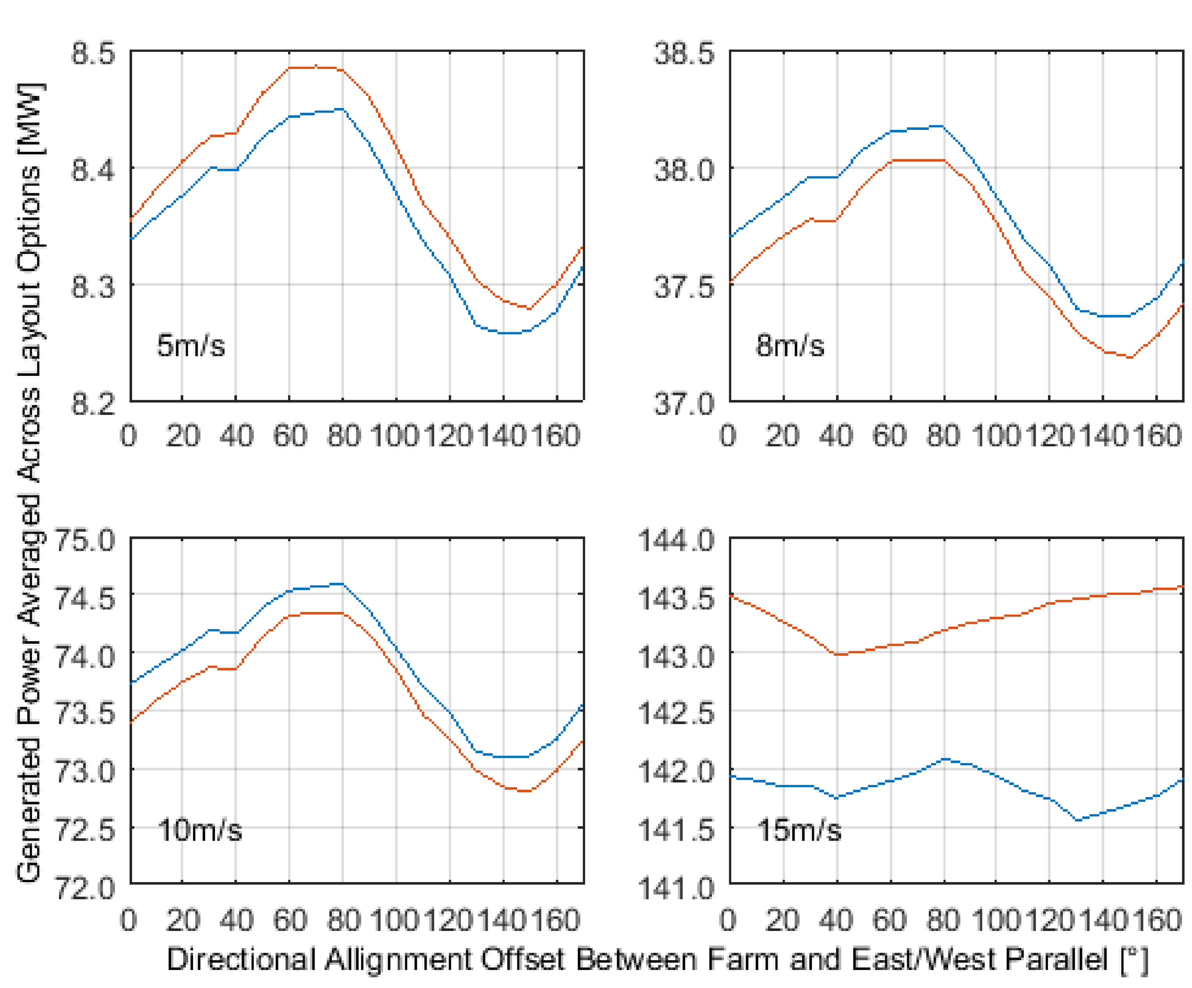

Figure 3. Variation in average power from regular (blue) and staggered (red) arrays caused by rotating the farm layout with respect to the wind rose.

