MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Calculation of Net Effects on Greenhouse Gas Emissions

Deadline: 6

Application Reference: EN010136

Document Number: MRCNS-J3303-RPS-10230

Document Reference: S_D6_41

27 February 2025

F02

Image of an offshore wind farm

www.morganandmona.com/morgan

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
F01	Deadline 5	RPS	Morgan Offshore Wind Limited	Morgan Offshore Wind Limited	January 2025
F02	Deadline 6	RPS	Morgan Offshore Wind Limited	Morgan Offshore Wind Limited	February 2025

Prepared by:	Prepared for:
RPS	**Morgan Offshore Wind Limited.**

Contents

Tables

Figures

Appendices Tables

Appendix

Glossary

Term	Meaning
Climate change	A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.
CO_2e	'carbon dioxide equivalent.' Used to measure and compare emissions from greenhouse gases based on how severely they contribute to global warming
Emissions	An amount of a substance that is produced and sent out into the air that is harmful to the environment, especially carbon dioxide.
Fossil fuel	A hydrocarbon-containing material formed naturally in the earth's crust from the remains of dead plants and animals.
Greenhouse Gas (GHG)	A gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect. Examples include carbon dioxide and methane.
Marginal generation source	Accounts for sustained changes in energy consumption for the purposes of cost-benefit analysis, including policy appraisal.
Maximum Design Scenario (MDS)	The scenario within the design envelope with the potential to result in the greatest impact on a particular topic receptor, and therefore the one that should be assessed for that topic receptor.
Renewable energy	Energy from a source that is not depleted when used, such as wind or solar power.
UK Grid Carbon Intensity	Carbon intensity is a measure of how clean UK Grid electricity is. It refers to how many grams of carbon dioxide (CO_2) are released to produce a kilowatt hour (kWh) of electricity.
Well-to-tank	Emissions associated with the production, transportation, transformation and distribution of fuels.

Acronyms

Acronym	Description
AEP	Annual energy production
BEIS	Department for Business, Energy and Industrial Strategy
CNP	Critical National Priority
DCO	Development Consent Order
DESNZ	Department for Energy Security and Net Zero
EIA	Environmental Impact Assessment
ExA	Examining Authority
ExQ	Examining Authority’s written questions
GHG	Greenhouse Gas
IP	Interested Party

Acronym	Description
IEMA	Institute of Environmental Management and Assessment
ISH	Issue Specific Hearing
MDS	Maximum Design Scenario
OFGEM	Office of Gas and Electricity Markets
OWF	Offshore Wind Farm
REGO	Renewable Energy Guarantees of Origin

Units

Unit	Description
%	Percentage
CO_2e	Carbon dioxide equivalent
GW	Gigawatts
Kg	Kilograms
$kgCO_2e$	Kilograms of carbon dioxide equivalent
Km	Kilometres
km^2	Square kilometres
MW	Megawatts
MWh	Megawatt hours
MWh/yr	Megawatt hours per year
tCO_2e	Tonnes of carbon dioxide equivalent
T	Tonnes

1 EXECUTIVE SUMMARY

1.1.1.1 This technical note provides a calculation of the effects of the Morgan Offshore Wind Project: Generation Assets (hereafter 'Morgan Generation Assets') on greenhouse gas (GHG) emissions, taking into account the potential for wake effects (i.e. any energy production losses that result from changes in wind speed caused by the impact of wind turbine generators on each other) from the Morgan Generation Assets on existing Ørsted Interested Parties (IPs) operational offshore wind farms (OWF). The note has two purposes: firstly, to determine the net effect on GHG emissions relating to the potential wake values put forward by the Ørsted IPs in their Wake Impact Assessment Report (REP5-059c); and secondly, to conceptually explore the effect of implementing mitigation for wake effects on net GHG emissions. To address these, a scenario-based approach has been used to calculate the net GHG emissions for three cases:

a) **Business as usual**: present day baseline scenario with continued energy production from existing Ørsted IPs OWFs in the Irish Sea in the absence of the Morgan Generation Assets.

b) **Presence and operation of the Morgan Generation Assets:** energy production from the Morgan Generation Assets, designed in accordance with the Maximum Design Scenario (MDS) as set out in Volume 1, Chapter 3: Project description (S_D6_15), as well as energy production from existing Ørsted IPs OWFs in the Irish Sea, accounting for a potential reduction in energy production due to Ørsted IPs estimated wake effects.

c) **Sensitivity study into the presence and operation of the Morgan Generation Assets under two alternate design scenarios:**

   1. **Presence and operation of the Morgan Generation Assets (Preliminary Environmental Information Report (PEIR) boundary):** energy production from the Morgan Generation Assets, representing the PEIR design parameters, as well as energy production from existing Ørsted IPs OWFs in the Irish Sea.

   2. **Presence and operation of the Morgan Generation Assets with indicative mitigation for potential wake effects:** energy production from the Morgan Generation Assets, re-designed to incorporate indicative mitigation for potential wake effects, as well as energy production from existing Ørsted IPs OWFs in the Irish Sea, with a corresponding reduction in potential wake effects.

1.1.1.2 For each scenario, net effects are presented with regard to the avoided GHG emissions (presented in tonnes of carbon dioxide equivalent (tCO2e)) due to overall renewable energy contribution to the UK electricity Grid. Two emissions factors have been used in the calculation of GHG emissions to estimate the potential avoided emissions as a result of each scenario, in line with the methodology detailed in Volume 4, Chapter 2: Climate change (APP-016). These are the long-run marginal emissions factor (carbon intensity of long-run marginal electricity generation and supply) and 'non-renewable fuels' (current estimated intensity from electricity supplied for 'all non-renewable fuels').

1.1.1.3 This note has been prepared to address Action Point 12 arising from Issue Specific Hearing 2: Environmental Matters and Other Sea Users (ISH2), updated at Deadline 6 to reflect the updated Ørsted IPs Wake Impact Assessment Report (REP5-059c) which is noted to reflect the Morgan Generation Assets application boundary and a correction to the capacity values for Burbo Bank. The calculations have applied the estimated wake effects on energy yield put forward by the Ørsted IPs (REP5-059c), however the use of these figures does not in any way indicate the Applicant's agreement with the Ørsted IPs wake assessment for the reasons set out in previous submissions on this topic (see for example REP4-009) or that there is a policy requirement to undertake an assessment. The application of the updated figures provided by the Ørsted IPs in REP5-059c does not change the conclusions of this technical note.

1.1.1.4 Additionally, this note has been prepared to address the Ørsted IPs comments in response to Deadline 4 submissions (REP5-057) and the second written questions of the Examining Authority (ExQ2) (REP5-059a) regarding the mitigation of wake effects as a result of changes to the Morgan Array Area (i.e. from the PEIR boundary to the DCO application boundary). A sensitivity case has been assessed to represent the Morgan Generation Assets' PEIR boundary, to demonstrate the mitigation that has been achieved as a result of the DCO design parameters.

1.1.1.5 An assumption to determining the outcomes of the assessment is the use of a conservative capacity factor to calculate the average energy production for the Morgan Generation Assets (presented in Volume 2, Chapter 12: Climate change (APP-016)). The capacity factor used is based on historic capacity reported in UK offshore wind projects, and as such does not account for efficiency improvements associated with technological advances in wind turbine design and manufacture. It is likely that the Morgan Generation Assets' capacity factor will be much improved. As such, it can be expected that the Morgan Generation Assets' energy production potential, and therefore associated avoided emissions, would be greater in reality.

1.1.1.6 The assessment concludes the following:

- **'Scenario a' Net GHG emissions for business as usual:** the total avoided emissions associated with the present-day baseline scenario of operational Ørsted IPs projects in the absence of the Morgan Generation Assets are 2,886,965 tCO_2e (Department for Energy Security and Net Zero (DESNZ) long-run marginal) and 27,042,721 tCO_2e (DESNZ 'non-renewable fuels').
- **'Scenario b' Net GHG emissions associated with the Morgan Generation Assets accounting for the Ørsted IPs wake assessment (REP5-059c):** the total lifetime avoided emissions associated with the Morgan Generation Assets alongside existing operational Ørsted IPs projects (accounting for a potential reduction in energy production due to Ørsted IPs estimated wake effects) would be 5,231,525 tCO_2e (DESNZ long-run marginal) and 79,863,381 tCO_2e (DESNZ 'non-renewable fuels'), demonstrating that the operation of the Morgan Generation Assets, installed in line with the MDS, would lead to an overall net benefit in terms of GHG emissions.
- The loss of avoided emissions by the Ørsted IPs projects as a result of the presence and operation of the Morgan Generation Assets is negligible when compared to the avoided emissions achieved by the Morgan Generation Assets. Under 'Scenario b' the Ørsted IPs projects result in a total loss of avoided emissions of 48,336 tCO_2e (DESNZ long-run marginal)/ 472,816 tCO_2e (DESNZ 'non-renewable fuels'), while the Morgan Generation Assets results in 2,404,980 tCO_2e (DESNZ long-run marginal)/53,411,680 tCO_2e (DESNZ 'non-renewable fuels'), thereby outweighing any loss (range presented using the long run marginal and non-renewable fuels emissions factors).
- The net change in avoided emissions which has been calculated for the Ørsted IPs projects based on the potential wake effects put forward by the Ørsted IPs (REP4-049) does not alter the conclusions of the climate change assessment as

presented in Volume 2, Chapter 12: Climate change (APP-016). This is because the assessment uses a conservative capacity factor for the Morgan Generation Assets. A range of factors have influenced project yields (on which the historic capacity factor is based) including wake effects, therefore the capacity factor used, adequately factors in the potential for wake effects.

