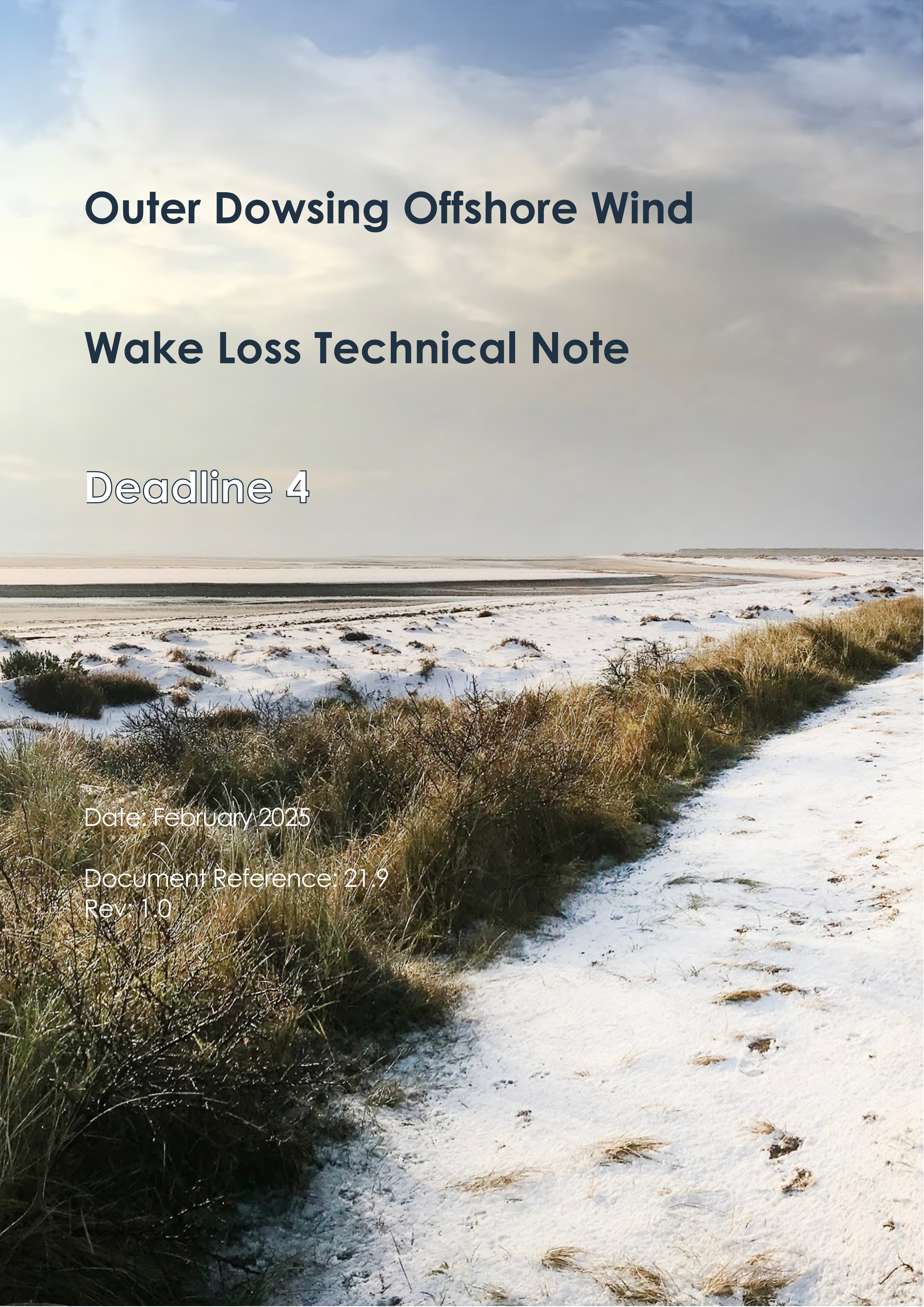

Outer Dowsing Offshore Wind

Wake Loss Technical Note

Deadline 4

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Table of Contents

Table of Tables

Acronyms & Definitions

Abbreviations / Acronyms

Abbreviation / Acronym	Description
CO2eq	carbon dioxide equivalent
DCO	Development Consent Order
DUKES	Digest of UK Energy Statistics
EIA	Environmental Impact Assessment
ExA	Examining Authority
GWh	Gigawatt hours
IP	Interested Party
Lidar	Light Detection and Ranging
MtCO2eq	Million Tonnes of carbon dioxide equivalent
NPS	National Policy Statement
OWF	Offshore Wind Farm
SAR	Synthetic-aperture radar
TWh	Terrawatt hours
WIPAFF	WInd PArk Far Fields
WTG	Wint Turbine Generator