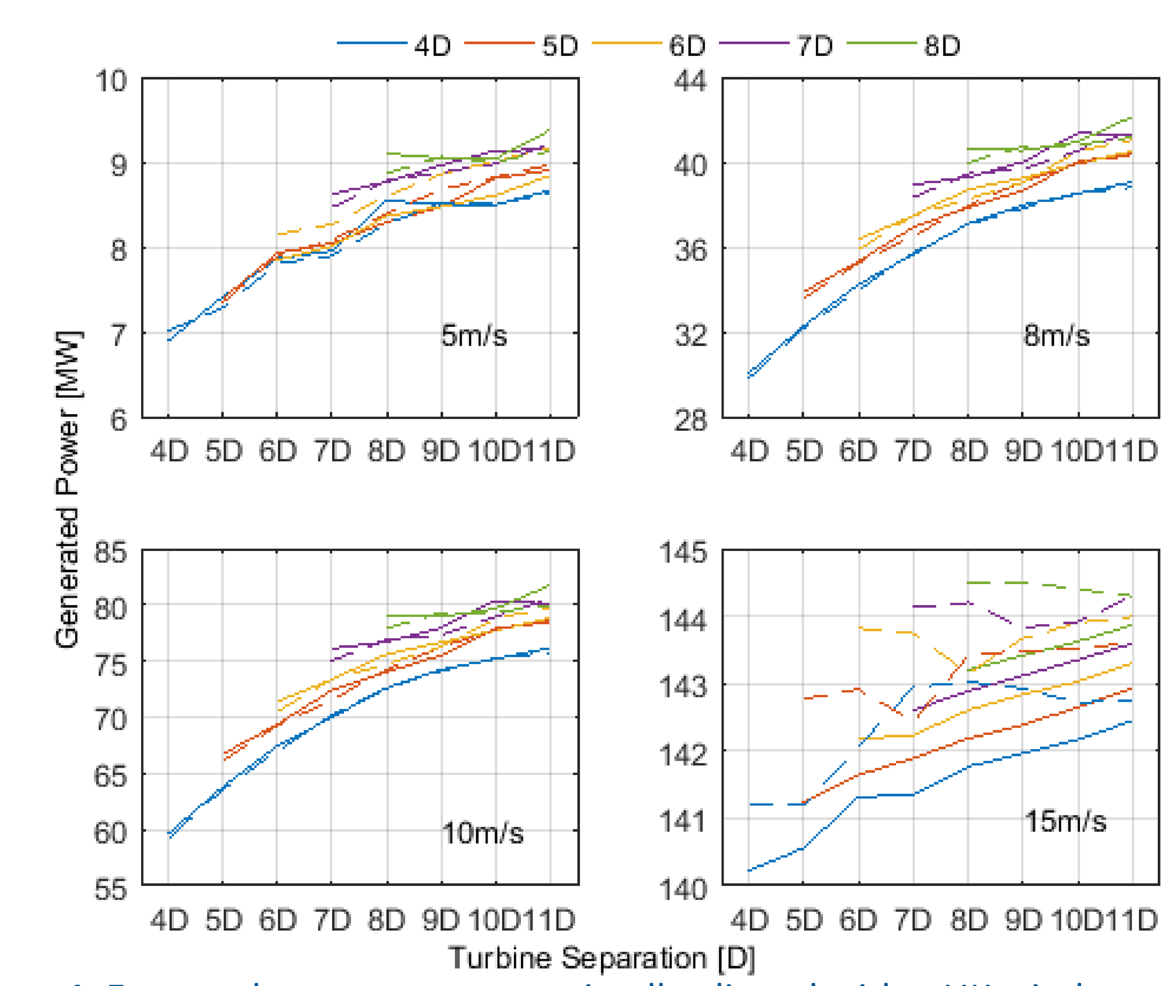

Figure 4. Expected power output, optimally aligned with a UK wind rose for both regular (solid lines) and staggered (dashed lines) array options.

Figure 5 shows that despite producing more power, greater turbine separation distances reduce the efficiency of sea area developed. For a given development area, increasing turbine numbers may be more beneficial than increasing spacing. Increased spacing is also shown (Figure 6) shown to significantly reduce both max and mean values of expected turbulence intensity values simulated at any turbine. Though this is less noticeable beyond 8D.