- **'Scenario c1' Change in net GHG emissions associated with the PEIR boundary:** The sensitivity study considers the impact on potential wake effects put forward by the Ørsted IPs resulting from the closer positioning of the Morgan Generation Assets aligning with the PEIR design parameters. The assessment demonstrates that under 'Scenario c1' there would be a reduction in net lifetime emissions overall. When compared with 'Scenario b', 'Scenario c1' results in 5,438 tCO_2e (DESNZ long-run marginal)/53,192 tCO_2e (DESNZ 'non-renewable fuels') fewer avoided emissions (range presented using the long-run marginal and non-renewable fuels emissions factors).

  This is because the sensitivity study confirms that the closer positioning of the Morgan Generation Assets to the Ørsted IPs projects (aligning with the PEIR boundary) would likely result in increased potential wake loss effects, reducing the Ørsted IPs projects' annual energy production (AEP). This therefore demonstrates that the refined boundary submitted with the Morgan Generation Assets' DCO application ('Scenario b') constitutes demonstrable mitigation on the potential wake loss effects experienced by the Ørsted IPs projects.

- **'Scenario c2' Change in net GHG emissions associated with indicative mitigation scenario:** The implementation of indicative mitigation by the Applicant to reduce the potential wake effects put forward by the Ørsted IPs projects would not result in a net benefit to GHG emissions reduction. The assessment demonstrated that under 'Scenario c2' (where indicative mitigation has been applied to the Morgan Generation Assets and the suggested wake losses experienced by existing Ørsted offshore wind farms in the Irish Sea are reduced) there would be a reduction in net lifetime avoided emissions overall, meaning any mitigation would have a counterproductive effect in achieving its net goal. When compared with 'Scenario b', 'Scenario c2' results in 40,716 tCO_2e (DESNZ long-run marginal)/1,245,100 tCO_2e (DESNZ 'non-renewable fuels') fewer avoided emissions (range presented using the long run marginal and non-renewable fuels emissions factors).

  This is because the indicative mitigation would result in increased wind turbine generator density within the Morgan Array Area, leading to increased internal wake effects reducing the Morgan Generation Assets' AEP. The corresponding reduction in potential wake effects on the Ørsted IPs OWFs associated with implementing such mitigation would be comparably small, which aligns with the general principle that wake effects internal to a project are greater than effects on external projects at a distance. The net loss in avoided emissions, therefore, is due to the decrease in the AEP of the Morgan Generation Assets resulting in a large loss of avoided emissions that outweigh those lost by the Ørsted IPs projects as a result of wake loss effects. This demonstrates that the implementation of mitigation does not support overall UK Government emissions reduction efforts.

1.1.1.7 The greatest benefit to national GHG emissions reduction, and UK renewable energy production, is achieved through the operation of the Morgan Generation Assets (without indicative mitigation), despite any potential losses experienced by the Ørsted IPs OWFs.

2 INTRODUCTION

2.1.1.1 This technical note provides a calculation of the net effects of the Morgan Generation Assets on greenhouse gas (GHG) emissions, taking into account the potential for wake effects from the Morgan Generation Assets on existing operational Ørsted IPs offshore wind farms (OWFs). The note has two purposes: firstly, to determine the net effect on GHG emissions relating to the potential wake values put forward by the Ørsted Interested Parties (IPs) in their Wake Impact Assessment Report (REP5-059c); and secondly, to determine the effect of implementing potential mitigation for wake effects on net GHG emissions. To address these, a scenario-based approach has been used to calculate the net GHG emissions for three cases:

a) **Business as usual:** present day baseline scenario with continued energy production from existing Ørsted IPs OWFs in the Irish Sea in the absence of the Morgan Generation Assets.

b) **Presence and operation of the Morgan Generation Assets:** energy production from the Morgan Generation Assets, designed in accordance with the Maximum Design Scenario as set out in Volume 1, Chapter 3: Project Description (S_D6_15), as well as energy production from existing Ørsted IPs OWFs in the Irish Sea, accounting for a potential reduction in energy production due to Ørsted IPs estimated wake effects.

c) **Sensitivity study into the presence and operation of the Morgan Generation Assets under two alternate design scenarios:**

   1. **Presence and operation of the Morgan Generation Assets (representative of the PEIR boundary):** energy production from the Morgan Generation Assets, representing the PEIR boundary , as well as energy production from existing Ørsted IPs OWFs in the Irish Sea.
   2. **Presence and operation of the Morgan Generation Assets (representative of the DCO application boundary) with indicative mitigation for potential wake effects:** energy production from the Morgan Generation Assets, re-designed to incorporate indicative mitigation for potential wake effects, as well as energy production from existing Ørsted IPs OWFs in the Irish Sea, with a corresponding reduction in potential wake effects.

2.1.1.2 For each scenario, net effects are presented with regard to the lifetime avoided GHG emissions (presented in tonnes of carbon dioxide equivalent (tCO_2e)) due to renewable contribution to the UK electricity Grid.

2.1.1.3 This note has been prepared to address Action Point 12 arising from Issue Specific Hearing 2: Environmental Matters and Other Sea Users (ISH2). The calculations utilised estimated wake effects on energy yield put forward by the Ørsted IPs (REP5-059c), however the use of these figures does not in any way indicate the Applicant's agreement with the Ørsted IPs wake assessment for the reasons set out in previous submissions on this topic (see for example REP4-009) or that there is a policy requirement to undertake an assessment.

3 BACKGROUND

3.1.1.1 The Ørsted IPs put forward, in their post-hearing submissions at Deadline 4 (REP4-047, REP4-048, and REP4-049) and updated submissions at Deadline 5 (REP5-059c), that preliminary results of modelling have indicated that the Morgan Generation Assets will have an impact on their existing operational developments of between 0.20 and 3.35% annual energy production AEP, and, when considered cumulatively with the Mona Offshore Wind Project and the Morecambe Offshore Windfarm: Generation Assets, between 1.63 and 5.21. A more detailed breakdown of the figures for each of the Ørsted IPs wind farms was provided by the Ørsted IPs in their Wake Impact Assessment Report (REP5-059c). The Applicant in no way agrees with the Ørsted IPs wake assessment, or that there is a policy requirement for such an assessment (as set out in the response to Hearing Action Point 25 arising from the Issue Specific Hearing 1 (ISH1) which was held on 10 September 2024 (REP1-016)). However, in response to the Examining Authority's second written questions (ExQ2) INF 2.3, the Applicant has carried out an exercise utilising the figures provided by the Ørsted IPs to provide a calculation of the net effects on GHG emissions:

3.1.1.2 'Provide a technical note to include an assessment on the potential net effect on Greenhouse Gas emissions, taking account of the Wake Impact Assessment Report [REP4-049] and the calculated reduction in energy yield of the six OWFs operated by the Ørsted IPs.

3.1.1.3 The Applicant set out its position in its Response to IP submissions submitted at Deadline 3 (REP3-070.6; REP4-009) as follows:

3.1.1.4 'The marginal *source of energy generation displaced by new renewable generation must be based on a prediction of the future long-term trends of generation type, which has inherent uncertainty built-in. Any assessment must be considered on the basis that the long-run marginal emission of future generation may at any point include more, or less, renewables generation from other generators than the long-run marginal data set assumes. In this regard at a high level, possible reduction of generation by the Orsted IPs and replacement of generation by alternative generators, is already factored into the assessment. It is also noteworthy that as the UK moves towards its 2050 net zero carbon target, the marginal source of electricity generation will likely become a combination of renewables (predominately solar and wind) and storage. Therefore, from circa 2040 onwards, comparing the Morgan Generation Assets' GHG impacts with the marginal source of generation is akin to comparing it with itself and has limited value.*

3.1.1.5 As noted in the IEMA Environmental Impact Assessment (EIA) Guidance on Assessing GHG Emissions *(IEMA, 2022) "the crux of significance therefore is not whether a project emits GHG emissions, nor even the magnitude of GHG emissions alone, but whether it contributes to reducing GHG emissions relative to a comparable baseline consistent with a trajectory towards net zero by 2050." The Applicant submits that it is uncontentious that factoring in any potential change in the Ørsted IPs generation output, when viewed against the long term-marginal source of electricity that would replace that generation, would not change the outcome of the EIA assessment for GHG net effects (see section 12.11 of Volume 2, Chapter 12: Climate change (APP-016)) as beneficial, and therefore of positive significance in EIA terms.*

3.1.1.6 However, the Applicant has confirmed (at ISH2, S_D4_4) that it will utilise the figures provided by the Ørsted IPs to provide a calculation of the effects of the project on climate, specifically the net effects on GHG emissions. The Applicant can confirm that *this assessment will be presented at Deadline 5. This would in no way suggest agreement with those figures (as set out in the Applicant's response to REP3-070.9). The Applicant would need to be provided with a more detailed breakdown of the output of the figures, in particular which impacts the Ørsted IPs consider relate to which project. If such figures are provided to the Applicant by the Ørsted IPs then it would provide a technical note on calculation of the net effects on GHG emissions'.*

3.1.1.7 In response to Action Point 5 from the Issue Specific Hearing 3 (ISH3) (EV6-011), the Ørsted IPs have submitted to the Applicant a paper concerning potential lifetime extensions for its Ørsted IPs projects. This paper was submitted previously as part of the Morecambe Offshore Windfarm: Generation Assets Examination in response to Action Point 23 of the hearing points arising from Issue Specific Hearing 3 (ISH3) (Morecambe Offshore Windfarm: Generation Assets Examination library reference EN010121 EV7-006). The paper states that *"The Applicant's assessment of the net GHG emissions arising from the Project must account for total loss of generation from the Orsted IPs' developments for 10 years beyond their 20- or 25-year lifetime, in order provide an accurate worst-case scenario."*

3.1.1.8 Should the Secretary of State deem it necessary to consider the potential for future lifetime extensions for consented Ørsted IPs projects a matter for the Examination, the Applicant has carried out an exercise which assumes a 10 year lifetime extension of the Ørsted IPs projects, presented in Appendix A: (in response to Action Point 6 of ISH3 (EV6-011)). It should be noted that no commensurate lifetime extension has been considered for the Morgan Generation Assets, but if the logic is applied to the Orsted assets then it could equally be applied to the Morgan Generation Assets.