Terminology

Term	Definition
The Applicant	GT R4 Ltd. The Applicant making the application for a DCO. The Applicant is GT R4 Limited (a joint venture between Corio Generation (and its affiliates), Total Energies and Gulf Energy Development (GULF)), trading as Outer Dowsing Offshore Wind. The Project is being developed by Corio Generation, TotalEnergies and GULF.
AfL array area	The area of the seabed awarded to GT R4 Ltd. through an Agreement for Lease (AfL) for the development of an offshore wind farm, as part of The Crown Estate's Offshore Wind Leasing Round 4.
Array area	The area offshore within which the generating station (including wind turbine generators (WTG) and inter array cables), offshore accommodation platforms, offshore transformer substations and associated cabling will be positioned.
Baseline	The status of the environment at the time of assessment without the development in place.
Cumulative effects	The combined effect of the Project acting additively with the effects of other developments, on the same single receptor/resource.
Cumulative impact	Impacts that result from changes caused by other past, present or reasonably foreseeable actions together with the Project.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP).

Term	Definition
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the sensitivity of the receptor, in accordance with defined significance criteria.
EIA Directive	European Union 2011/92/EU (as amended by Directive 2014/52/EU).
EIA Regulations	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Regulations, including the publication of an Environmental Statement (ES).
Environmental Statement (ES)	The suite of documents that detail the processes and results of the EIA.
Mitigation	Mitigation measures are commitments made by the Project to reduce and/or eliminate the potential for significant effects to arise as a result of the Project. Mitigation measures can be embedded (part of the project design) or secondarily added to reduce impacts in the case of potentially significant effects.
Offshore Restricted Build Area (ORBA)	The area within the array area, where no wind turbine generator, offshore transformer substation or offshore accommodation platform shall be erected.
Outer Dowsing Offshore Wind (ODOW)	The Project.
Order Limits:	The area subject to the application for development consent, The limits shown on the works plans within which the Project may be carried out.
The Planning Inspectorate	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
The Project	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated onshore and offshore infrastructure.
Wind turbine generator (WTG)	A structure comprising a tower, rotor with three blades connected at the hub, nacelle and ancillary electrical and other equipment which may include J-tube(s), transition piece, access and rest platforms, access ladders, boat access systems, corrosion protection systems, fenders and maintenance equipment, helicopter landing facilities and other associated equipment, fixed to a foundation.
WTG area	The area within the order limits where Wind Turbine Generators (WTG), offshore transformer substations and offshore accommodation platform can be located following the introduction of the Offshore Restricted Build Area (ORBA).

1 Introduction and Document Purpose

This document sets out the Applicant's precautionary analysis of possible wake loss effects from offshore windfarms in the vicinity of the Project (or which have been consented and are planned to be constructed in the vicinity of the Project) in the context of and in relation to the examination of the DCO application for the Project. This document has been prepared solely for the purpose of assessing potential environmental effects and concludes that they are not significant in EIA terms, and that they do not materially affect the substantial benefits that the Project would deliver. To that end, this document considers the academic papers submitted by the Ørsted IPs at Deadline 2 (REP2-076) and summarises the outcome of a precautionary wake loss assessment undertaken by the Applicant following the methodology used by Ørsted in their submissions to the Mona Offshore Wind Farm DCO Examination undertaken by Wood Thilsted. This document therefore provides the information necessary to address the Action Point 2 in Action Points - Issue Specific Hearing 2 (ISH2) - 4 December 2024 (EV6-004), namely, to "Provide a technical note which summarises the Applicant's assessment of how wake loss effects for offshore wind farms, including Triton Knoll and the Dudgeon Extension Project should be taken into account for the Proposed Development."

The wake impact assessment summarised in this note has been undertaken by a wind energy yield analyst working for the Applicant responsible for layout design, wind resource and energy yield assessment. The author is a wind expert holding a Masters degree in Science and Engineering from the National Institute of Applied Sciences of Rouen, with more than 7 years of experience in the wind energy sector conducting pre-construction and operational energy yield assessment, both in the offshore and onshore environments. With expertise in wind measurement campaigns, data analysis, wind farm design and optimization and energy yield assessment, included wake loss assessment for both onshore and offshore windfarms mainly in Europe. For the last three years the author has focused on offshore wind projects in the UK.

