Hornsea Project Four

Position Statement between Hornsea Project Four and bp

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1 Introduction

1.1.1.1 This position statement has been agreed between Orsted Hornsea Project Four Limited (registered number 08584182) ("the Applicant") and BP Exploration Operating Company Limited (registered number 00305943) ("bp").

1.1.1.2 It has been drafted to provide the Examiners of the Hornsea Four DCO application with an overview of the ongoing technical discussions between the parties, which are taking place in relation to the potential or otherwise for coexistence between Hornsea Four and the Carbon Storage Project (both as described further below) within an overlapping area of seabed (“the Overlap Zone”).

1.1.1.3 The Applicant has proposed protective provisions for the benefit of the licensee from time to time of the UK Carbon Dioxide Appraisal and Storage Licence CS001 in Part 8 of Schedule 9 of the draft DCO for Hornsea Four, which envisage co-existence in the Overlap Zone. bp has put forward alternative protective provisions for the benefit of the licensee, which would prevent the development of Hornsea Four infrastructure in the part of the Overlap Zone in which the Carbon Storage Project would be located ("the Exclusion Area"). A copy of bp's proposed protective provisions is provided as part of Appendix 2 to this position statement.

2 Background

2.1.1.1 The commercial relationship between the Applicant and bp is governed by an agreement made between (1) The Crown Estate Commissioners, (2) National Grid Twenty Nine Limited and (3) Smart Wind Limited on 14 February 2013 (the "Interface Agreement").

2.1.1.2 National Grid Twenty Nine Limited and Smart Wind Limited were defined in the Interface Agreement as the "Carbon Entity" and "Wind Entity" respectively, in relation to their proposed carbon storage and offshore wind farm projects.

2.1.1.3 Both projects were proposed to be situated within an overlapping area of the seabed (defined in the Interface Agreement as the "Overlap Zone"), and so the parties agreed to enter into the Interface Agreement to seek to regulate and co-ordinate their activities with a view to managing potential and resolving actual conflicts.

2.1.1.4 The Interface Agreement was varied by a Deed of Adherence and Variation dated 12 September 2016 and then subject to a subsequent Deed of Covenant and Adherence dated 10 February 2021, following which it is acknowledged by the parties that bp is now the Carbon Entity and the Applicant is now the Wind Entity, under the Interface Agreement.

2.1.1.5 The Interface Agreement prevented either party from lodging any objection or making any representation in respect of the consent applications of the other party for the projects sited within the Overlap Zone. However, on 8th March 2022 the Applicant and bp agreed (subject to certain conditions) to mutually waive certain obligations under the Interface Agreement to allow representations to be made for the purposes of obtaining necessary consents for Hornsea Four and the Carbon Storage Project (respectively).

3 The Carbon Storage Project

3.1.1.1 bp is the appointed operator on behalf of the licence holders of UK Carbon Dioxide Appraisal and Storage Licence CS001. The licence holders are Carbon Sentinel Limited (previously known as National Grid Twenty Nine Limited), Equinor New Energy Limited and bp. The licence is held in relation to the carbon storage facility for the Northern Endurance Partnership project (the "NEP Project"). The NEP Project provides for an offshore transportation and geological storage facility in the Southern North Sea region of the UK continental shelf, to transport and store CO2 from both Teesside and the Humber area and is, in part, proposed to be situated in the Overlap Zone.

3.1.1.2 The Teesside onshore components of the NEP Project form part of a wider Carbon Capture Use and Storage project proposal which also includes an onshore gas-fired power generation facility with a carbon capture plant located in Teesside (together the "NZT Project").

3.1.1.3 A DCO application for the NZT Project was submitted on 19 July 2021 and accepted for examination on 16 August 2021. The applicant for the NZT Project has requested a delay to the start of the Examination of the NZT DCO application.

3.1.1.4 The applications for the necessary consents for the offshore component of the NEP Project are still to be submitted.

4 Hornsea Four Offshore Wind Farm

4.1.1.1 The Applicant is proposing to develop an offshore wind farm comprising up to 180 wind turbine generators together with associated offshore and onshore infrastructure and all associated development. The wind farm is located approximately 69km off Flamborough Head on the Yorkshire Coast and is, in part, proposed to be situated in the Overlap Zone.

4.1.1.2 The Examination of the Hornsea Four DCO application began on 22 February 2022.

5 Status of Discussions

5.1.1.1 The Applicant and bp have been engaging proactively with each other over several years to explore the viability of coexistence between Hornsea Four and the NEP Project in the Overlap Zone.

