SHEPHERD+ WEDDERBURN

EXPLANATORY MEMORANDUM REGARDING DOCUMENTS SUBMITTED IN RESPONSE TO EXQ1 ON BEHALF OF

(1) BARROW OFFSHORE WIND LIMITED (REF: 20049595) (2) BURBO EXTENSION LTD (REF: 20049590) (3) WALNEY EXTENSION LIMITED (REF: 20048542) (4) MORECAMBE WIND LIMITED (REF: 20049596) (5) WALNEY (UK) OFFSHORE WINDFARMS LIMITED (REF: 20049592) (6) ØRSTED BURBO (UK) LIMITED (REF: 20049589) (THE “ØRSTED IPs”)

IN CONNECTION WITH THE Application by Morgan Offshore Wind Limited for an Order Granting Development Consent for the Morgan Offshore Wind Farm

Introduction

1.1 We represent six owners[1] of operational offshore windfarms in the East Irish Sea, who we refer to together as the "**Ørsted IPs**" in respect of the application by Morgan Offshore Wind Farm Limited (the "**Applicant**") for an Order under the Planning Act 2008 (the "**Act**") granting Development Consent for the Morgan Offshore Wind Farm (the **"Project**").

1.2 This document provides some brief commentary on research and articles provided by the Ørsted IPs in response to question INF1.4 of the written questions of the examining authority [PD-004] ("**ExQ1**"), in accordance with Deadline 3 of the examination timetable.

1.3 The research and articles, which provide evidence for material wake loss effects occurring at farm-farm separation distances greater than 30km, fall into the following categories:

1.3.1 Satellite observations and aircrafts;

1.3.2 Scanning LiDAR;

1.3.3 Wake and other atmospheric models; and

1.3.4 Observations from existing turbines' SCADA data.

1.4 In this document, we provide some commentary these different groups of evidence, and passages of particular relevance from the articles and research submitted are noted.

2. Satellite Observations and aircrafts

2.1 Synthetic Aperture Radar or 'SAR' installed on satellites can be used to directly observe wakes in the sea. The papers referred to below (documents 1-3 in the index) combine this approach with specially equipped research aircraft and laser measurements or models to measure the wake impact directly.

2.2 Key relevant findings of this research regarding wake loss beyond 20km include:

2.2.1 Platis, A., Siedersleben, S., Bange, J. et al 'First in situ evidence of wakes in the far field behind offshore wind farms':[2]

> *"…satellite imagery reveals wind-farm wakes to be several tens of kilometres in length under certain conditions (stable atmospheric stratification), which is also predicted by numerical models. The first direct in situ measurements of the existence and shape of large wind farm wakes by a specially equipped research aircraft in 2016 and 2017 confirm wake lengths of more than tens of kilometres under stable atmospheric conditions, with maximum wind speed deficits of 40%..."*

2.2.2 Platis, A et al 'Long-range modifications of the wind field by offshore wind parks – results of the project WIPAFF':[3]

> *"The in situ measurements recorded on-board the research aircraft DO128 and remote sensing by laser scanner and SAR prove that wakes of more than 50 kilometers exist under certain atmospheric conditions."*

2.2.3 Hasager, C.B.; Vincent, P.; Badger, J.; Badger, M.; Di Bella, A.; Peña, A.; Husson, R.; Volker, P.J.H, 'Using Satellite SAR to Characterize the Wind Flow around Offshore Wind Farms':[4]

> *"The approximate extent of the individual wind farm wakes is outlined in the image. The longest is at Belwind around 55 km long while at Thornton Bank it is 45 km…"*

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[1] As set out relevant representations RR-005, RR-007, RR-023, RR-032, RR-043, RR-044.

[2] Platis, A., Siedersleben, S., Bange, J. et al. First in situ evidence of wakes in the far field behind offshore wind farms. Sci Rep 8, 2163 (2018). (**Document 1** in index of documents).