Implications for carbon payback have been provided in section 5 by experienced environmental consultants SLR Consulting.

2 Policy Background

The Applicant has set out below the relevant policy context to this consideration of wake effects.

As submitted by the Applicant in Issue Specific Hearing 2 (REP3-041), the relevance and application of this policy is an issue that will come before the Secretary of State for determination through the Examination of the Mona and Morgan OWF DCOs. Both of these schemes are further advanced in the process and the issue will therefore likely come before the for Secretary of State and be decided before a decision is made on the Applicant's DCO.

Should the Secretary of State decide the policy issue in favour of the applicants in those cases then the legal issues discussed in the Applicant's response to written question OG 1.2 (REP2-051) will not require further consideration. If the Secretary of State decides against the applicant in those cases, attention can turn to the case-specific matters on which the Applicant has made submissions in this note; in Issue Specific Hearing 2, and in response to Q1 OG 1.2 (REP2-051).

The Applicant's view is that (1) relevant policy does not require further assessment in the circumstance of its application but (2) should the ExA or the Secretary of State take a different view, the information provided in this note provides the information needed to address any potential effects. It demonstrates that the impacts on relevant receptors would not lead to a significant environmental effect and that any adverse would be very limited and not such as materially to affect the overall planning balance.

2.1 Policy

The passages from policy potentially relevant for the consideration of the question of conducting a wake loss assessment are provided below. The Applicant notes that it has also made submissions on its compliance with the policy relevant to considering wake loss in the context of (1) site selection and design and (2) project viability and, on this basis, has not reiterated them here.[1]

National Policy Statement (NPS) EN-3 paragraphs 2.8.196 to 2.8.198 states (emphasis added):

"2.8.196 The scale and location of future offshore wind development around England and Wales means that development has occurred, and will continue to occur, ***in or close to areas where there is other offshore infrastructure****.*

2.8.197 ***Where a potential offshore wind farm is proposed close to existing operational offshore infrastructure, or has the potential to affect activities for which a licence has been issued by government, the applicant should undertake an assessment of the potential effects of the proposed development on such existing or permitted infrastructure or activities.***[2]

1 This information is set out in response to REP2-051; Q1 OG 1.2.

2 Note that this wording is almost identical to the wording in paragraph 2.6.179 of the previous version of NPS EN-3, which was the subject of debate at examination of the Awel y Mor Wind Farm Development Consent Order, following submissions by Rhyl Flats Wind Farm.

2.8.198 The assessment should be undertaken for all stages of the lifespan of the proposed wind farm ***in accordance with the appropriate policy and guidance for offshore wind farm EIAs****..."*

The above paragraphs relate to the assessment of the effects of a proposed offshore wind development on other existing or consented offshore infrastructure. Paragraph 2.8.196 sets the context for the paragraphs which follow and explains that the principal scenarios in which assessment may be required are those in which a development is being carried out "*in or close to*" areas where there is other offshore infrastructure.

Paragraph 2.8.197 sets out – within this important context – that an applicant should undertake an assessment of the potential effects of the proposed offshore wind farm on existing or permitted offshore infrastructure or activities. That assessment is required under this policy if the proposed offshore wind farm is: a) to be located close to existing offshore infrastructure; or b) has the potential to affect activities for which a licence has been issued by government. In relation to b), paragraphs 2.8.196 and 2.8.197 combine to make clear that in order for there to be a potential to affect activities for which a licence has been issued by government, there must be sufficient proximity between the licensed activities and the proposed offshore wind farm. [3] Paragraph 2.8.198 then explains that such an assessment ought to be carried out in accordance with the principles of environmental impact assessment.