5.1.1.2 The Applicant's position with regard to the existence of the two projects in the Overlap Zone is set out in Appendix 1. bp's conclusions with regard to the existence of the two projects in the Overlap Zone, together with an explanation of the protective provisions that it seeks, are set out in Appendix 2.

5.1.1.3 bp and the Applicant will continue to update the Examining Authority through-out the Examination.

Signed on behalf of Orsted Hornsea Project Four Limited

[redacted]

Jamie Baldwin

[redacted]

Signed on behalf of BP Exploration Operating Company Limited

Andy Lane

6 Appendices

6.1.1.1 APPENDIX 1 – THE APPLICANT'S POSITION STATEMENT

6.1.1.2 APPENDIX 2 – BP'S POSITION STATEMENT

Hornsea Project Four

Summary of the Applicant's position regarding the interface with the Northern Endurance Partnership Project

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1 Introduction

1.1 This position statement sets out the position of Orsted Hornsea Project Four Limited (registered number 08584182) ("the Applicant") and the interface with the Northern Endurance Partnership Project (the "NEP Project"). The operator of the NEP Project being BP Exploration Operating Company Limited (registered number 00305943) ("bp").

1.2 It has been drafted to provide the Examiners of the Hornsea Four DCO application with an overview of the ongoing commercial and technical discussions between the parties, which are taking place with the aim of seeking to ensure coexistence between Hornsea Four and the NEP Project (both as described further below) within an overlapping area of seabed ("the Overlap Zone"). For the avoidance of doubt the term coexistence includes co-location which in turn is defined as the shared use of seabed**.**

1.3 The position statement also presents each party's preferred form of protective provisions to be included in the Hornsea Four DCO, along with an explanation of the protection sought. The Applicant is committed to continuing discussions relating to the protective provisions.

1.4 bp have set out their position in their own words in the position statement appended to the document G1.29 Appendix 2.

2 Background

2.1 The commercial relationship between the Applicant and bp is governed by an agreement made between (1) The Crown Estate Commissioners, (2) National Grid Twenty Nine Limited and (3) Smart Wind Limited on 14 February 2013 (the "Interface Agreement").

2.2 National Grid Twenty Nine Limited and Smart Wind Limited were defined in the Interface Agreement as the "Carbon Entity" and "Wind Entity" respectively, in relation to their proposed carbon storage and offshore wind farm projects.

2.3 Both projects were proposed to be situated within an overlapping area of the seabed (defined in the Interface Agreement as the "Overlap Zone"), and so the parties agreed to enter into the Interface Agreement to seek to regulate and co-ordinate their activities with a view to managing potential and resolving actual conflicts.

2.4 The Interface Agreement was varied by a Deed of Adherence and Variation dated 12 September 2016 and then subject to a subsequent Deed of Covenant and Adherence dated 10 February 2021, following which it is acknowledged by the parties that bp is now the Carbon Entity and the Applicant is now the Wind Entity, under the Interface Agreement. The Crown Estate Commissioners remain a party to the Interface Agreement.

2.5 On 25 January 2022 the Applicant and bp agreed (subject to certain conditions) to mutually waive certain obligations under the Interface Agreement to allow joint representations to be made for the purposes of obtaining necessary consents for Hornsea Four and the Carbon Storage Project (respectively). The Applicant continues to focus its efforts on progressing a commercial solution between the parties to ensure coexistence in line with its obligations under the Interface Agreement. The Applicant and bp have agreed to the disclosure of the Interface Agreement. The permission of the Crown Estate has also been requested.

3 The NEP Project

3.1 bp is the appointed operator on behalf of the licence holders of UK Carbon Dioxide Appraisal and Storage Licence CS001. The licence holders are Carbon Sentinel Limited (previously known as National Grid Twenty Nine Limited), Equinor New Energy Limited and bp. The licence is held in relation to the carbon storage facility for the NEP Project. The NEP Project provides for an offshore transportation and geological storage facility in the Southern North Sea region of the UK continental shelf, to transport and store CO2 from both Teesside and the Humber area and is, in part, proposed to be situated in the Overlap Zone.

3.2 The NEP Project forms the offshore component of a wider Carbon Capture Use and Storage (CCUS) project proposal which also includes an onshore gas-fired power generation facility with a carbon capture plant located in Teesside (the "NZT Project").

3.3 The DCO application for the NZT Project was submitted on 19 July 2021 and accepted for examination on 16 August 2021. The applicant for the NZT Project has requested a delay to the start of the Examination and this has been accepted by the Planning Inspectorate further to a letter dated 16th February 2022. The preliminary meeting is being considered for May.

