EAST ANGLIA TWO LIMITED'S REPLIES TO THE EXAMINING AUTHORITY'S SECOND WRITTEN QUESTIONS (EXQ2)

In connection with Five Estuaries Offshore Windfarm Project (the "Project")

Application Ref: EN010115

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ExQ2 No.	Question	Response
General and Cross-topic questions (GC)		
GC.2.05	Wake Loss In your Deadline 2 written submission [REP2-079] you contend *"... The turbines associated with the current application will inevitably cause wake loss in the context of the East Anglia Two project arrays. Given the proximity, it is likely that the losses will be material*". a) What evidence to do you have to support the contention that the siting of the wind turbine generators forming part of the Proposed Development would interfere with the operation of the East Anglia Two Offshore Wind Farm? b) How much of East Anglia Two's generating capacity do you consider would be impaired because of the proximity of the Proposed Development's wind turbine generators?	a) The impact of wind farms on the production of neighbouring wind farm projects is a known industry issue which has been further discussed with the increased density of offshore projects, particularly in the North Sea. We attach a schedule which summarises a range of evidence which supports the conclusion that adverse wake effects will arise from this Project. The evidence includes information arising from the following: • Satellite observations and aircrafts • Scanning Light Detection and Ranging ("LiDAR") • Existing turbines' Supervisory Control and Data Acquisition ("SCADA") data The recent evidence produced by owners of offshore portfolios provides an overwhelming evidence base for adverse wake effects. b) In order to undertake a wake impact assessment of a particular project, it is important to ensure that appropriate assumptions are made in respect of the project. The Applicant is in the best place to provide such information and as a result, we initiated discussions with the Applicant with a view to sharing data and agreeing a set of assumptions on which a wake loss calculation can be made. The Applicant

		has declined to engage on this specific topic. We would invite the Examining Authority to encourage the Applicant to cooperate to ensure that the Examining Authority is given the best available evidence on this matter. If the Applicant fails to cooperate then East Anglia TWO Limited will provide the results of our own assessment based on assumed layouts and turbine sizes, which may differ from what is proposed by the Applicant. At this stage, we have only conducted a preliminary evaluation which has been based on a number of assumptions. At this stage we would not regard this information as robust. We would expect losses at East Anglia TWO offshore windfarm to be within a similar range. We would wish a greater understanding of the application parameters in order to make a more accurate assessment.
Navigation and Shipping (NS)		
NS.2.05	Assessment of shipping and navigation risk Your Deadline 2 submission [REP2-079] notes that you are still evaluating the potential consequences of any navigational risks created by this project. When can the ExA expect to see your analysis, noting that we are almost a third of the way through the six month Examination period?	Following a full review of the Safety Case included in the Navigational Risk Assessment [APP-240], East Anglia TWO Limited are content that the navigational corridor between the two sites will be established and managed in accordance with COLREGS and other relevant guidance and legislation (MGN 654, PIANC and MARIN guidance). Recognising the proximity between the two sites, East Anglia TWO Limited propose that a Statement of Comment Ground is established to ensure the appropriate sharing of information on relevant traffic movements and emergent risk issues throughout the construction, operation and decommissioning of the projects.

APPENDIX – EXPLANATORY MEMORANDUM REGARDING DOCUMENTS REFERRED TO IN RESPONSE TO EXQ2 GC.2.05 ON BEHALF OF EAST ANGLIA TWO LIMITED

1. Introduction

1.1 This appendix provides some brief commentary on research and articles referred to by East Anglia TWO Limited in response to the Examining Authority's second written question GC.2.05.

1.2 We have not submitted copies of the below noted research and article but can do so if the Examining Authority would like us to.

1.3 The research and articles fall into the following categories:

1.3.1 Satellite observations and aircraft;

1.3.2 Scanning LiDAR;

1.3.3 Wake and other atmospheric models; and

1.3.4 Observations from existing turbines' SCADA data.

2. Satellite Observations and Aircrafts

2.1 Synthetic Aperture Radar ("SAR") installed on satellites can be used to directly observe wakes in the sea. The papers referred to below 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'[1]:

"...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'[2]:

"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'[3]:

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[1] 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)

[2] 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

[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. Energies 2015, 8, 5413-5439

"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..."

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 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'[4]:

"Our results showed clear wind speed deficits that can be related to the wakes of wind farm clusters up to 55km 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-rangescanning wind lidar measurements and mesoscale modelling'[5]:

"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 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'[6]:

"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'[7]:

"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 COSMOCLM'[8]:

"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"

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4 J. Schneemann et al. Cluster wakes impact on a far-distant offshore wind farm's power. Wind Energ. Sci., 5, 29–49, 2020

5 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

6 D. Rosencrans et al.: Seasonal variability of wake impacts on offshore wind plant power production. Wind Energ. Sci., 9, 555-583, 2024

7 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)

8 R. Borgers et al.: Mesoscale modelling of North Sea wind resources with COSMO-CLM. Wind Energ. Sci., 9, 697–719, 2024.

4.2.4 Sara C. Pryor, Rebecca J. Barthelmie, Tristan J. Shepherd ‘Wind power production from very large offshore wind farms’[9]:

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

4.2.5 P. Baas et al ‘Energy production of multi-gigawatt offshore wind farms’[10]:

“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?’[11]:

“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’[12]:

“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 farms that are installed globally increases.

5.2 Several industry studies have been conducted on this, the following provide very good examples:

5.2.1 DNV and RWE, Waking up to the magnitude of cluster and far-field wakes[13] where two areas were assessed and found that wind farm wakes detected in SCADA for a distance of 30km, although simulations suggest the wakes can persist even further, with losses of up to 3.8%;

5.2.2 DNV, Far-distant offshore wakes: How far is too far and are we getting it right?[14] Where four operational wind farms in the North Sea were assessed and found that increasing wind farm layout density, larger turbines and regional build out increases wake propagation distances and that industry standard engineering models need updating so they can better capture far distance wakes ; and

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9 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

10 P. Baas et al. Energy production of multi-gigawatt offshore wind farms. Wind Energ. Sci., 8, 787–805, 2023

11 Sanchez Gomez M. et al. Can mesoscale models capture the effect from cluster wakes offshore? Journal of Physics: Conference Series 2767 (2024) 062013

12 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

13 DNV and RWE, Waking up to the magnitude of cluster and far-field wakes. Effect on a wind farm annual energy production, 10 June 2024

14 DNV, Far-distant offshore wakes: How far is too far and are we getting it right? 24 June 2022

5.2.3 A presentation delivered at the Wind Europe Technology Workshop 2023 by Ørsted A/S[15] is referenced in a Frazer-Nash Consulting Study prepared for The Crown Estate[16]. The presentation uses operational data from 37 offshore wind farm pairs located in Northern Europe to illustrate the neighbouring wake effect through the reduction of power generated by front row turbines. The presentation illustrates that when a wind farm is in the wake of a neighbour at a distance of 30km 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 presentation also showed 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.

6. Conclusion

6.1 The evidence for wake effects is overwhelming. This is based upon the papers identified above but also the real live examples provided by both RWE and Ørsted.

15 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"

16 Frazer-Nash Consultancy, Offshore Wind Leasing Programme, Array Layout Yield Study, 5 October 2023