Where this issue has previously been scrutinised in detail, the phrase "close to" was applied to a distance of 5.1km between an existing and proposed wind farm array, where significant emphasis was placed on this level of proximity.[4]

As noted above, paragraph 2.8.198 explains that any assessment of effects on third party infrastructure ought to be carried out in accordance with the principles of environmental impact assessment. It is a well-established principle of environmental impact assessment, that such an assessment is only required in order to establish the likely significant effects of the project on the environment.[5]

Paragraph 4.3.10 of NPS EN-1 states that "*an applicant must provide information proportionate to the scale of the project*" and cross refers to the Guidance on EIA in the context of town and country planning applications. That guidance states: "*the emphasis should be on the "main" or "significant" environmental effects to which a development is likely to give rise. The Environmental Statement should be proportionate and not be any longer than is necessary to assess properly those effects.*"

3 The relevant distances in the Applicant's case are set out in Q1 OG 1.2 and REP3-041; 20.4.3 The Applicant's Written Summary of oral case put at Issue Specific Hearing 2 on Offshore matters, 4th Dec

4 The distance being between the Awel y Mor proposed OWF and the pre-existing Rhyl Flats OWF.

5 See Regulation 14 and para 5, Schedule 4 of the infrastructure Planning (Environmental Impact Assessment) Regulations 2017

There is no requirement for an assessment to be carried out for an effect which is not likely to be significant. An effect which is categorised in relevant literature as likely to be "vanishingly small" or even simply "small" cannot reasonably be said to be significant.[6]

The Applicant has conducted the assessment set out in this note to provide further comfort that potential wake loss effects even when considered on a precautionary basis cannot, in the context of this Project, be considered significant in EIA terms.

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[6] As set out in the Applicant's response to Q1 OG 1.2, the Offshore Wind Leasing Programme Array Layout Yield Study (REP2-056) indicates that wake effects level off with approximately 10km separation between OWFs, and at separation distances over 20km wake effects become "vanishingly small". The study also states that "*For even the smallest separations between wind farms (2km or one turbine spacing) farm-to-farm wake loss remains small (2.0% in this case) compared to the loss due to internal wakes and blockage (7.7% in this case).* All of the Ørsted IP's OWF array areas substantially greater than 20km away from the Applicant's WTG Area.

3 Response to Ørsted IPs Response to ExAQ1 (REP2-0769) Appendices

In response to the Examining Authority's First Written Questions (PD-013) Hornsea 1 Limited, the collective of Breesea Limited, Soundmark Wind Limited, Sonningmay Limited and Optimus Wind Limited (the "Hornsea 2 Companies"), Orsted Hornsea Project Three (UK) Limited, Orsted Hornsea Project Four Limited, Lincs Wind Farm Limited, Westermost Rough Limited and Race Bank Wind Farm Limited (together or in any combination, the "Ørsted IPs") submitted several academic papers in relation to wake effect, with a focus on far wake (REP2-076). This section of the Note provides a high-level response to those academic papers.

The standard practice to perform an energy yield assessment and evaluate the external wake impact starts by using wind measurements performed according to International Electrotechnical Commission (IEC) standard 61400[7] (and British Standard BS EN IEC 61400-50:2022 Wind energy generation systems - Wind measurement being the UK implementation of EN IEC 61400-50:2022[8]. It is identical to IEC 61400-50:2022.) for a period of at least one year. This onsite measurement should be analysed, processed and compared with long-term references to be extrapolated to a long-term period. This allows the assessment to be representative of the long-term wind conditions over the lifetime of a windfarm and avoid any bias. The calculation of the production and the associated wake loss over the lifetime of a windfarm should be based on the long-term representative wind conditions. No such assessment is performed in any of the academic papers submitted by the Ørsted IPs (REP2-076).

The majority of the academic papers submitted by Ørsted such as "First in situ evidence of wakes in the far field behind offshore wind farms ", "Impact of long-distance wakes between offshore wind farms" are considering only certain wind conditions, such as a certain wind direction sector, certain wind speeds, certain period of time and in some cases only a few hours for some studies, therefore not considering the long-term wind condition and associated energy production and losses. All these specific site conditions assessed in these papers are selected in order to identify and prove existence of wake effect sometimes over long distances. Therefore, they should be considered extremely conservative and not representative of normal long-term operations over the lifetime of a windfarm.

Additionally, the majority of papers such as "Long-range modifications of the wind field by offshore wind parks – results of the project WIPAFF", "Using Satellite SAR to Characterize the Wind Flow around Offshore Wind Farms", "Offshore wind farm cluster wakes as observed by long-range-scanning wind lidar measurements and mesoscale modelling" are based on satellite data, airborne observation, and scanning lidar measurements to observe the wind speed reduction due wake effect. These measurement technologies are only used for academic and research purposes and are not

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[7] IEC (2022) 61400-5- Wind energy generation systems - Part 50: Wind measurement https://webstore.iec.ch/en/publication/69215

[8] BSI Standards Publication (2022), Wind energy generation systems BS EN IEC 61400-50:2022 | 31 Oct 2022 | BSI Knowledge

included in the IEC standard 61400[9] nor do they follow any industry best practices or are considered to be robust enough to perform a wind resource and energy yield assessment. The outcome of these studies is neither applicable nor even helpful when undertaking an assessment of production and likely associated loss due to the external wake effect induced by neighbouring windfarm.