3.4 The applications for the necessary consents for the offshore component of the NEP Project are still to be submitted. The Applicant understands the application to be at the scoping stage with the Environmental Statement to be submitted to BEIS (OPRED) in quarter 2 2022. The Applicant expects to be fully consulted (in line with the obligations under the Interface Agreement) as part of the public consultation process.

4 Hornsea Four Offshore Wind Farm

4.1 The Applicant is proposing to develop an offshore wind farm comprising up to 180 wind turbine generators together with associated offshore and onshore infrastructure and all associated development. The wind farm is located approximately 69km off Flamborough Head on the Yorkshire Coast and is, in part, proposed to be situated in the Overlap Zone.

4.2 The Examination of the Hornsea Four DCO application began on 22 February 2022.

4.2.1 The area of overlap of the Hornsea Four red line boundary has been reduced to avoid the significant impacts upon ornithological and navigational receptors. In the interim bp have optimised the area required for the CO2 store. The remaining Overlap Zone therefore is as a result of both projects independently optimising their projects within the known constraints and as a consequence of the significant impacts identified. The objective of the Applicant is to avoid or mitigate or compensate (in that order) for all significant impacts. In the case of the NEP Project the Applicant is confident that the impact upon the NEP Project can be mitigated. It is understood pursuant to bp's proposed protective provisions that the objective of bp is to force exclusion so that the Applicant cannot locate turbines in the Overlap Zone rather than focus upon mitigating the impact of either project upon the other.

5 Status of Discussions

5.1 The Applicant and bp have been engaging proactively with each other over several years to seek a solution for the Overlap Zone between Hornsea Four and the NEP Project.

5.2 The matters remaining between the parties are highly technical, and generally involve requirements for the CCUS Measurement, Monitoring and Verification (MMV) plan and the ability to accommodate potential future relief wells or other infrastructure for the NEP Project and the interaction of those requirements with the presence of the Hornsea Four infrastructure.

5.3 bp has shared their Carbon Capture, Usage and Storage and Offshore Wind (OW) Project Overlap Report: A Technical Assessment of the Endurance Reservoir and Hornsea Project Four Wind Farm (the "NEP Overlap Report") with the Applicant, which summarises four key considerations that, in bp's view, mean a reasonable and practicable degree of separation between Hornsea Four and the NEP project is required. The first is their requirements for MMV. The second, third and fourth considerations relate to access to NEP infrastructure and activities pertaining to their infrastructure, namely: (i) relief well access, (ii) helicopter access and (iii) rig access ("the Access Issues"). bp is unable at this stage to provide details as to the location of their proposed infrastructure in the Overlap Zone as this is currently unknown and it is therefore difficult for the Applicant to assess the impact of the OW infrastructure upon the NEP infrastructure particularly in relation to the Access Issues. The Applicant however has gone over and above their standard methodology for cumulative effects assessments and sought to assess the impact of Hornsea Four upon the NEP Project. This is despite the lack of information regarding the location of the NEP Infrastructure. It is hoped that the necessary level of detail will become available in view of bp's intention to submit their application for the offshore consents at some point this year. It is anticipated however that not all of the information regarding the location of offshore infrastructure will be forthcoming from bp as the applications will relate only to phase 1 of the NEP Project. The Applicant will continue to update its cumulative effects assessment as further information becomes available. Parallels can be drawn with the Applicant's experience with working with oil and gas operators. The Applicant is currently working with a number of operators of oil and gas platforms in the vicinity of Hornsea Four and is confident of being able to resolve these issues to ensure coexistence in line with policy. The interface therefore between the NEP Project and Hornsea Four regarding the Access Issues are considered surmountable.

5.4 The Applicant's proposed protective provisions address the known uncertainties and seek to put in place a process to ensure successful coexistence.

5.5 The first key consideration relates to towed streamer seismic surveys access which is part of the proposed MMV plan. This consideration is the most pertinent, in that with the current bp strategy it would not allow for coexistence in the northern part of the windfarm array. Based on senior level meetings between bp and the Applicant, it is understood that clarification is needed for the NEP Project from BEIS or a future CCUS regulator that it would be acceptable for other MMV methods to be used.

5.6 The Applicant has shared with NEP an independent report, conducted by ORE Catapult, Net Zero Technology Centre and the Energy Transition Alliance ("OREC Co-location Review") considering the specific NEP and Hornsea Four overlap and opportunities for co-location, in furtherance of The Crown Estate's 2020-2021 overlap study called Project Vulcan. The OREC Co-Location Review is attached as an annex to this Position Statement.