[3] Platis, A et al. Long-range modifications of the wind field by offshore windparks – results of the project WIPAFF. Meteorologische Zeitschrift Vol. 29 No. 5 (2020), p. 355 – 376. (**Document 2** in index documents).

[4] Hasager, C.B.; Vincent, P.; Badger, J.; Badger, M.; Di Bella, A.; Peña, A.; Husson, R.; Volker, P.J.H. Using Satellite SAR to Characterize the Wind Flow around Offshore Wind Farms. *Energies* 2015, *8*, 5413-5439. (**Document 3** in index documents).

3. Scanning LiDAR

3.1 Scanning LiDARs are wind measurement devices that use the doppler shift of laser beams to accurately measure wind speed. The majority of modern offshore wind farms have their energy yield analysis based on measurements from LiDAR technology. The papers referred to below (documents 4-5 in the index) contain relevant findings based on this data source:

3.1.1 J. Schneemann et al. ‘Cluster wakes impact on a far-distant offshore wind farm’s power’:[5]

“Our results showed clear wind speed deficits that can be related to the wakes of wind farm clusters up to 55 km upstream in stable and weakly unstable stratified boundary layers resulting in a clear reduction in power production…”

3.1.2 B. Cañadillas et al. ‘Offshore wind farm cluster wakes as observed by long-range-scanning wind lidar measurements and mesoscale modelling’:[6]

“Both the observations (Fig. 8a) and model (Fig. 9) show a wake extending at least 40 km downstream of the N-3 wind farm cluster…”

4. Wake and other atmospheric models

4.1 Mathematical models can also be used to predict the extent of offshore wakes by modelling the behaviour of the atmosphere when interacting with offshore wind farms. In all cases these models have been validated on operational data from offshore wind farms and hence can be relied on as good predictors of the behaviour of offshore wakes.

4.2 The following papers (documents 6-12 in the index) contain relevant findings based on these models:

4.2.1 D. Rosencrans et al ‘Seasonal variability of wake impacts on offshore wind plant power production’:[7]

“The strongest wakes, propagating 55 km, occur in summertime stable stratification…”

4.2.2 Akhtar, N., Geyer, B., Rockel, B. et al. ‘Accelerating deployment of offshore wind energy alter wind climate and reduce future power generation potentials’:[8]

“The mean deficit, which decreases with distance, can extend 35–40 km downwind during prevailing southwesterly winds.”

4.2.3 R. Borgers et al ‘Mesoscale modelling of North Sea wind resources with COSMO-CLM’:[9]

“In weakly stable conditions, absolute capacity factor reductions are much higher, as these exceed 13 % over large zones within and outside the wind farm clusters and 5 % more than 20 km from wind farm clusters and larger wind farms”

4.2.4 Sara C. Pryor, Rebecca J. Barthelmie, Tristan J. Shepherd ‘Wind power production from very large offshore wind farms’:[10]

“Under some flow conditions whole wind-farm wakes can extend up to 90 km downwind of the largest lease areas…”

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[5] J. Schneemann et al. Cluster wakes impact on a far-distant offshore wind farm’s power. Wind Energ. Sci., 5, 29–49, 2020. (**Document 4** in index of documents).

[6] B. Cañadillas et al.: Offshore wind farm cluster wakes as observed by long-range-scanning wind lidar measurements and mesoscale modelling. Wind Energ. Sci., 7, 1241–1262, 2022. (**Document 5** in index of documents).

[7] D. Rosencrans et al.: Seasonal variability of wake impacts on offshore wind plant power production. Wind Energ. Sci., 9, 555-583, 2024. (**Document 6** in index of documents).

[8] Akhtar, N., Geyer, B., Rockel, B. et al. Accelerating deployment of offshore wind energy alter wind climate and reduce future power generation potentials. Sci Rep 11, 11826 (2021). (**Document 7** in index of documents).