There is significant conservatism within the papers submitted and we observe discrepancies between the papers regarding the wake model used to assess the impact such as “Long-range modifications of the wind field by offshore wind parks – results of the project WIPAFF”, “Estimating Long-Range External Wake Losses in Energy Yield and Operational Performance Assessments Using the WRF Wind Farm Parameterization”. These discrepancies highlights that there is no consensus within the industry and that results are uncertain due to the model applied. The weaknesses of these assessments are discussed especially regarding the uncertainty of the wake calculation. For example, the papers “Seasonal variability of wake impacts on US mid-Atlantic offshore wind plant power production “, “Impact of long-distance wakes between offshore wind farms” are focusing only on a very small number of turbines or the front row of the windfarm that is the most susceptible to wake effects. This approach is not relevant to assess the impact on the overall annual energy production of the windfarm and the level of losses in these studies should not be considered representative of a windfarm.

The influence of some parameters such as the stability of the atmosphere on wake effect is discussed is these papers e.g. “Seasonal variability of wake impacts on US mid-Atlantic offshore wind plant power production”. This parameter is not considered in most papers. When considered it represents a worst case scenario in terms of wake effect. The atmospheric stability is shown to enhance wake effect under stable conditions, often happening during summertime when the wind and associated production is lower. The atmosphere is, most of the time, unstable especially during high wind events. Therefore, the impact should be lower and what is assessed in these studies under stable condition should be considered to be overestimating the wake impact over the course of a year or over the lifetime of a windfarm.

Some papers such as “Offshore wind farm cluster wakes as observed by long-range-scanning wind lidar measurements and mesoscale modelling” have a focus on examples of wake effect impact for windfarm clusters especially the German cluster with windfarms separated by minimal distances which isn’t the case for the Project and neighbouring windfarms. In these studies, the impact between clusters is analysed, without consideration being given to the impact of individual windfarms on neighbours within the cluster or to a neighbouring cluster. The outcome of these studies can’t be applied to the Project and the UK East North Sea cluster.

These papers do not attempt to calculate the production loss of relevant windfarms on an annual basis or over the lifetime of the project, nor do they comment on the significance of any effects. Due to the site-specific aspect of the site and the assessment undertaken in these papers, this can’t be transposed or applied to the Project.

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[9]IEC (2022) 61400-5- Wind energy generation systems - Part 50: Wind measurement https://webstore.iec.ch/en/publication/69215

The papers submitted by Ørsted IPs (REP2-076) are academic papers, only showing the existence of a wake effect from a windfarm visible over long distances, but not showing any significant impact on the average energy production of a windfarm over its lifetime. The purpose of these academic studies is only to prove the existence of wake effect, but not to perform any assessment of its potential significance following the standard practices for an energy yield assessment within the industry.

The Project agrees these papers recognise wake effects can exist between windfarms, sometimes over long distances, but they do not seek to draw conclusions on the consequences of the "snap shot" of wake effects identified. Beyond making conclusions that wake loss can, under certain conditions, be experienced, we do not consider that the information included within these papers are applicable or even helpful in undertaking an assessment of the issues which Ørsted IP's have raised.

4 Wake Loss Assessment

A wind resource and energy yield assessment has been performed by the Applicant using more than a year of data from an onsite Floating lidar measurement campaign, extrapolated to be representative of long-term conditions, complying with the best industry practice to perform wind resource and energy yield assessments. The long-term wind conditions obtained were spatially extrapolated across the region to consider all neighbouring offshore windfarms.

The energy yield assessment demonstrated a layout with 100 WTGs being the worst case scenario in terms of wakes due to the higher number of turbines and a worst thrust that induces higher wake effect than other turbine scenarios. Therefore, this scenario was used to assess external wake loss induced by the Project on neighbouring offshore windfarms presented in this note, to take a conservative worst case approach.

Assumptions regarding the WTG model and associated power curves have been made for projects not yet built (such as Hornsea 3, Hornsea 4 and Dudgeon Extension). These assumptions represent the Applicant's best view according to the information available at this point in time. As part of this energy yield assessment, the production of neighbouring windfarms was evaluated along with a focus on the potential external wake effect induced by the Project.