4 METHODOLOGY

4.1 Scenarios

4.1.1.1 This technical note calculates the net effect on GHG emissions for three scenarios:

a) **Business as usual:** present day baseline scenario with continued energy production from existing Ørsted IPs OWFs in the Irish Sea in the absence of the Morgan Generation Assets. Additional context on why this assessment is limited to just Ørsted IPs can be found in paragraph 4.2.3.6.

b) **Presence and operation of the Morgan Generation Assets:** energy production from the Morgan Generation Assets, designed in accordance with the MDS as set out in Volume 1, Chapter 3: Project description (S_D6_15), as well as energy production from existing Ørsted IPs OWFs in the Irish Sea, accounting for a potential reduction in energy production due to Ørsted IPs estimated wake effects.

c) **Sensitivity study into the presence and operation of the Morgan Generation Assets under two alternate design scenarios:**

1. **Presence and operation of the Morgan Generation Assets (representative of the PEIR boundary):** energy production from the Morgan Generation Assets, representing the PEIR boundary , as well as energy production from existing Ørsted IPs OWFs in the Irish Sea.

2. **Presence and operation of the Morgan Generation Assets (representative of the DCO application boundary) with indicative mitigation for potential wake effects**: energy production from the Morgan Generation Assets, re-designed to incorporate indicative mitigation for wake effects, as well as energy production from existing Ørsted IPs OWFs in the Irish Sea, with a corresponding reduction in potential wake effects.

4.1.1.2 The indicative assessment of the wake loss effects associated with the Morgan Generation Assets' PEIR boundary comprised decreasing the separation distance between two projects representative of the Morgan Generation Assets and the Ørsted IPs projects. Further detail regarding this indicative assessment of the PEIR boundary is included at section 4.2.4.

4.1.1.3 The indicative mitigation comprises increasing the separation distance between two projects (representative of the Morgan Generation Assets and the Ørsted IPs projects placed collectively at the closest separation), resulting in a shrinking of the mitigated project and a corresponding increase in the density of the wind turbine generator layout. Further detail regarding this indicative mitigation is included at section 4.2.4.

4.1.1.4 Cumulative calculations of avoided emissions considering the Morgan Generation Assets with the Mona Offshore Wind Project and the Morecambe Offshore Windfarm: Generation Assets has not been considered within this note (see paragraph 5.3.2.3 for further discussion).

4.1.1.5 For each scenario, the following methodology has been applied to determine the net effects on GHG emissions:

- Calculation of lifetime energy production:
  - Baseline energy production has been determined for operational Ørsted IPs OWFs and for the Morgan Generation Assets (detailed in section 4.2.2).

  - For operational Ørsted IPs OWFs, baseline energy production has been adjusted for estimated wake losses associated with the Morgan Generation Assets, as provided by Ørsted IPs (REP5-059c) (detailed in section 4.2.3).
  - For the Morgan Generation Assets, baseline AEP has been adjusted for the reduction in energy production resulting from the implementation of mitigation for potential wake effects on existing offshore wind projects (detailed in section 4.2.4).
- The resulting avoided GHG emissions (tCO_2e) associated with the energy production have been calculated for the above scenarios on a lifetime basis, as detailed in section 4.3.

4.1.1.6 Data sources used in the calculations are detailed in Table 4.1 below.

Table 4.1: Data sources used in the calculations.

Dataset	Source
Operational offshore wind farm annual electricity generation	Renewable Energy Guarantees of Origin (REGO) certificate reporting by Office of Gas and Electricity Markets (OFGEM), 2024.
Operational offshore wind farm decommissioning dates	Ørsted IPs decommissioning dates available in the public domain for their Irish Sea projects (from Ørsted IPs submissions into the Mona Offshore Wind Project Examination (Mona Offshore Wind Project Examination Library Reference REP4-130)).
Wake losses for Ørsted IPs operational offshore wind farms	Estimated wake losses calculated by the Ørsted IPs for Morgan Generation Assets from scenario 1 in Table 5-4 of the Ørsted IPs Deadline 4 Submission - Wood Thilsted Wake Impact Assessment Report (REP4-049 as updated in REP5-059c to reflect the Morgan Generation Assets application boundary and an update to the capacity values for Burbo Bank). The Applicant highlights that use of the Ørsted IPs estimated wake loss values does not in any way imply it is in agreement with these values (as set out in section 3 above).
Morgan Generation Assets AEP	Table 12.16 of Volume 2, Chapter 12: Climate change (APP-016).
Morgan Generation Assets internal losses resulting from mitigation	Sensitivity study by the Applicant to assess the reduction in AEP which would result from increasing the distance between OWFs, as detailed in section 4.2.4 below.

4.2 Energy generation methodology

4.2.1.1 The sections below detail the methodology undertaken to calculate the energy generation for each scenario, in order to inform the GHG assessment.

4.2.2 Scenario a) Business as usual

Ørsted IPs OWFs

4.2.2.1 An average AEP (MWh/yr) for each of the Ørsted IPs projects listed in Table 4.2 has been calculated based on the AEP since 2014 sourced from publicly available REGO certificate reporting provided by OFGEM (2024) in the absence of more detailed project-specific information on AEP being made available in the Ørsted IPs Wake Impact Assessment Report (REP4-049).

4.2.2.2 Lifetime energy production has been calculated based on the decommissioning dates for each project, as set out in Table 4.2. This is consistent with the approach for the Morgan Generation Assets which has assumed a 35-year life.

Table 4.2: Ørsted IP's relevant projects with decommissioning dates.

Ørsted IPs developments		Decommissioning date	Remaining lifetime (months)*
Burbo Bank 1		December 2031	23
Burbo Bank 2 (extension)		May 2041	136
Barrow		September 2030	8
Walney	Walney 1	July 2035	66
	Walney 2	June 2036	77
Walney Extension	Walney 3	May 2042	148
	Walney 4	May 2042	148
West of Duddon Sands		October 2038	105

*Remaining lifetime of each project from the operation of Morgan Generation Assets (2030) to each project's decommissioning date.

4.2.2.3 When calculating the lifetime production (MWh) of each Ørsted IPs project, the average historic production (as informed by OFGEM, 2024) has been scaled for each Ørsted IPs project over its remaining lifetime. Such average production figures do not account for any fluctuations in energy production due to factors such as major component replacement and technological upgrades, and changing wind resource, nor potential wake loss benefits as a result of the decommissioning of neighbouring wind projects. Likewise, when calculating lifetime production for the Morgan Generation Assets, the same factors have not been accounted for.

4.2.2.4 In order to define a timeframe over which to undertake the assessment, the Ørsted IPs decommissioning dates have been used alongside the expected lifetime of the Morgan Generation Assets (35 years). The AEP and associated avoided emissions have been scaled by the remaining lifetime of the Ørsted IPs project (see Table 4.2) from the first year of operation of the Morgan Generation Assets (2030). Scenarios where projects (i.e. Morgan Generation Assets and/or Ørsted IPs projects) extend beyond these lifetimes have not been considered.

4.2.3 Scenario b) Presence and operation of Morgan Generation Assets

Morgan Generation Assets

4.2.3.1 Annual and lifetime energy generation for the Morgan Generation Assets have been extracted from Volume 2, Chapter 12: Climate change (APP-016). The climate change assessment took a Maximum Design Scenario approach and assumed a conservative worst case.

4.2.3.2 The average energy production (MWh) calculated for the Morgan Generation Assets presented in Volume 2, Chapter 12: Climate change (APP-016) uses a conservative capacity factor based on historic capacity reported in UK offshore wind projects, and as such does not account for efficiency improvements associated with technological advances in wind turbine design and manufacture. This capacity factor was used in order to present a conservative assessment when final design information was not available to refine assumptions. It is likely that the Morgan Generation Assets' capacity factor will be much improved. As such, it can be expected that any reported losses in the Morgan Generation Assets' AEP potential and associated avoided emissions would be greater in reality. Therefore, this note presents a conservative comparison to the Ørsted IPs project losses, and underplays the benefits of the Morgan Generation Assets due to that conservatism.

Ørsted IPs OWFs

4.2.3.3 The Ørsted IPs Wake Impact Assessment Report: Irish Sea Cluster (REP5-059c) details the extent to which Ørsted IPs consider that the Morgan Generation Assets may result in additional wake effects on the future operational energy production of the Ørsted IPs projects. Ørsted's report has assessed the energy yield and subsequent impact of the potential wakes produced by individual wind farms using WindFarmer: Analyst software.

4.2.3.4 The potential wake loss values provided by the Ørsted IPs for the Morgan Generation Assets only scenario (as summarised within Table 4.3) have been used to scale the Ørsted IPs project parameters (as detailed at section 4.2) to calculate an updated AEP.

4.2.3.5 The Applicant highlights that use of the Ørsted IPs estimated wake loss values does not in any way imply it is in agreement with these values (as set out in section 3 above).