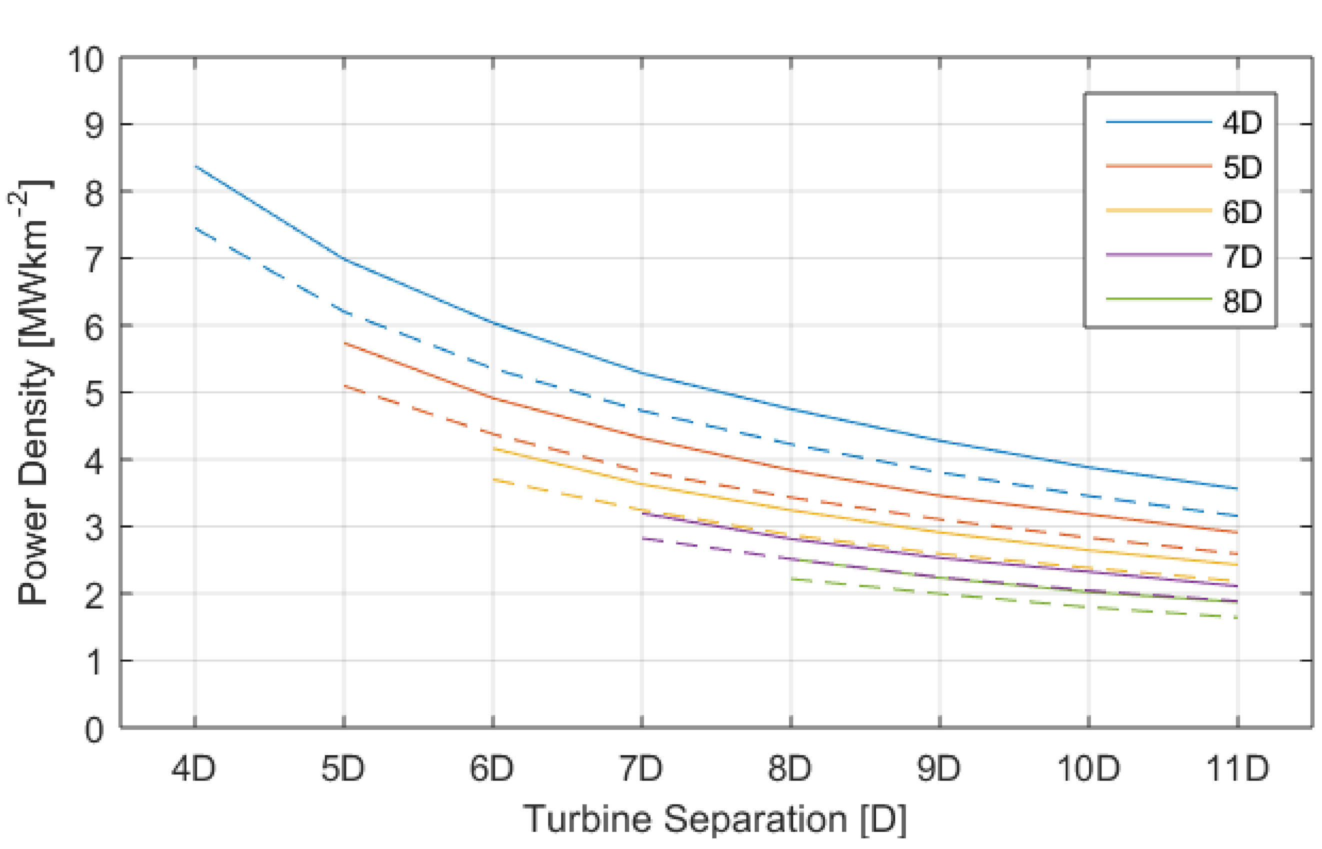

Figure 5. Power densities for each turbine layout option

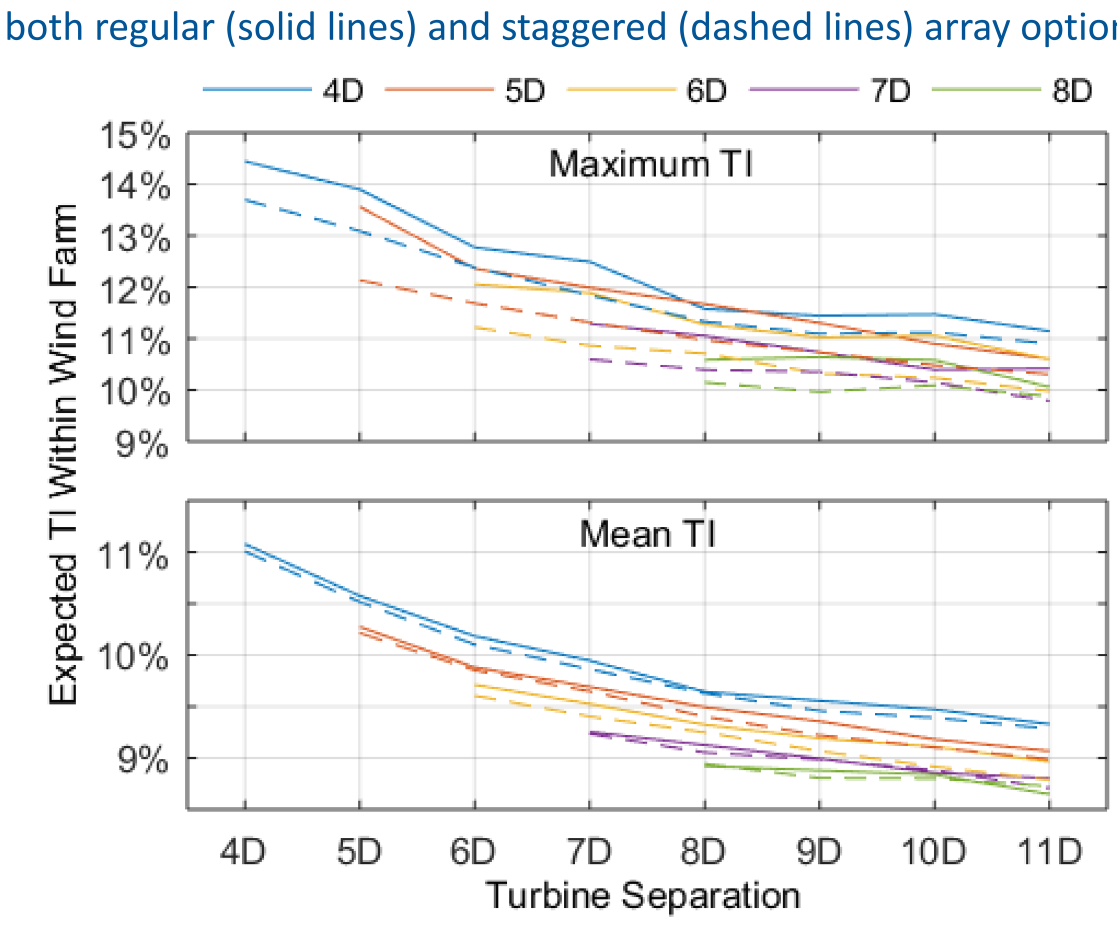

Figure 6. Expected turbulence intensity at any given wind turbine

Conclusions

This work presented production and turbulence results for 60 different turbine layouts from 4 wind speeds at 10° intervals. The farm was found to have an optimal orientation parallel to the 350-170° axis in terms of total power production. Difference in productivity due to farm alignment, was smaller than the increases with turbine separation distances. Results from both regular and staggered arrays showed additional power production was less significant beyond 8D turbine separation. Turbulence intensity was shown to decrease as turbines are located further apart, most significantly for separation distances less than 8D, though improvements are still observable for the furthest separation, 11D by 8D.

References

1. Montavon C, Jones I, Staples C, Strachan C, Gutierrez I. Practical Issues in the use of CFD for Modelling Wind Farms," *Proceedings EWEA Conference and Exhibition*, Marseille, 2009

2. Argyle P. & Watson S.J.: "A Comparison of the UK Offshore Wind Resource from the Marine Data Exchange", *Proceedings: Wind Energy,* Hamburg 2016