In order to assess external wake loss, the assessment was undertaken by adopting, in so far as is possible, the approach to the "wake impact assessment" study undertaken by Wood Thilsted[10] on behalf of Ørsted to evaluate wake effect and associated loss of production for the Irish Sea cluster, published as part of the examination process of the Mona offshore windfarm. Therefore, this assessment is using an engineering wake model based on Eddy viscosity with a deep array correction for large windfarm.

As shown in the study submitted by Ørsted into the Mona examination, the sum of the wake impact of isolated windfarms is higher than the cumulative wake impact of many windfarms in a cluster. The Project being sited in a region including many existing windfarms, its single impact on Ørsted IPs offshore windfarms is lower within this cluster than it would have been if there were no existing windfarms and is expected not to be significant. This is because the impact of the Project on neighbouring offshore wind farms is diluted due to the existing cumulative impact of all neighbouring offshore wind farms on the Ørsted IPs offshore wind farms.

The wake loss as a percentage of the annual energy production of the neighbour offshore windfarm is presented in Table 4-1. Considering that some of these offshore windfarms are built and have been operating for many years, and the extension of Dudgeon and Sheringham Shoal windfarms, and Hornsea 3 and 4 are assumed to be in operation before the Project will be built, the associated wake loss impact induced by the Project over the lifetime of these windfarms will be lower than the annual values presented below. These windfarms will have been operating for years without the project's

[10] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010137/EN010137-001769-Shepherd%20&%20Wedderburn%20LLP%20on%20behalf%20of%20%C3%98rsted%20IPs%20-%20Response%20to%20ExQ2%20(attachment).pdf

wake impact and the average loss over the lifetime of the project will be lower than presented in this assessment. The Applicant does not consider these wake effects to be significant in EIA terms.

It has been suggested that wake effects can be mitigated by design. However, any reduction of the size of the Project WTG area would lead to a denser layout introducing a significant increase of internal wake losses that would substantially reduce the production of the Project. This would only result in a very minimal reduction of the impact on other windfarms. Therefore, the overall cumulative production of the Project and neighbouring windfarms in the region would be lower if such an approach was taken, because the reduction in external wake impact would be negligible compared to the substantial reduction of the Project's production as a result of internal wake loss.

Another potential mitigation of the wake impact on neighbouring windfarm would be to remove some wind turbines but this again would significantly reduce the capacity of the Project. To achieve a reduction of external wake loss, the closest turbines to neighbouring windfarms located on the edges of the Project layout would be removed (as these would be having the biggest impact). Turbines located on the edge of the layout are the most efficient for the Project and would significantly reduce the production. The resulting reduction of wake loss induced by the Project on neighbouring windfarms would again be very minimal, but the cumulative production of the Project and neighbouring windfarms would be significantly reduced.

The use of fewer larger turbines within the Project may have the effect of reducing wake loss further from the worst case assessment set out within this report. However, the Project requires the limited flexibility it is seeking in terms of envelope to ensure the Project is deliverable and can contribute to clean energy generation within the timescales proposed.

Overall therefore it is considered that any mitigation capable of achieving a further reduction to the worst case wake losses set out above, would disproportionately reduce the clean energy generation from the Project (and consequently the cumulative clean energy contribution from all of the projects taken together). This outcome is consistent with the findings of the Frazer Nash "Array Layout Yield Study "[11] undertaken on behalf of The Crown Estate, stating the following:

"In the case of a constrained seabed, the penalty in production from introducing a buffer is a result of two competing effects: the potential gain in production associated with increased separation and reduced farm-to-farm wakes is outweighed by the penalty associated with reducing turbine spacing.".

It is not therefore considered to be appropriate in EIA or policy terms to require any further mitigation in these circumstances.