4.2.3.6 The Applicant notes that the Ørsted IPs Wake Impact Assessment Report: Irish Sea Cluster (REP5-059c) considers the potential for wake effects on projects operated by Ørsted IPs only and does not present potential wake values for other planned or operational projects within the Irish Sea. As a result, the calculation of potential wake losses for operational offshore wind farms in the Irish Sea which are not operated by the Ørsted IPs has not been included in this note. These non-Ørsted IP operational wind farms have not made any submissions on wake effects or provided estimated values for potential wake effects on energy production. The assessment is therefore limited to those projects for which potential wake losses have been estimated within the Ørsted IPs wake impact assessment report (REP5-059c) only.

Table 4.3: Ørsted IPs projects additional potential wake losses as a result of Morgan Generation Assets only as provided by Ørsted IPs (REP5-059c).

	Burbo Bank 1	Burbo Bank 2	Barrow	Walney 1	Walney 2	Walney Extension[1]	West Duddon Sands	Total
Morgan Generation Assets only	-0.25%	-0.20%	-0.45%	-1.58%	-2.18%	-3.29%	-1.28%	-1.68%

[1]Average case for Walney Extension 3 and Walney Extension 4 presented here.

4.2.4 Scenario c) Sensitivity study into the presence and operation of the Morgan Generation Assets under two alternate design scenarios

Methodology

4.2.4.1 To estimate both the effect of the Morgan Generation Assets' design parameter changes between consultation on the PEIR and the DCO application (i.e. the increased distance between the Morgan Generation Assets and the Ørsted IPs projects), and the potential mitigation effect of further increasing the distance between the Morgan Generation Assets and the Ørsted IPs projects, thereby reducing wake effects on the Ørsted IPs projects, the Applicant has performed a simple sensitivity study based on a generic model of two interacting wind farms, to provide an indication of how the potential wake impacts may be impacted by changing their separation distance. This exercise does not seek to accurately replicate or reflect the real-world situation in the Irish Sea, as, for reasons explained in previous submissions (see for example REP4-009) the Applicant does not have a number of key pieces of information needed to undertake this. Instead, it seeks to demonstrate principles of effect on the respective wind farms when applying spatial mitigation.

4.2.4.2 Further, the exercise presents hypothetical indicative scenarios to test the theory of potential mitigation, and does not present mitigation that could be accommodated by the Morgan Generation Assets given known and unknown constraints and commitments regarding wind turbine generator layouts.

4.2.4.3 All calculations were performed in Openwind software with the wake model TurbOPark developed by Ørsted. The wind resource and thus wind direction and wind speed were based on the Applicant's data for the Morgan Generation Assets and are representative of the meteorological conditions on site.

4.2.4.4 The generic model is detailed in Figure 4.2 below. The impacted 'OWF1' is assumed to have 1.4 GW installed capacity with 200 generic wind turbine generators (7.0 MW, hub height 105 m). The proposed 'OWF2' is assumed to have 1.5 GW installed capacity with 70 generic wind turbine generators (21.5 MW, hub height 170 m).

4.2.4.5 The following array boundary scenarios were investigated for the proposed 'OWF2' to inform 'Scenario c1' (as shown in Figure 4.1):

- A 300 km^2 array boundary with a gridded layout, at an average distance of 9.5 km from 'OWF1', which is representative of the relative locations of the Ørsted IP's projects and Morgan Generation Assets to each other. The closest two points of the respective array areas have a distance of 8.1 km, but due to the irregular shape of both, the Applicant has applied a mean distance in this indicative scenario to better capture the overall effect.
- A 300 km^2 array boundary with a gridded layout (consistent with the above scenario), at an average distance of 7.5 km from 'OWF1', which is representative of the relative locations of the Ørsted IP's projects and Morgan Generation Assets to each other under the PEIR boundary.

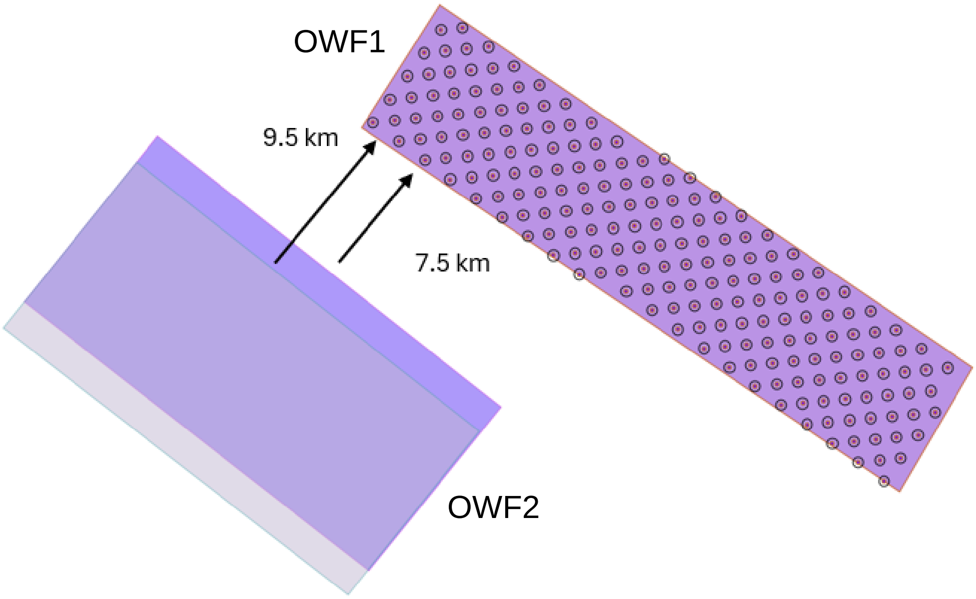

Figure 4.1: Scenario c1) Sensitivity study array boundary options.

4.2.4.6 The 2 km average change in distance between 'OWF1' and 'OWF2' under the above-described boundary scenarios (7.5km to 9.5km based on the DCO application to PEIR Boundary), increases the potential wake impact on 'OWF1' by 0.15% (from 1.68% to 1.83%), a relative increase of 9%. No corresponding increase in the internal wake loss for 'OWF2' was assessed.

4.2.4.7 The following array boundary scenarios were investigated for the proposed 'OWF2' to inform 'Scenario c2' (as shown in Figure 4.2):

- A 300 km^2 array boundary with a gridded layout, at a distance of 9.5 km from 'OWF1', which is representative of the relative locations of the Ørsted IP's projects and Morgan Generation Assets to each other. The closest two points of the respective array areas have a distance of 8.1 km, but due to the irregular shape of both, the Applicant has applied a mean distance in this indicative scenario to better capture the overall effect.
- A reduction in the array boundary area by 50% to 150 km^2, and increase in the distance of 'OWF2' to 'OWF1' to 15.5 km. This reduction results in an increase of the capacity density of 'OWF2' from 5 MW/km^2 to 10 MW/km^2, with correspondingly reduced turbine separation distances.

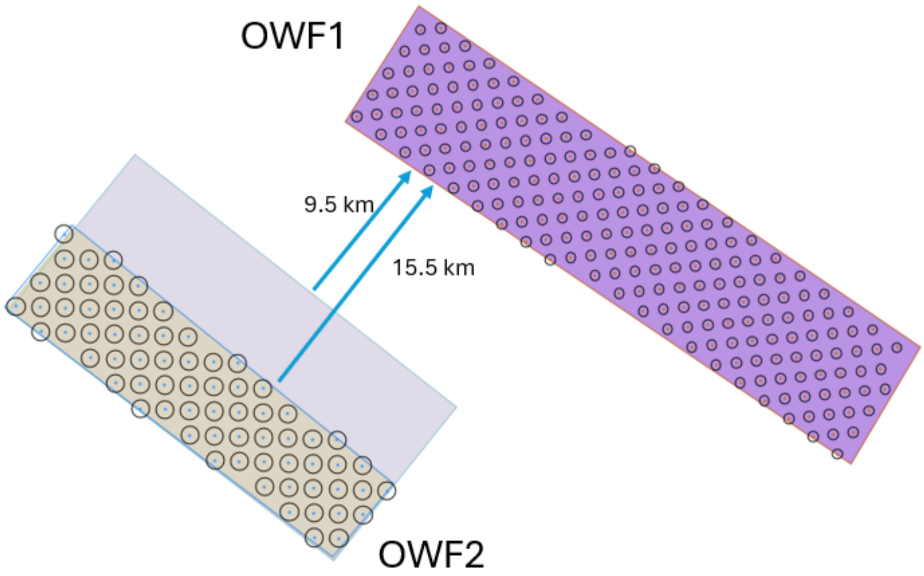

Figure 4.2: Scenario c2) Sensitivity study array boundary options.

4.2.4.8 The 50% reduction in array boundary area reduces the potential wake impact on 'OWF1' by 0.29% (from 2.21% to 1.93% - an improvement of 0.29%, translating to ~87% of the reported wake effects still occurring). The corresponding increase in the internal wake loss for 'OWF2' was 2.29% (from 9.85% to 12.14%), a relative increase of 23%. It is noted that a 50% reduction in the proposed 'OWF2' array boundary is not a realistic mitigation scenario without adapting the installed capacity. This scale of reduction was selected in order to achieve a meaningful modelled change in the potential wake impact on 'OWF1'. This first-principles study reflects the Applicant's experience of layout design.

Results

Scenario c1) Morgan Generation Assets

4.2.4.9 The above sensitivity study has been applied to the Morgan Generation Assets to indicate the impact on the Ørsted IPs projects under a scenario representative of the Morgan Generation Assets' PEIR boundary, where 'OWF2' is considered to represent the Morgan Generation Assets.