5.7 In the Applicant's view, the OREC Co-location Review provides a more realistic overview on risks and opportunities of coexistence. The OREC Co-location Review states that there are current solutions but also emerging technologies relating to the proposed MMV plan that allow for future coexistence but does not opine upon the timescales within which those emerging technologies will become available. The Applicant is willing to have joint discussions regarding timescales for the emerging technology. It is understood that bp maintain the technology maturation of the emerging technologies are outside of the timescales needed for the NEP Project to be authorised and implemented. This assertion of it taking at least 10 years for technology to mature and fully understand the Endurance CO2 store has not been substantiated. bp refer to the need for certainty by the target final investment decision ("FID") of mid-2023.

5.8 bp are also concerned that the regulatory framework is yet to be finalised. The Applicant acknowledges that bp requires guidance from the appointed regulator as to what is and is not acceptable in terms of obtaining approval of their MMV Plan and ensuring investor confidence. The Applicant's proposed Protective Provisions acknowledge the uncertainties and allow for consideration of a plan of works setting out the proposed form of technology prior to FID. If the regulator stipulates (i) the level of accuracy for the seismic imaging and (ii) the technology to be used to obtain the data then this can be included within the plan of works to be submitted pursuant to the Applicant's proposed Protective Provisions and the Applicant shall have regard to it. This approach gives bp and the Applicant more time to consider the accuracy of the data required and the form of technology. An important point to note is that the initial acquisition of seismic data to form the baseline will occur before wind turbines are located in the Overlap Zone. This will be followed by repeating the seismic acquisition on a regular basis (planned to be every 5 years) so the next survey will also take place before the wind turbines are in situ (2027). It is understood on bp's timescales that the third survey is therefore unlikely to occur before 2032. The Applicant therefore considers it highly likely that either the cost of Ocean Bottom Node seismic monitoring will have significantly reduced or emerging technology would have reached maturation to allow for seismic to be undertaken with wind turbines in situ, particularly with the added certainty of a sparser layout.

5.8.1 In light of the timing of the acquisition of seismic data as outlined above the Applicant is confident of coexistence. bp also maintains that the same methodology must be deployed through the lifetime of the NEP Project but also acknowledges that future technical solutions may allow potential co-development of wind and CCUS. These positions appear contradictory in terms but on the premise that bp accept an alternative technology can be used should it become available for future surveys, the Applicant would seek to accelerate the maturation of the technologies to be ready for deployment once the wind turbines are in situ.

5.8.2 The Applicant is willing to progress discussions between the parties together with BEIS and the Oil and Gas Authority (understood to be the interim regulator) to determine the level of certainty required for the acquisition of seismic surveys to ensure sufficient investor confidence. It is also possible, in the interests of the policy drive towards coexistence and Net Zero that the parties consider how the additional costs to facilitate coexistence are factored into the Government Support Package as part of the Transportation and Storage Regulated Investment (TRI) model. The Applicant considers this to be an opportunity to achieve the governments CCUS aspirations but also ensure the capacity targets for offshore wind and energy security targets are not put at risk.

5.8.3 For the avoidance of doubt the Applicant maintains that OBN seismic monitoring and short offset towed streamers are available today. The focus therefore is the application of acquiring seismic data for CCUS utilising this existing technology. Further technical investigation is needed in the CCUS industry in collaboration with the regulator regarding the level of required near surface detail and horizontal coverage.

5.9 The OREC Co-location Review is in line with some of the conclusions in NEP's Overlap Report namely that a sparser layout could potentially mitigate the access issues. On the MMV plan it states there are opportunities if the two projects are willing to investigate both joint technical and economically feasible solutions and focus on finding a hybrid solution. It acknowledges further studies are required due to lack of literature and therefore understanding of the impact of co-locating projects. The Applicant sees the initiatives as proposed by The Crown Estate initiated Offshore Wind and CCUS Co-location Forum (including field trials) as a vehicle to obtain the required details for a definitive conclusion. As noted above the timeframes for exploring various initiatives work in conjunction with the timescales set out in the Applicant's DCO protective provisions for Endurance, providing sufficient time to identify and deploy the most suitable technology for the specific needs of the two projects in the Overlap Zone prior to construction.