[9] R. Borgers et al.: Mesoscale modelling of North Sea wind resources with COSMO-CLM. Wind Energ. Sci., 9, 697–719, 2024. (**Document 8** in index of documents).

[10] Sara C. Pryor, Rebecca J. Barthelmie, Tristan J. Shepherd. Wind power production from very large offshore wind farms. Joule 5, 2663–2686, October 20, 2021. (**Document 9** in index of documents).

4.2.5 P. Baas et al ‘Energy production of multi-gigawatt offshore wind farms’:[11]

“In this case, a clear wake is visible, which is still present as the flow reaches the southern edge of the domain. Clearly, for studying wake lengths behind windfarms of this size, much larger domains are required than the present 80 km.”

4.2.6 Sanchez Gomez M. et al ‘Can mesoscale models capture the effect from cluster wakes offshore?’:[12]

“Long wakes from offshore wind turbine clusters can extend tens of kilometers downstream, affecting the wind resource of a large area”

4.2.7 Stoelinga M. et al ‘Estimating Long-Range External Wake Losses in Energy Yield and Operational Performance Assessments Using the WRF Wind Farm Parameterization’:[13]

“The simulations produced dramatic hub-height project-scale wake swaths that extended over 50 km downwind, with a specific example showing a waked wind speed deficit of 7% extending 100 km downwind from the array of turbines that produced it.”

5. Observations from existing turbines’ SCADA data

5.1 Another way to evidence the impact of wake effects at distances of greater than 30km is to use observations of the power produced by existing wind turbines both before and after a neighbour wind farm has been installed. These “natural experiments” occur with increasing frequency as the number of offshore wind arms that are installed globally increases. As the owner of the world’s largest offshore wind portfolio, Ørsted A/S (the parent company of the Ørsted IPs) is uniquely placed to use its own operational data to observe the wake impacts of neighbouring wind farms.

5.2 In a presentation delivered at the Wind Europe Technology Workshop 2023, Ørsted’s Nicolai Nygaard shared some of this evidence.[14]

5.3 The presentation (document 13 in the index) is referenced in the Fraser-Nash Consulting Study referred to by the Applicant. The presentation uses operational data from 37 offshore wind farm pairs located in Northern Europe to demonstrate the neighbouring wake effect through the reduction of power generated by front row turbines. The presentation demonstrates that when a wind farm is in the wake of a neighbour at a distance of 30 km you can expect a power reduction of just under 10%, whereas at 50km the reduction is still about 5% of the available power. It should be noted that the paper provides these impacts for a wind speed of 8m/s. The power also shows how the wake impact varies depending on the wind speed, the stability of the atmosphere at the time of the observation and also the size, distance, shape and density of the neighbour wind farm.

5.4 As the Project is anticipated to be 1.5 GW, and is in the predominant wind direction of many of the Ørsted IPs’ developments, the Ørsted IPs expect the wake impact to be material on the wind available to the Ørsted IPs’ developments. This expectation has been confirmed by preliminary results of external modelling commissioned by the Ørsted IPs, as outlined in their substantive response to ExQ1.

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[11] P. Baas et al. Energy production of multi-gigawatt offshore wind farms. Wind Energ. Sci., 8, 787–805, 2023. (**Document 10** in index of documents).

[12] Sanchez Gomez M. et al. Can mesoscale models capture the effect from cluster wakes offshore? Journal of Physics: Conference Series 2767 (2024) 062013. (**Document 11** in index of documents).

[13] Stoelinga M. et al, Estimating Long-Range External Wake Losses in Energy Yield and Operational Performance Assessments Using the WRF Wind Farm Parameterization. This paper is a white paper produced by Arcvera Renewables, a renewable consultancy specialising in atmospheric modelling. (**Document 12** in index of documents).

[14] Presentation by Nygaard, Nicolai at wind Europe Technology Workshop (June 2023): “*Wind farms interacting with the boundary layer: Impact of long-distance wakes between offshore wind farms assessed using operational data*”. (**Document 13** in index of documents).