4.2.4.10 Under 'Scenario c1' there is no change in the density of the wind turbine generator layout of the Morgan Generation Assets from those presented under 'Scenario b'. This is because under both the PEIR and DCO design parameters the Morgan Generation Assets would meet the AEP proposed. Any internal wake loss effects are likely to have been accounted for through the use of conservative capacity factors presented in Volume 2, Chapter 12: Climate change (APP-016).

Scenario c2) Morgan Generation Assets

4.2.4.11 The above sensitivity study has been applied to the Morgan Generation Assets to indicate the impact on the Morgan Generation Assets and the Ørsted IPs projects under an indicative mitigation scenario, whereby 'OWF2' is considered to represent the Morgan Generation Assets.

4.2.4.12 Given that the Morgan Generation Assets is limited to the Order Limits specified within the DCO application, to implement such mitigation without reducing the wind farm capacity would necessitate reducing the spatial coverage of the Morgan Generation

Assets, thereby increasing the density of the wind turbine generator layout. This would have a corresponding negative effect on internal wake losses, reducing the wind farm's capacity factor, leading to an overall reduction in the Morgan Generation Assets AEP.

4.2.4.13 As stated at paragraph 4.2.4.8, for the purpose of providing an estimate of potential loss associated with a reduction in the array boundary, the increase in internal wake loss on the Morgan Generation Assets as a result of the change in array boundaries was conservatively considered to be 2%, based on the sensitivity study.

Scenario c1) Ørsted IPs OWFs

4.2.4.14 The potential wake effects detailed within the Ørsted IPs Wake Impact Assessment Report (REP5-059c) have been assumed to increase by 9% as a result of the outputs of the sensitivity study (see paragraph 4.2.4.6). This figure is applied to the wake effects reported by Ørsted IPs as shown in Table 4.4, to demonstrate the impact of the PEIR boundary on the Ørsted IPs projects' wake loss effects. This therefore highlights the benefits of the mitigation applied through the refined boundary presented in the DCO application (i.e. the increased separation distance between the Morgan Generation Assets and Ørsted IPs projects).

4.2.4.15 The revised potential wake effects for each of the Ørsted IPs projects are presented in Table 4.4, alongside those presented in Table 4.3 and informed by Ørsted IPs Wake Impact Assessment Report (REP5-059c).

Table 4.4: Ørsted IPs projects revised potential wake effects as a result of Morgan Generation Assets PEIR boundary.

	Burbo Bank 1	Burbo Bank 2	Barrow	Walney 1	Walney 2	Walney Extension[1]	West of Duddon Sands	Total
Scenario b potential wake losses	-0.25%	-0.20%	-0.45%	-1.58%	-2.18%	-3.29%	-1.28%	-1.68%
Scenario c1 potential wake losses	-0.27%	-0.22%	-0.49%	-1.72%	-2.38%	-3.58%	-1.40%	-1.83%

Scenario c2) Ørsted IPs OWFs

4.2.4.16 As detailed, the results of the above sensitivity study have been applied to the Morgan Generation Assets to an indicative level of reduction that the mitigation scenario would have on the predicted wake effect values generated by the Ørsted IPs. The potential wake effects detailed within the Ørsted IPs Wake Impact Assessment Report (REP5-059c) have been assumed to improve by only 0.29% as a result of the outputs of the sensitivity study (see paragraph 4.2.4.8). This confirms a general estimate of 80% of the reported wake effects still occurring, despite significant (and unrealistic, at 50% area reduction) amendments to the indicative project representative of the Morgan Generation Assets. This conservative figure is applied to the wake effects reported by Ørsted IPs as shown in Table 4.5, to assess the impact of the mitigation.

4.2.4.17 The revised potential wake effects for each of the Ørsted IPs projects are presented in Table 4.5, alongside those presented in Table 4.3 and informed by Ørsted IPs Wake Impact Assessment Report (REP5-059c).

Table 4.5: Ørsted IPs projects revised potential wake effects as a result of Morgan Generation Assets indicative spatial mitigation.

	Burbo Bank 1	Burbo Bank 2	Barrow	Walney 1	Walney 2	Walney Extension[1]	West Duddon Sands	Total
Scenario b potential wake losses	-0.25%	-0.20%	-0.45%	-1.58%	-2.18%	-3.29%	-1.28%	-1.68%
Scenario c2 potential wake losses	-0.20%	-0.16%	-0.36%	-1.26%	-1.74%	-2.63%	-1.02%	-1.34%

4.3 Greenhouse gas assessment methodology

4.3.1.1 The lifetime production for the Ørsted IP projects and Morgan Generation Assets under each scenario, as relevant, have been scaled by emissions factors to calculate the avoided emissions resultant from each scenario. The following emissions factors have been used, and are further detailed below:

- Electricity supplied by all non-renewable fuels
- Long run marginal electricity generation.

4.3.1.2 This methodology is consistent with that undertaken within Volume 2, Chapter 12: Climate change (APP-016).

4.3.1.3 The renewable generation assets from Ørsted IPs and the Morgan Generation Assets will likely contribute to the abatement of the amount of fossil fuel generation within the UK Grid (i.e. UK Grid carbon intensity). As such, the current baseline (at the time of the application submission) with regard to UK Grid-average emission factor for electricity generation is 252.974 kgCO_2e/MWh (including well-to-tank, excluding transmission and distribution losses) (DESNZ and Defra, 2023) and estimated intensity from electricity supplied for ‘all non-renewable fuels,’ 424 kgCO_2e/MWh (DESNZ, 2023a). These figures were accurate at the time of submission of the Morgan Generation Assets DCO application. As such, these static emission factors have been considered in this report. It should be noted that the figure for fossil fuel generation only is considered to be the higher avoided emission scenario, and as such is the static figure presented in the assessment below to detail the greatest potential avoided emissions. The methodology to present the lowest potential avoided emissions is summarised below.

4.3.1.4 The future baseline for electricity generation that would be displaced by the Morgan Generation Assets depends broadly on future energy and climate policy in the UK, and more specifically (with regards to day-to-day emissions) on the demand for the operation of the Morgan Generation Assets, compared to other generation sources available; this will be influenced by commercial factors and National Grid’s needs.

4.3.1.5 The carbon intensity of baseline electricity generation is projected to reduce over time and so too would the intensity of the marginal generation source, displaced at a given time.

4.3.1.6 The DESNZ (formerly Department for Business, Energy and Industrial Strategy (BEIS)) publishes projections of the carbon intensity of long-run marginal electricity generation and supply that would be affected by small (on a national scale) sustained changes in generation or demand (DESNZ, 2023b). DESNZ projections over the operating lifetime of the Morgan Generation Assets (as outlined in Table 5.2) are used to estimate the potential avoided emissions as a result of the Morgan Generation Assets.

4.3.1.7 The net lifetime reduction in avoided emissions associated with each scenario is presented, alongside their resultant total avoided emissions accounting for potential wake loss that has been predicted by Ørsted IPs. When considering the net impact of the Morgan Generation Assets on the Ørsted IPs projects, the reduction in energy production (MWh) and associated avoided emissions (tCO_2e) are provided to the decommissioning dates detailed in Table 4.2.

5 RESULTS

5.1 Overview

5.1.1.1 The following sections detail the energy generation values for each scenario and the subsequent net avoided GHG emissions associated with the Ørsted IP projects and Morgan Generation Assets under each scenario.

5.2 Energy generation results

5.2.1.1 Each section below details energy generation as relevant for each scenario, in order to inform the results of the GHG assessment detailed at section 5.

5.2.2 Scenario a) Business as usual

Ørsted IPs OWFs

5.2.2.1 AEP (MWh/yr) by the Ørsted IPs projects since 2014 has been presented in Table 5.1. Data is presented for whole year only energy production; where projects are operational for part of a year, this year has not been included as part of this assessment as this would likely skew the averages.

5.2.2.2 An average production[1] and average operational capacity factor[2] have been calculated and presented for each Ørsted IPs project (Table 5.1). This forms the baseline for the operational energy production of the existing Ørsted IPs projects whereby an assessment of net effects can be completed.

[1] Average of historic production output for each of Ørsted IPs projects.

[2] Calculated by scaling the installed capacity (MW) by the number of hours in a year (8,766 hours, to account for leap years) to reach the installed energy capacity (MWh). The average production (MWh) was then divided by this installed energy capacity (MWh) to reach the implied capacity factor.

Table 5.1: Historic energy production for Ørsted IPs projects sourced from OFGEM (2024).

Parameter	Year	Burbo Bank 1	Burbo Bank 2	Barrow	Walney 1	Walney 2	Walney Extension	West Duddon Sands
Historic AEP (MWh)	FY14/15	284,724	-	288,248	636,173	758,729	-	1,207,406
	FY15/16	312,474	-	307,971	679,323	501,578	-	1,449,863
	FY16/17	243,971	-	273,157	601,247	713,332	-	1,476,641
	FY17/18	227,429	936,208	302,012	727,680	845,893	-	1,686,408
	FY18/19	246,936	841,960	265,885	578,479	699,586	2,604,710	1,462,783
	FY19/20	269,645	993,919	284,915	658,513	800,215	2,904,033	1,571,852
	FY20/21	273,558	945,299	258,393	634,192	731,267	2,688,669	1,542,449
	FY21/22	206,807	803,587	236,987	552,230	634,615	2,178,171	1,334,335
	FY22/23	240,878	833,763	255,103	596,599	712,188	2,669,112	1,514,781
	FY23/24	213,113	918,643	246,913	599,660	692,184	2,542,900	1,522,975
Average AEP (MWh)		**251,954**	**896,197**	**271,958**	**626,410**	**708,959**	**2,597,933**	**1,476,949**
Predicted lifetime production (MWh)*		**482,912**	**10,156,899**	**181,305**	**3,445,255**	**4,549,154**	**32,041,174**	**12,923,304**
Installed capacity (MW)		90	258	90	183.6	183.6	659	389
Implied capacity factor		32%	40%	34%	38%	43%	44%	43%

*Remaining lifetime of each project from the operation of Morgan Generation Assets (2030) to each project's decommissioning date as stated in Table 4.2.