5.10 The Applicant acknowledges that neither the NEP Overlap Report nor the OREC Co-location Review offer a clear and final solution for the technological considerations and uncertainties of the Endurance development, but that is not to say a solution will not be found in the future. As set out above more time is required to find that. As the technological and regulatory landscapes for CCUS progress, the Applicant believes that a mutually acceptable solution will be found, which may include, but not necessarily be limited to, one or a combination of the following options (subject to the Applicant receiving financial compensation, as explained in paragraph 7.2):

- Sparse layout: co-location with a sparse windfarm layout in the Overlap Zone, which would be feasible with an alternative MMV method;
- Optimised cut-off for co-existence opposed to bp's proposed exclusion area in the NEP Overlap Report, assuming bp's current MMV plan involving towed long streamers over the majority of the Overlap Zone;
- No co-located infrastructure in the Overlap Zone as proposed by bp in the NEP Overlap Report.

5.11 A project of a similar capacity (2.6GW) would be significantly impacted in terms of the electricity generated if the developable area is reduced by removing the Overlap Zone. In broad terms this would equate to a loss of approximately 2.5% annual energy production (AEP) due to an increased density of turbines in the southern part of the Agreement for Lease (AfL) area. This would have the impact of making the project far less commercially competitive and potentially result in Hornsea Four being unable to compete for a contract for difference.

5.11.1 bp maintain that using fewer, larger turbines would achieve the same generating capacity without any wake loss impacts occurring. This assumption is incorrect. The largest current model commercially available is 14MW. Vestas have announced a 15MW wind turbine which may be commercially available however even based on the 15MW turbine the Applicant still requires 180 turbines to build out the secured grid capacity of 2.6GW once transmission losses are factored in. The Overlap Zone represents approximately 25% of the developable area. A 25% reduction in turbine numbers would mean a loss of 45 turbines resulting in a project capacity of 630mw to 675mw depending upon whether a 14 or 15 mw turbine is deployed. If the turbines are located to the southern part of the array the additional wake losses will, as set out above, make the project uncompetitive and potentially result in a failure to achieve full grid capacity of 2.6GW. The impact upon Hornsea Four will impact the government's wider drive towards net zero. This is addressed in the attached policy statement in more detail.

5.12 The developable area approach promoted by the Applicant has sought to optimise the remaining AfL area taking into account known constraints and demonstrable impacts. There remains too much uncertainty in bp's plans at this stage to risk the significant loss of AEP should some or all turbines be lost or relocated. To mitigate the impact of the options referred to above on the viability of Hornsea Four financial compensation is necessary.

5.13 The nature of the requirements of both NEP's project and Hornsea Four and possible technical solutions are under discussion between the parties. Pending a resolution of these discussions, each party has proposed its own set of protective provisions, which are presented below.

6 The Applicant's proposed protective provisions

6.1 The Applicant has proposed protective provisions for the benefit of the licensee from time to time of the UK Carbon Dioxide Appraisal and Storage Licence CS001 in Part 8 of

Schedule 9 of the draft DCO for Hornsea Four. As noted above, the current licensee of licence CS001 is Carbon Sentinel Limited (previously known as National Grid Twenty Nine Limited), Equinor New Energy Limited and bp. bp is the operator of licence CS001 on behalf of the other licensees.

6.2 The provisions are structured as follows:

a. No part of the Hornsea Four works in the Overlap Zone must commence until a Coexistence and Proximity Agreement ("CPA") is entered into between the Undertaker and the Licensee (or the parties agree none is required);

b. Provided all necessary Endurance Consents (i.e. consents for the licensee's works within the Overlap Zone) are obtained within three months of the coming into force of the Hornsea Four DCO, the Undertaker will begin to prepare the CPA;

c. To facilitate preparation of the CPA, each party must prepare a plan of work (essentially a programme, method statement etc. for the development of each project) and provide it to the other party. The CPA must be based on those plans of work and the other matters referred to in paragraph 10 of the protective provisions;

d. The Undertaker can request additional detail from the Licensee if it considers the Licensee's plan of work provides insufficient detail of the planned works having been minimised to avoid adverse effects on the programming siting design construction or operation of Hornsea Four works in the Overlap Zone;

e. If the Endurance Consents are not obtained within three months of the grant of the Hornsea Four DCO, or insufficient detail is provided by the Licensee in response to a request for information from the Undertaker, the restriction on Hornsea Four works within the Overlap Zone ceases to apply.

f. Arbitration provisions have been included to govern disputes.

g. There is an obligation for each party to keep the other informed of relevant activities.

h. The provisions are without prejudice to in the parties' rights and obligations under the existing Interface Agreement.

i. The obligations on the Undertaker cease to have effect in the event the licence is terminated and no longer has effect, or the Endurance Consents are not obtained within three months of the coming into force of the Hornsea Four DCO.