[11] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010125/EN010125-000798-10.23%20Array%20Layout%20Yield%20Study%20(Wake%20Loss%20Report_Fraser%20Nash%202023).pdf

Table 4-1: Results of the external wake impact assessment from the Project on neighbouring offshore windfarms

Offshore Wind Farm	Race Bank	Dudgeon	Triton Knoll	Hornsea 1	Hornsea 2	Hornsea 3	Humber Gateway	Inner Dowsing	Lincs	Lynn	Sheringham Shoal	Westermost Rough	Hornsea 4	Sheringham Shoal Extension	Dudgeon Extension
Distance to the Project's WTG area (km)	23.5 km	19.9 km	8.5 km	24.6 km	22.2 km	60.6 km	46.5 km	51.5 km	46.05 km	54.4 km	34 km	60.4 km	41.3 km	26.1 km	13.5 km
The Project's impact (Additional external wake loss caused by the Project on other OWFs)	**0.2%**	**0.8%**	**0.8%**	**0.2%**	**0.3%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.1%**	**0.0%**	**0.0%**	**0.2%**	**0.8%**

5 Possible Consequences of Wake Effects

Two net benefit assessments were conducted on the basis of highly conservative hypothetical scenarios where the wake effect of the Project results in either a 0.5% or 1% loss of energy production from a number of neighbouring OWFs. The total gross annual energy production figures (including existing wake loss before the Project is added) of these OWFs has been calculated using data from the Project wind measurement campaigns, and using data related to other OWFs from the MapStand database and 4c offshore wind.

The OWFs considered in this assessment, their total annual energy production figures, and 0.5% and 1% of these figures are shown in Table 5-1 (noting that from the above assessment (Section 4 Table 4-1) figures are, for most projects, substantially below the 0.5% and therefore the below values are hypothetical).

Table 5-1: Annual electricity production figures of the OWFs considered

Wind Farm	Gross production including wake (GWh/yr)	0.5% of the Gross production	1% of the Gross production
Race Bank	1,968	9.8	19.7
Dudgeon	1,468	7.3	14.7
Triton Knoll	3,287	16.4	32.9
Hornsea 1	5,695	28.5	57.0
Hornsea 2	5,819	29.1	58.2
Hornsea 3	14,078	70.4	140.8
Humber Gateway	954	4.8	9.5
Inner Dowsing	381	1.9	3.8
Lincs	1,181	5.9	11.8
Lynn	377	1.9	3.8
Sheringham Shoal	1,199	6.0	12.0
Westermost Rough	798	4.0	8.0
Hornsea 4	11,277	56.4	112.8
Sheringham Shoal Extension	1,620	8.1	16.2
Dudgeon Extension	2,178	10.9	21.8
Total	52,280	261.4	522.8

Table 5-2 shows how the 0.5% and 1% of annual electricity production figures for these OWFs compares with the predicted annual electricity production of the Project.

Table 5-2: Predicted annual electricity generation of the Project compared with 0.5% and 1% of the annual electricity generation for the OWFs considered

Project annual electricity generated (GWh/yr)	5332
0.5% of all electricity generated (GWh/yr) by neighbouring Wind Farms	261.4
1% of all electricity generated (GWh/yr) by	522.8
Ratio of the Project's annual electricity generation to 0.5% of that of its neighbouring Wind Farms	20.4
Ratio of the Project's annual electricity generation to 1.0% of that of its neighbouring Wind Farms	10.2

Table 5-2 shows that the predicted annual electricity generation of the Project is 20.4 times larger than 0.5% of the total annual electricity generation of the neighbouring OWFs considered, and 10.2 times larger than 1% of it. **Therefore, the first conclusion that can be drawn is that the building of the Project would still result in a significant net increase in renewable energy generation under these hypothetical scenarios.**

We have also analysed how the expected carbon pay-back times for the Project change under these two hypothetical scenarios. The following tables present this information.

Table 5-3 shows the expected electricity generation of the Project, and the amount of carbon dioxide equivalent (CO2eq) emissions it is expected to offset under normal circumstances. The calculations assume a load factor of 40.58%, based on a calculation by RenewableUK[12] that determined the average of the past five years of published data from the Digest of UK Energy Statistics (DUKES) from DESNZ. The two offset emissions numbers are based on the Project offsetting either a mix of all non-renewable energy sources, or just gas.

Table 5-3: Original Project electricity generation and offsetting figures

Total annual power generation (GWh)	5,332
Total power generation over 35 year lifetime (TWh)	186.6
35 years of counterfactual "all non-renewables CO2eq emissions" (MtCO2eq)	79.1
35 years of counterfactual Gas CO2eq emissions (MtCO2eq)	69.2

Table 5-4 shows the expected pay-back times, which were calculated from the electricity generation and offsetting figures presented above. The payback times are shown for two scenarios, where the foundation choice for the Project turbines is either a 50:50 combination of jacket/pile foundations and gravity based structures, or 100% jacket/pile foundations.