5.2.3 Scenario b) Presence and operation of Morgan Generation Assets

Morgan Generation Assets

5.2.3.1 Key energy generation parameters for the Morgan Generation Assets from Volume 2, Chapter 12: Climate change (APP-016) are presented in Table 5.2.

Table 5.2: Morgan Generation Assets parameters.

Parameter	Value
Input parameter - rated power (based on current estimates) MW	1,500
Capacity factor %	34.9
Output parameter – Annual Energy Production MWh	4,585,860
Lifetime output MWh	160,505,100
Operation Commencement Date	2030
Decommissioning Date	2065

Ørsted IPs OWFs

5.2.3.2 The generation losses presented within Table 4.3 have been applied to the average AEP from each Ørsted IPs project (displayed within Table 5.1) to calculate revised electricity production, accounting for potential wake effects from the Morgan Generation Assets as presented by the Ørsted IPs in REP5-059c. Results are presented in Table 5.3.

5.2.3.3 Additionally, the AEP and energy loss has been scaled by the remaining lifetime of the Ørsted IPs project (see Table 4.2) from the first year of operation of the Morgan Generation Assets (2030) to provide the lifetime energy production for the Ørsted IPs projects.

5.2.3.4 It should be noted that the total lifetime production loss of Ørsted IPs projects (833,338 MWh), as informed by Ørsted IPs estimate of wake effects presented in REP4-049, is significantly outweighed by one year of operation by the Morgan Generation Assets (4,585,860 MWh).

Table 5.3: Scenario b) Revised Ørsted IPs projects output parameters.

	Burbo Bank 1	Burbo Bank 2	Barrow	Walney 1	Walney 2	Walney Extension	West Duddon Sands	Total
Average AEP (MWh) (OFGEM)	251,954	896,197	271,958	626,410	708,959	2,597,933	1,476,949	6,830,360
AEP loss (MWh)	-504	-1,434	-979	-7,918	-12,364	-68,274	-15,124	-106,597
Revised AEP (MWh)	251,450	894,763	270,979	618,492	696,595	2,529,659	1,461,825	6,723,763
Predicted lifetime production (MWh) (OFGEM)	482,912	10,156,899	181,305	3,445,255	4,549,154	32,041,174	12,923,304	63,780,003
Lifetime production loss (MWh)	-1,207	-20,314	-816	-54,435	-99,172	-1,052,553	-165,418	-1,393,914
Revised lifetime production (MWh) [3]	481,705	10,136,586	180,489	3,390,820	4,449,982	30,988,621	12,757,885	62,386,088

[3] From first year of Morgan Generation Assets up to decommissioning date.

5.2.4 Scenario c1) Presence and operation of the Morgan Generation Assets (PEIR boundary)

Morgan Generation Assets

5.2.4.1 Under 'Scenario c1' there is no change in the density of the wind turbine generator layout of Morgan Generation Assets from those presented under 'Scenario b', see paragraph 5.2.3.1.

Ørsted IPs OWFs

5.2.4.2 As detailed at section 4.2.4, high level assessment by the Applicant has identified that as a result of the PEIR boundary, potential wake effects impacting the Ørsted IPs projects would be increased by 9% (relative increase, compared to DCO design parameters, resulting in a 0.15% absolute increase).

5.2.4.3 Revised potential wake losses presented in Table 4.4 have been applied to the baseline values presented in Table 5.1 to calculate revised AEP and lifetime production associated with the Ørsted IPs projects under the PEIR boundary scenario, presented in Table 5.4.

Table 5.4: Scenario c1) Revised Ørsted IPs projects output parameters.

Parameter	Ørsted IPs projects
Revised AEP (MWh)	6,685,122
AEP loss (MWh)	-145,238
Revised lifetime production (MWh)[4]	**62,260,636**
Lifetime production loss (MWh)	**-1,519,367**

5.2.5 Scenario c2) Presence and operation of the Morgan Generation Assets with indicative mitigation for potential wake effects

Morgan Generation Assets

5.2.5.1 The internal wake losses on the Morgan Generation Assets under the indicative mitigation scenario are subject to a relative increase of 23% (2%, absolute increase in wake loss) were applied to the baseline AEP for the Morgan Generation Assets (see Table 5.2) to reach amended AEP and lifetime production for scenario c2. This is presented in Table 5.5.

[4] From first year of Morgan Generation Assets up to decommissioning date.

Table 5.5: Scenario c2) Morgan Generation Assets revised project parameters.

Parameter	Morgan Generation Assets
Capacity factor change	-2%
Revised AEP (MWh)	4,494,143
Loss of AEP (MWh)	-91,717
Revised lifetime production (MWh)	**157,294,998**
Loss of lifetime production (MWh)	**-3,210,102**

Ørsted IPs OWFs

5.2.5.2 As detailed at section 4.2.4, high level assessment by the Applicant has identified that as a result of mitigation for potential wake effects by Morgan Generation Assets, potential wake effects impacting the Ørsted IPs projects would be reduced to 80% of those detailed within Ørsted's Wake Impact Assessment Report (REP4-049).

5.2.5.3 Revised potential wake losses presented in Table 4.5 have been applied to the baseline values presented in Table 5.1 to calculate revised AEP and lifetime production associated with the Ørsted IPs projects under the mitigation scenario, presented in Table 5.6.

Table 5.6: Scenario c2) Revised Ørsted IPs projects output parameters.

Parameter	Ørsted IPs projects
Revised AEP (MWh)	6,723,763
AEP loss (MWh)	-106,597
Revised lifetime production (MWh)[5]	62,664,871
Lifetime production loss (MWh)	**-1,115,131**

5.3 Greenhouse gas emissions results

5.3.1 Scenario a) Business as usual

5.3.1.1 The baseline avoided emissions for the Ørsted IPs projects has been calculated by scaling the predicted lifetime production (detailed in Table 5.1) by the relevant emissions factors as described in section 4.3. The resultant lifetime avoided emissions arising from the electricity generated by the Ørsted IPs projects is detailed in Table 5.7.

[5] From first year of Morgan Generation Assets up to decommissioning date.

Table 5.7: Scenario a) Ørsted IPs projects lifetime avoided emissions.

	DESNZ long-run marginal	DESNZ 'non-renewable fuels'
Ørsted IPs projects baseline lifetime avoided emissions (tCO_2e)	2,886,965	27,042,721

5.3.2 Scenario b) Presence and operation of Morgan Generation Assets

5.3.2.1 The avoided emissions associated with the Ørsted IPs projects, accounting for the potential wake loss effects provided by Ørsted IPs in REP4-049 as a result of the Morgan Generation Assets, have been calculated by scaling the revised lifetime production (detailed in Table 5.3) by the relevant emissions factors as described in section 4.3. The resultant lifetime avoided emissions arising from the electricity generated by the Ørsted IPs projects is detailed in Table 5.8, alongside the avoided emissions resultant from the energy generated by the Morgan Generation Assets (sourced directly from Volume 2, Chapter 12: Climate change (APP-016)).

Table 5.8: Scenario b) Ørsted IPs projects and Morgan Generation Assets lifetime avoided emissions.

		DESNZ long-run marginal	DESNZ 'non-renewable fuels'
Ørsted IPs projects	Baseline lifetime avoided emissions (tCO_2e)	2,886,965	27,042,721
	Total loss of avoided emissions associated with Morgan Generation Assets (tCO_2e)	-48,336	-472,816
	Revised lifetime avoided emissions (tCO_2e)	2,827,776	26,462,804
Morgan Generation Assets	Lifetime avoided emissions (tCO_2e)	2,404,980	53,411,680
Total avoided emissions (tCO_2e)		**5,231,525**	**79,863,381**

5.3.2.2 As a result of the potential wake effects from Morgan Generation Assets, as provided by the Ørsted IPs calculation of potential wake loss effects in REP4-049, it is estimated that the Ørsted IPs projects may result in between 59,189 tCO_2e (DESNZ long-run marginal) and 579,917 tCO_2e (DESNZ 'non-renewable fuels') of avoided emissions no longer achieved. When compared to the total avoided emissions resulting from the electricity generated by the Morgan Generation Assets (sourced directly from Volume 2, Chapter 12: Climate change (APP-016)), it is considered that such a loss is negligible.

5.3.2.3 Whilst this calculation has not considered cumulative scenarios of the Morgan Generation Assets with the Mona Offshore Wind Project and the Morecambe Offshore Windfarm: Generation Assets, it is anticipated that similar principles would apply in a cumulative scenario, whereby the cumulative net GHG benefit resulting from these projects would significantly outweigh a small reduction in avoided emissions for the Ørsted IPs projects.

5.3.3 Scenario c1) Presence and operation of the Morgan Generation Assets (PEIR boundary)

5.3.3.1 As detailed at section 4.2.4, consideration of the potential wake loss effects on the Ørsted IPs projects based on a project representative of the PEIR boundary for the Morgan Generation Assets was given in the sensitivity study. It was estimated that, as a result of the closer proximity of the projects, the likely wake loss effect experienced by the Ørsted IPs projects would increase by 0.15%, or a relative increase of 9%.