6.3 Orsted maintains that coexistence in the whole of the Overlap Zone is possible and the protective provisions have been designed to allow additional time for the NEP Project (and the novel carbon capture storage technology) to mature to resolve any outstanding bp concerns in this regard.

6.4 The Applicant believes these provisions strike the appropriate balance to manage the interests between the parties and the requirement for coexistence prescribed in the Interface Agreement and relevant policy. Upon award of the Hornsea Four DCO, it is imperative that bp has sufficiently advanced the development of its infrastructure in the Overlap Zone to warrant any restriction on or delay to the development of Hornsea Four. These protective provisions mean that when determining the DCO application for Hornsea Four a decision does not need to be made as to which project should be excluded from the

Overlap Zone. This is important from a policy perspective because the two projects have equal importance in terms of the contribution to be made to decarbonization. Therefore, it would be undesirable to have to select a project to prioritise at an early stage in project development. The more reasonable and policy compliant solution is to allow more time and a process for a mutually acceptable coexistence solution for the Overlap Zone to be found and to secure that in the protective provisions. That is precisely what the Applicant's protective provisions offer and would achieve.

7 bp's proposed protective provisions

7.1 bp's proposed protective provisions preclude the construction of the authorised development in the Exclusion Area as defined in the protective provisions. The Applicant would contend that there is no need for such a draconian approach and it is not policy compliant. It would be premature at the time of determining the DCO application for Hornsea Four to preclude construction in the Exclusion Zone as (i) the timeframes for exploring various initiatives to coexist work in conjunction with the timescales set out in the Applicant's DCO proposed protective provisions, providing an opportunity to deploy the most suitable technology for the specific needs of the Exclusion Zone prior to construction (ii) the future use of the Exclusion Zone remains uncertain. bp is in the scoping stage and has not submitted the Environmental Statement in support of the offshore infrastructure. Further to this the NZT Application has been delayed. The Applicant has gone further than the methodology for Cumulative Effect Assessment and certainty in development proposals in seeking to assess the impact of the authorised development upon bp's proposed development and consider the impact upon common receptors of both projects. It is however very premature to preclude construction of the authorised development where bp are not yet at the stage of project development when they can progress the applications for consents and appropriate licences for its project in the Exclusion Zone and (iii) although the NEP Project has been selected as a Track 1 project of the CCUS Cluster Sequencing Process there are standby projects in case Track 1 projects cannot be progressed further to technical and/or commercial examination. The government also announced the Scottish Cluster as a reserve cluster if a backup is needed. It is understood that during phase 2 government shall continue to engage with the Scottish Cluster which means that if the government choose to disengage with a cluster in Track 1 they can engage with the reserve cluster instead. The government therefore recognises that there are a number of risks that have to be managed carefully in seeking to deploy CCUS by the mid 2020's. bp have made the assumption that the CO2 store would be lost if Hornsea Four were granted consent to locate turbines in the Overlap Zone but UK's CCUS ambition is not a requirement of policy but an aspiration in recognition of the known risks in deployment. In the 6th Carbon Budget, the Carbon Climate Committee stated in December 2020 that "Industry must either adopt technologies that use electricity or hydrogen instead of fossil fuels or install carbon capture and storage". It is clear therefore that the deployment of CCUS should not be to the detriment of offshore wind which is relatively low risk, low cost and proven low carbon energy production, particularly in circumstances where coexistence is a real possibility.

7.2 bp's proposed protective provisions also seek to disapply the Interface Agreement. This would constitute an abuse of process and as a matter of law would be ineffective. Protective provisions cannot have legal effect such than one party can unilaterally set aside a contract it no longer likes, without the consent of the other parties to that contract. It would not be appropriate for the Secretary of State to interfere with that private contract, which has managed the relationship of the parties to it since 2013. If any amendments to the Interface Agreement were deemed to be required, the appropriate and lawful course of action would be for bp, the Applicant and The Crown Estate to negotiate a deed of variation to the Interface Agreement. Bp's rationale for disapplying the Interface Agreement is that it is necessary in the public interest to remove the risk that the terms of the agreement lead to award of compensation to the Applicant in relation to an adverse impact of the NEP Project on Hornsea 4 which renders the NEP project unviable. In response to that: (i) this potential liability has been known to those promoting the NEP Project since 2013, and bp entered into the Interface Agreement cognoscente of it, therefore it is a potential liability that should have been factored into the financial modelling of the NEP Project and to have progressed this far suggests the liability would not render the NEP Project unviable; (ii) to the extent (if any) that there is public interest in this matter as bp suggests, it applies at least equally in respect of the public interest in not allowing a nascent technology to curtail the generation capacity of offshore wind and undermine the path to Net Zero; (iii) bp has failed to justify the lawful basis for the disapplication of the Interface Agreement; and (iv) it appears that bp has not sought the views of TCE on this matter. The Applicant's position remains that financial compensation is needed to facilitate coexistence and the parties' rights and obligations under the Interface Agreement should be left unfettered.. The Interface Agreement is not contrary to policy and is simply a mechanism to facilitate coexistence. Contrast the approach taken by bp with the reasonable approach taken by the Applicant whose protective provisions are without prejudice to the rights or obligations of all the parties under the terms of the Interface Agreement.