[12] RenewableUK, 2023, Wind Energy Statistics Explained UK Wind energy database (UKWED) | RenewableUK

Table 5-4: Original Project payback times under two foundation scenarios

	50:50 combination	100% Jacket/pile foundations
Lifetime emissions (MtCO2eq)	5.2	6.3
Total carbon savings for "all non renewables"(MtCO2eq)	73.8	72.8
Total carbon savings for gas (MtCO2eq)	64.0	62.9
Payback time for "all non-renewables" (years)	2.3	2.8
Payback time for gas (years)	2.6	3.2

5.1 Carbon Payback for 0.5% Wake Effect Scenario

For the first comparison, the total annual electricity generation of 0.5% of all the neighbouring OWFs (261.4GWh) has been subtracted from the expected Project total annual electricity generation, leaving the net additional electricity that the Project would generate after wake effects. This results in a new annual electricity generation figure of 5,071GWh for the purposes of pay-back times.

Table 5-5 shows this new electricity generation, and the amount of carbon dioxide equivalent emissions it is expected to offset under these circumstances.

Table 5-5: Project electricity generation and offsetting figures under the 0.5% wake effect hypothetical scenario

Total annual power generation (GWh)	5,071
Total power generation over 35 year lifetime (TWh)	177.5
35 years of counterfactual "all non-renewables CO2eq emissions" (MtCO2eq)	75.2
35 years of counterfactual Gas CO2eq emissions (MtCO2eq)	65.8

Table 5-6 shows how this reduced carbon dioxide equivalent offsetting translates to the pay-back times, both for the two foundation scenarios.

Table 5-6: Project payback times under two foundation scenarios and the 0.5% wake effect hypothetical scenario

	50:50 combination	100% Jacket/pile foundations
Lifetime emissions (MtCO2eq)	5.2	6.3
Total carbon savings for "all non renewables"(MtCO2eq)	70.0	68.9
Total carbon savings for gas (MtCO2eq)	60.6	59.5
Payback time for "all non-renewables" (years)	2.4	2.9
Payback time for gas (years)	2.8	3.3

5.2 Carbon Payback for 1% Wake Effect Scenario

For the second comparison, the same process was used, with the total annual electricity generation of 1% of all the neighbouring OWFs (522.8GWh) being subtracted from the expected Project total annual electricity generation, leaving the net additional electricity that the Project would generate after wake effects. This results in a new annual electricity generation figure of 4,809GWh for the purposes of pay-back times.

Table 5-7 shows this new electricity generation, and the amount of carbon dioxide equivalent emissions it is expected to offset under these circumstances.

Table 5-7: Project electricity generation and offsetting figures under the 1% wake effect hypothetical scenario

Total annual power generation (GWh)	4,809
Total power generation over 35 year lifetime (TWh)	168.3
35 years of counterfactual "all non-renewables CO2eq emissions" (MtCO2eq)	71.3
35 years of counterfactual Gas CO2eq emissions (MtCO2eq)	62.4

Finally, Table 5-8 shows how this reduced carbon dioxide equivalent offsetting translates to the pay-back times, both for the two foundation scenarios.

Table 5-8; Project payback times under two foundation scenarios and the 1% wake effect hypothetical scenario

	50:50 combination	100% Jacket/pile foundations
Lifetime emissions (MtCO2eq)	5.2	6.3
Total carbon savings for "all non renewables"(MtCO2eq)	71.3	65.0
Total carbon savings for gas (MtCO2eq)	62.4	56.1
Payback time for "all non-renewables" (years)	2.6	3.1
Payback time for gas (years)	2.9	3.5

Considering Table 5-3, Table 5-4, Table 5-5, Table 5-6, Table 5-7 and Table 5-8, **the second conclusion to be drawn from this hypothetical scenario is that the carbon pay-back times for the Project would increase from between 2.3 and 3.2 years (the original numbers) to between 2.4 and 3.3 years for the 0.5% wake effect scenario, and to between 2.7 and 3.5 years for the 1% wake effect scenario**. These changes are an increase from the original numbers of between 4% and 6% for the 0.5% wake effect scenario, and between 10% and 11% for the 1% wake effect scenario.

Overall, then, we see that, if the Wake Effects from the Project reduced electricity production from neighbouring OWFs by 0.5%, its carbon payback time would increase to 2.4-3.3 years, while if it reduced electricity production by 1%, its carbon payback time would increase to 2.7-3.5 years. These increases are not considered to be material for the purposes of EIA.