5.3.3.2 The avoided emissions associated with the Ørsted IPs projects, accounting for increased potential wake loss effects as a result of the increased proximity of the Morgan Generation Assets under the PEIR boundary scenario, have been calculated by scaling the revised lifetime production (detailed in Table 5.4) by the relevant emissions factors as described in section 4.3.

5.3.3.3 The avoided emissions associated with the Morgan Generation Assets, are consistent with those stated for 'Scenario b', see Table 5.8.

5.3.3.4 Revised avoided emissions arising from both the Ørsted IPs projects and Morgan Generation Assets (PEIR boundary) are summarised in Table 5.9.

Table 5.9: Scenario c1) Ørsted IPs projects and Morgan Generation Assets (PEIR boundary) lifetime avoided emissions.

		DESNZ long-run marginal	DESNZ 'non-renewable fuels'
Ørsted IPs projects	Baseline lifetime avoided emissions (tCO_2e)	2,886,965	27,042,721
	Total loss of avoided emissions associated with Morgan Generation Assets (tCO_2e)	-65,858	-644,211
	Revised lifetime avoided emissions (tCO_2e)	2,821,107	26,398,510
Morgan Generation Assets	Baseline lifetime avoided emissions (tCO_2e)	2,404,980	53,411,680
Net emissions (tCO_2e)		**5,226,087**	**79,810,190**
Net change in avoided emissions from scenario b		**-5,438**	**-53,192**

5.3.3.5 When comparing the net emissions associated with 'Scenario c1' (where an indicative assessment of the PEIR boundary has been undertaken) to those associated with 'Scenario b' (associated with the current DCO design parameters), it can be concluded that the PEIR boundary result in a comparative loss of net avoided emissions. This net loss is due to the decrease in the AEP of the Ørsted IPs projects as a result of the increased wake loss effect, leading to a greater loss of avoided emissions. This demonstrates that the changes to the Morgan Generation Assets' design parameters between consultation on the PEIR and the DCO application ('Scenario b') constitutes demonstrable mitigation on the potential wake loss effects experienced by the Ørsted IPs projects.

5.3.4 Scenario c2) Presence and operation of Morgan Generation Assets with indicative mitigation for potential wake effects

5.3.4.1 As detailed at section 4.2.4 indicative mitigation considered for the Morgan Generation Assets results in a >2% absolute reduction in Morgan Generation Assets' capacity factor as a result of internal wake loss effects. Alongside this, the potential wake loss effects on the Ørsted IPs projects, as provided by the Ørsted IPs in REP4-049, are anticipated to reduce by only 0.29% (as per paragraph 4.2.4.16, this confirms a general estimate of 80% of the reported wake effects still occurring despite the significant (and unrealistic, at 50% area reduction) amendments to the indicative project representative of the Morgan Generation Assets).

5.3.4.2 The avoided emissions associated with the Ørsted IPs projects, accounting for reduced potential wake loss effects as a result of the mitigation of the Morgan Generation Assets, have been calculated by scaling the total loss of avoided emissions associated with the Morgan Generation Assets (as presented within Table 5.8) by a conservative estimate of 80% to reach a revised lifetime loss, as presented in Table 5.10.

5.3.4.3 The avoided emissions associated with the Morgan Generation Assets, accounting for internal wake loss effects as a result of the mitigation, have been calculated by scaling the revised lifetime production (detailed in Table 5.5) by the relevant emissions factors as described in section 4.3.

5.3.4.4 Revised avoided emissions arising from both the Ørsted IPs projects and Morgan Generation Assets are summarised in Table 5.10.

Table 5.10: Scenario c2) Ørsted IPs projects and Morgan Generation Assets lifetime avoided emissions.

		DESNZ long-run marginal	DESNZ 'non-renewable fuels'
Ørsted IPs projects	Baseline lifetime avoided emissions (tCO_2e)	2,886,965	27,042,721
	Total loss of avoided emissions associated with Morgan Generation Assets (tCO_2e)	-48,336	-472,816
	Revised lifetime avoided emissions (tCO_2e)	2,838,629	26,569,905
Morgan Generation Assets	Baseline lifetime avoided emissions (tCO_2e)	2,404,980	53,411,680
	Total loss of avoided emissions associated with mitigation (tCO_2e)	-52,554	1,361,083
	Revised lifetime avoided emissions (tCO_2e)	2,352,426	52,050,597
Net emissions (tCO_2e)		**5,191,055**	**78,620,502**
Net change in avoided emissions from scenario b		**-40,470**	**-1,242,879**

5.3.4.5 When comparing the net emissions associated with 'Scenario c2' (where indicative wake loss mitigation has been implemented for the Morgan Generation Assets) to those associated with 'Scenario b' (where no mitigation has been implemented for the

Morgan Generation Assets), it can be concluded that the mitigation results in a net loss of avoided emissions. This net loss is due to the decrease in the AEP of the Morgan Generation Assets resulting in a large loss of avoided emissions that outweigh those lost by the Ørsted IPs projects as a result of wake effects.

6 SUMMARY AND CONCLUSIONS

6.1.1.1 Table 6.1 and Figure 6.1 summarises the associated net avoided GHG lifetime emissions for the three scenarios considered in this note. Each indicative Scenario is compared to 'Scenario b' (presence and operation of Morgan Generation Assets designed in accordance with Volume 1, Chapter 3: Project description (S_D6_15)).

6.1.1.2 It is demonstrated that under 'Scenario b', as a result of the operation of the Morgan Generation Assets, net lifetime avoided GHG emissions greatly exceed those associated with 'Scenario a' (business as usual without Morgan Generation Assets).

6.1.1.3 The loss of avoided emissions by the Ørsted IPs projects as a result of the presence and operation of the Morgan Generation Assets is negligible when compared to the avoided emissions achieved by the Morgan Generation Assets. Under 'Scenario b' the Ørsted IPs projects result in a total loss of avoided emissions between 48,336 tCO_2e (DESNZ long-run marginal) and 472,816 tCO_2e (DESNZ 'non-renewable fuels'), while the Morgan Generation Assets results in between 2,404,980 tCO_2e (DESNZ long-run marginal) and 53,411,680 tCO_2e (DESNZ 'non-renewable fuels'). This demonstrates that the avoided emissions arising from the operation of the Morgan Generation Assets greatly exceed any loss in avoided emissions by Ørsted IPs projects resulting from potential wake effects. It should also be noted that lifetime production loss (1,393,914 MWh) is outweighed by one year of operation by the Morgan Generation Assets (4,585,860 MWh).

6.1.1.4 In order to assess the benefits to the Ørsted IPs projects as a result of a change in Morgan Generation Assets' design parameters between consultation on the PEIR and the DCO application, a sensitivity study was used to consider indicative scenarios representative of the change in design parameters. As shown in Table 6.1, the scenario representative of the PEIR boundary results in reduced net avoided emissions as a result of increased wake loss effects on the Ørsted IPs projects. This indicates that the Morgan Generation Assets' design changes between consultation on the PEIR to submission of the DCO application have resulted in an improvement to the wake loss effect experienced by the Ørsted IPs projects, thereby demonstrating that mitigation has been applied.

6.1.1.5 In order to assess whether further mitigation by the Morgan Generation Assets would result in a net improvement in avoided emissions (compared to 'Scenario b'), an indicative mitigation scenario was considered, which reviewed the impact of increasing the distance between OWFs. As shown in Table 6.1, the scenario results in reduced net avoided emissions, demonstrating that the implementation of mitigation by the Morgan Generation Assets to reduce the potential wake effects on the Ørsted IPs projects would not result in a net benefit in terms of emissions. This is because the indicative mitigation would result in increased wind turbine generator density within the Morgan Array Area, leading to increased internal wake effects reducing Morgan Generation Assets' AEP. The corresponding reduction in potential wake effects on the Ørsted IPs OWFs associated with implementing such mitigation would be comparably small, which aligns with the general principle that the greatest wake effects are within wind farms (i.e. wake effects internal to a project are greater than effects on external projects at a distance). This net loss of avoided emissions is due to the decrease in the AEP of the Morgan Generation Assets resulting in a large loss of avoided emissions that outweigh those lost by the Ørsted IPs projects as a result of wake effects.

6.1.1.6 National Policy Statement EN-1 confirms the urgent need for new (emphasis added) electricity infrastructure to be brought forward as soon as possible to meet the Government's commitment to reducing GHG emissions by 78% by 2035 under carbon budget 6 (see paragraphs 3.3.5 and 3.3.58). New offshore wind capacity is also considered to be critical national priority (CNP) infrastructure (paragraph 3.3.63) and the deployment of new offshore wind capacity is a key element of the recently published Clean Energy Strategy 2030 which states at page 74:

6.1.1.7 *'Renewable technologies will form the foundation of our clean power system, and we need to see very significant deployment to make this a reality. Meeting the renewable capacities set out in the DESNZ 'Clean Power Capacity Range' is achievable, but will require deployment at a sharply accelerated scale and pace. This can only be delivered by unblocking delivery challenges throughout the development lifecycle'*.

6.1.1.8 The greatest benefit to national GHG emissions reduction, and UK renewable energy production, is achieved through the presence of the Morgan Generation Assets (without indicative mitigation), despite any potential losses experienced by the Ørsted IPs OWFs.

6.1.1.9 The application of the updated figures provided by the Ørsted IPs in REP5-059c does not change the conclusions of this technical note.

Table 6.1: Summary of net GHG avoided emissions.