8 UK Policy Support for Hornsea Four and the Carbon Storage Project

8.1 To assist the Examination of Hornsea Four, the Applicant attaches a detailed statement of UK Policy Support for offshore wind and carbon capture and storage projects. It is hoped that the policy position can be agreed between the Parties so that Examination time is not taken up on policy discussions.

Hornsea Project Four

Position Statement between Hornsea Project Four and bp
Appendix 1.1: Northern Endurance CCUS Co-location Review – Engineering Report

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NORTHERN ENDURANCE CCUS CO-LOCATION REVIEW

Energy Transition Alliance

ENGINEERING REPORT

AUTHOR // Sam Robertson (ORE Catapult), James McAreavey (Xodus)

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Executive Summary

The Carbon Capture, Utilisation and Storage (CCUS) and Offshore Wind industries have been highlighted as key industries by the UK government to reduce greenhouse gas emissions to net zero by 2050. This has been highlighted in the carbon budgets, most recently the 6th, by the Climate Change Committee last published in late 2020.

Ørsted have commissioned the Energy Transition Alliance (ETA), a consortium of The Offshore Renewable Energy Catapult (OREC) and Net Zero Technology Centre (NZTC), as well as working partners Xodus, to carry out a comprehensive and unbiased study to examine the risks highlighted within Project Vulcan in a real-world example. The Ørsted's Hornsea 4 offshore wind development and BP's CCUS Northern Endurance project situated approximately 70 km off the Yorkshire coast, UK have been considered in this study.

This report has reviewed a number of different areas of co-location risks by carrying out reviews of the information provided by Ørsted on the Hornsea 4 project, publicly available information on the Northern Endurance project as well as desktop research and stakeholder engagement on the areas of MMV Survey Interaction, Direct Physical Impacts and Infrastructure Blocking Seabed Access.

Although the report provides context and answers to many of the original questions, the ETA has concluded that while there is information available on the individual aspects of CCUS and Offshore Wind there is a lack of literature and therefore understanding of the impact of co-locating projects. This is specifically around the impact of turbine layout and noise on MMV activities and how to monitor plume development away from wells. Further studies are required before a definitive conclusion can be made. Until these issues have been addressed, a standard minimum square grid formation of 1 turbine every 2 km would need to be implemented. This relates to around 9 diameters of the proposed turbines and would allow for rig access and opens the potential to use towed streamer acquisition for monitoring storage conformance and CO2 plume development away from wells. This would be unless the cost of Ocean Bottom Node technology can be justified/reduced or a series of other MMV technologies can be compiled to provide full coverage. This layout would need to be investigated by the wind and CCUS operator to identify if this is feasible and economical for the project to continue.

The report discusses direct physical impacts due to co-location and concluded after interviews with the helicopter industry and rig operators that there is limited impact from helicopters, due to the perceived limited reliance on helicopter operations during emergency situations unlike the oil and gas (O&G) industry. A 2 km minimum separation distance between turbines was identified as this would allow for safe rig operations as well as a 500 m exclusion zone around wells and the rig during drilling operations.

The risk and cost associated with infrastructure blocking seabed access was investigated within the report and an assessment of deviating a well concluded that the safest and most cost effective deviated well option would be a S Profile, 19° through Reservoir that would give an offset distance of 542 m at a cost of £2.2 m per well. The report also highlights a cost of around £150 per m to relocate inter array cabling, however cable crossings between projects was identified as one of the key focus areas in terms of risk and cost.

Further areas of study are not limited to but include;

- CCUS operator to provide current MMV requirements for CO_2 plume monitoring for the Northern Endurance site.
- Detailed independent study on MMV technologies based on current understanding of storage site characteristics and proposed MMV plan to understand viable options for co-location.
- Real world study on the impact of offshore wind turbine noise on MMV survey activities.