Project	Parameter	Scenario			
		a: Business as usual (no Morgan Generation Assets)	b: Presence and operation of Morgan Generation Assets	c1: Sensitivity case - indicative PEIR boundary	c2: Sensitivity case - indicative mitigation
Morgan Generation Assets	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)	0	53,411,680	53,411,680	52,050,597
	DESNZ long-run marginal avoided emissions (tCO_2e)	0	2,404,980	2,404,980	2,352,426
Ørsted IPs Projects	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)	27,042,721[1]	26,451,701[2]	26,398,510	26,569,905[3]
	DESNZ long-run marginal avoided emissions (tCO_2e)	2,886,965[1]	2,826,545[2]	2,821,107	2,838,629[3]
Net emissions	**DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)**	**27,042,721**	**79,863,381**	79,810,190	78,620,502

Project	Parameter	Scenario			
		a: Business as usual (no Morgan Generation Assets)	b: Presence and operation of Morgan Generation Assets	c1: Sensitivity case - indicative PEIR boundary	c2: Sensitivity case - indicative mitigation
	DESNZ long-run marginal avoided emissions (tCO_2e)	**2,886,965**	**5,231,525**	5,226,087	**5,191,055**
Net change in emissions from Scenario b	**DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)**	n/a	**0**	-53,192	-1,242,879
	DESNZ long-run marginal avoided emissions (tCO_2e)	n/a	**0**	**-5,438**	**-40,470**

[1] Informed by baseline OFGEM reporting, not accounting for potential wake loss associated with the Morgan Generation Assets.

[2] Accounting for potential wake loss resulting from the Morgan Generation Assets, as calculated by Ørsted IPs in REP4-049.

[3] Accounting for a reduction in potential wake loss resulting from the Morgan Generation Assets, as calculated by Morgan Offshore Wind Limited.

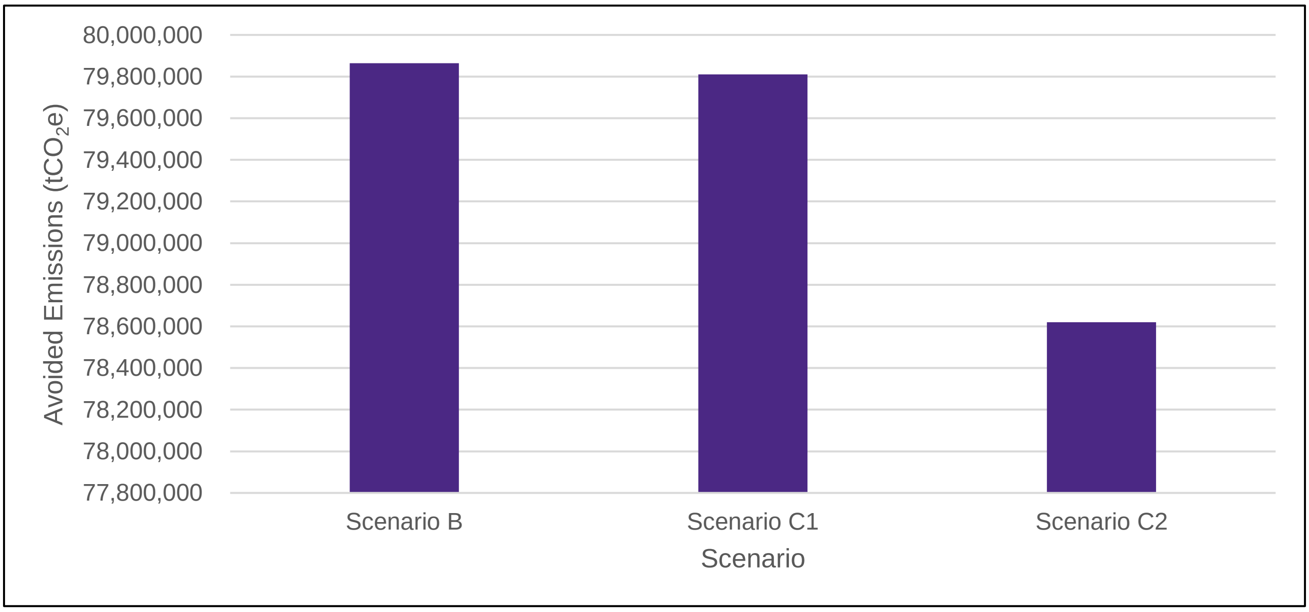

Figure 6.1: Net Avoided GHG Emissions for Scenarios B, C1 and C2

REFERENCES

DESNZ (2023a) Digest of UK Energy Statistics (DUKES): electricity. Available: https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes#full-publication-update-history. Accessed December 2023.

DESNZ (2023b) Valuation of Energy Use and Greenhouse Gas: Supplementary guidance to the HM Treasury Green Book. Available: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal. Accessed December 2023.

Department for Energy Security and Net Zero, and Department for Environment, Food & Rural Affairs (2023) UK Government GHG Conversion Factors for Company Reporting. Available at: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting. Accessed December 2023.

OFGEM (2024) Ofgem Renewables and Combined Heat and Power register [redacted]

Appendix A: Ørsted IPs Lifetime Extension Sensitivity Assessment

A.1.1.1.1 As detailed in paragraphs 3.1.1.7 to 3.1.1.8 of this note, the Ørsted IPs have detailed potential lifetime extensions for the referenced Ørsted IPs projects in response to ISH3 Action Point 5: *Submit details of approach to lifetime extensions of the individual Ørsted IPs arrays to the Applicant directly no later than Wednesday 19 February and at D6 to the Examining Authority.*

A.1.1.1.2 In response to Action Point 6 from the ISH3 (EV6-011), the Applicant has carried out an exercise in this Appendix to demonstrate whether such lifetime extensions proposed by the Ørsted IPs would have a material impact on the conclusions presented within this note.

A.1.1.1.3 The Applicant has included the lifetime extension duration (10 years) put forward by the Ørsted IPs (in its submission for the Morecambe Offshore Windfarm: Generation Assets Examination in response to Action Point 23 of the hearing points arising from Issue Specific Hearing 3 (ISH3) (EN010121 EV7-006)) and presented this in Table A.1 against the publicly available decommissioning dates for each project.

Table A.1: Ørsted IP's projects including 10 year lifetime extension to the publicly available decommissioning dates.

Ørsted IPs developments		Decommissioning date**	Decommissioning date + 10 year extension	Remaining lifetime (months) including 10 year extension*
Burbo Bank 1		December 2031	December 2041	143
Burbo Bank 2 (extension)		May 2041	May 2051	256
Barrow		September 2030	September 2040	128
Walney	Walney 1	July 2035	July 2045	186
	Walney 2	June 2036	June 2046	197
Walney Extension	Walney 3	May 2042	May 2052	268
	Walney 4	May 2042	May 2052	268
West of Duddon Sands		October 2038	October 2048	225

*Remaining lifetime of each project from the operation of the Morgan Generation Assets (2030) to each project's decommissioning date + 10 year extension.

**Ørsted IPs decommissioning dates from Ørsted IPs submissions into the Mona Offshore Wind Project Examination (Mona Offshore Wind Project Examination Library Reference REP4-130).

A.1.1.1.4 When considering the proposed lifetime extensions of Ørsted IPs projects, the same methodology has been applied (as per section 4 of this note, but considering the extended Ørsted IPs project lifetimes as presented in Table A.1) to identify a potential reduction in AEP as a result of the wake effects scenarios A through to C (as described in paragraph 2.1.1.1). Consideration of the PEIR boundary scenario C1 has not been considered in this exercise, as this scenario was confirming the indirect mitigation applied by the Applicant and the resultant reduction in potential wake effects on Ørsted IPs projects.

A.1.1.1.5 The results presented within Table A.2 demonstrate that the conclusions presented in section 6 of this note have not been altered when accounting for 10 year lifetime extensions for Ørsted IPs projects. This is without accounting for lifetime extension for the Morgan Generation Assets which would increase the strength of conclusions further.

Table A.2: Summary of net GHG avoided emissions accounting for Ørsted IPs lifetime extension.

Project	Parameter	Scenario		
		a: Business as usual (no Morgan Generation Assets)	b: Presence and operation of Morgan Generation Assets (no mitigation)	c2: Sensitivity case - indicative mitigation
Morgan Offshore Wind Project	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)	0	53,411,680	52,050,597
	DESNZ long-run marginal avoided emissions (tCO_2e)	0	2,404,980	2,352,426
Orsted IPs Projects	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)	56,003,447	54,847,466	55,078,662
	DESNZ long-run marginal avoided emissions (tCO_2e)	3,655,490	3,583,439	3,597,849
Net emissions	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)	56,003,447	108,259,146	107,129,259
	DESNZ long-run marginal avoided emissions (tCO_2e)	3,655,490	5,988,419	5,950,275
Net change from unmitigated scenario	DESNZ 'non-renewable fuels' avoided emissions (tCO_2e)	n/a	-	-1,129,887
	DESNZ long-run marginal avoided emissions (tCO_2e)	n/a	-	-38,144

A.1.1.1.6 It can be noted that the net avoided emissions for each scenario would increase as a result of the proposed 10 year lifetime extension of the Ørsted IPs projects, however, the greatest benefit to national GHG emissions reduction, and UK renewable energy production, would remain the presence of the Morgan Generation Assets (without any further mitigation applied), despite any potential losses experienced by the Ørsted IPs OWFs. This is without any potential lifetime extension being applied to the Morgan Generation Assets, which (if the Orsted asset extension is deemed likely, then the same logic would likely apply to the Morgan Generation Assets in the future, and) would only increase the net contribution to national GHG emissions reduction and UK renewable energy production.