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Nomenclature

2D	2 Dimensional
3D	3 Dimensional
4D	4 Dimensional
CAA	Civil Aviation Authority
CCUS	Carbon Capture Utilisation and Storage
CO2	Carbon Dioxide
COWRIE	Collaborative Offshore Wind Research into the Environment
CS	Compressive Sensing
DAS	Distributed Acoustic Sensing
DTS	Distributed Temperature Sensing
dB	Decibels
ETA	Energy Transition Alliance
Gal	Galileo (unit of acceleration)
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
Hz	Hertz
IWT	Industrial Wind Turbine
JUV	Jack Up Vessel
km	Kilometres
kV	Kilovolts
LAT	Lowest Astronomical Tide
m	Metre
M	Million
mm	Millimetre

MMV	Measurement Monitoring and Verification
ms	Milliseconds
Mt CO_2/year	Metric Tons of Carbon Dioxide per Year.
MW	Megawatts
NPT	Non Productive Time
NZTC	Net Zero Technology Centre
O&G	Oil and Gas
O&M	Operations and Maintenance
OBC	Ocean Bottom Cable
OBN	Ocean Bottom Nodes
°C	Degrees Celsius
OREC	Offshore Renewable Energy Catapult
PRM	Permanent Reservoir Monitoring
SI	Seismic Interference
SOV	Service Operation Vessel
TVD	Total Vertical Depth
TVDSS	True Vertical Depth SubSea
UK	United Kingdom
US	United States
USV	Uncrewed Service Vessels
WTG	Wind Turbine Generator

1 Introduction

The UK Government signed The Paris Agreement in 2015 which aims to limit global warming to between 1.5 and 2 degrees compared to pre-industrial levels. Both offshore wind and Carbon Capture Utilisation and Storage (CCUS) are planned to be key building blocks in the government's push to net zero by 2050.

To meet these legally binding targets the UK government has committed to 40 gigawatts of offshore wind capacity by 2030 and a potential target of 75 – 150 gigawatts by 2050 [1] with an additional commitment to capture 10 MtCO2/year by 2030, increasing to between 60 and 180 MtCO2/per year by 2050 [2].

With this commitment to both industries from the UK Government the risk of co-locating projects and overselling the seabed, especially in high demand areas, is real. The Crown Estate commissioned the Energy Transition Alliance (ETA), a consortium of The Offshore Renewable Energy Catapult (OREC) and Net Zero Technology Centre (NZTC) as well as working partners Xodus, to carry out a comprehensive and unbiased study to examine the additional risks that may result from overlapping of Offshore Wind and CCUS projects and how these risks may be managed [3].

Based on the results and conclusions of The Crown Estates commissioned work (Project Vulcan), Ørsted have contracted the ETA to expand on the high-level recommendations outlined within project Vulcan and develop site specific solutions and recommendations based on the existing sites of Ørsted's Hornsea 4 offshore wind development and BP's CCUS Northern Endurance project situated approximately 70 km off the Yorkshire coast, UK.

Although this study has been funded by Ørsted this report provides an unbiased assessment of the current co-location situation based on the publicly available information around the CCUS site and high-level confidential information provided by Ørsted on their offshore wind development at Hornsea 4. This work has otherwise been compiled independently from Ørsted and BP and any other project partners. The study will outline the specific site risks and opportunities to the project as well as detailed information and possible solutions and/or options in order to inform Ørsted so they may develop, implement and plan to minimise the disruption posed by overlapping projects. This detailed study will be a key part in the planning stage of Hornsea 4 and the deployment of future offshore wind projects.

The work packages and corresponding primary objectives for this study were:

Work Package 1: Measurement, Monitoring and Verification (MMV) Survey Interaction

- Conduct desktop research into available MMV technologies that could be used for the Northern Endurance project while carrying out stakeholder engagement with industry experts to provide detailed current information.
- Provide an overview of how wind turbines could interact with seismic acquisitions through noise generation and reflection of turbines.

Work Package 2: Direct Physical Impacts

- Conduct desktop research and stakeholder engagement to review helicopter and drilling rig access and movement in a wind farm and make comment on the safe working distance and existing policies currently in place.
- Review the existing work carried out on behalf of Ørsted relating to the risk of corrosion damage to offshore assets from brine release wells.

Work Package 3: Infrastructure Blocking Seabed Access

- Make comment on existing infrastructure blocking access to the seabed.
- Look at the feasibility and cost associated in deviated injector and relief wells and highlight the minimum separation distance of cables, umbilicals and pipelines within the wind farm.

2 Overview of Northern Endurance and Hornsea 4

2.1 Northern Endurance

The infrastructure proposed for the Northern Endurance Partnership CCUS project has been produced from publicly available information and can be summarised as follows:

Initial Development Infrastructure:

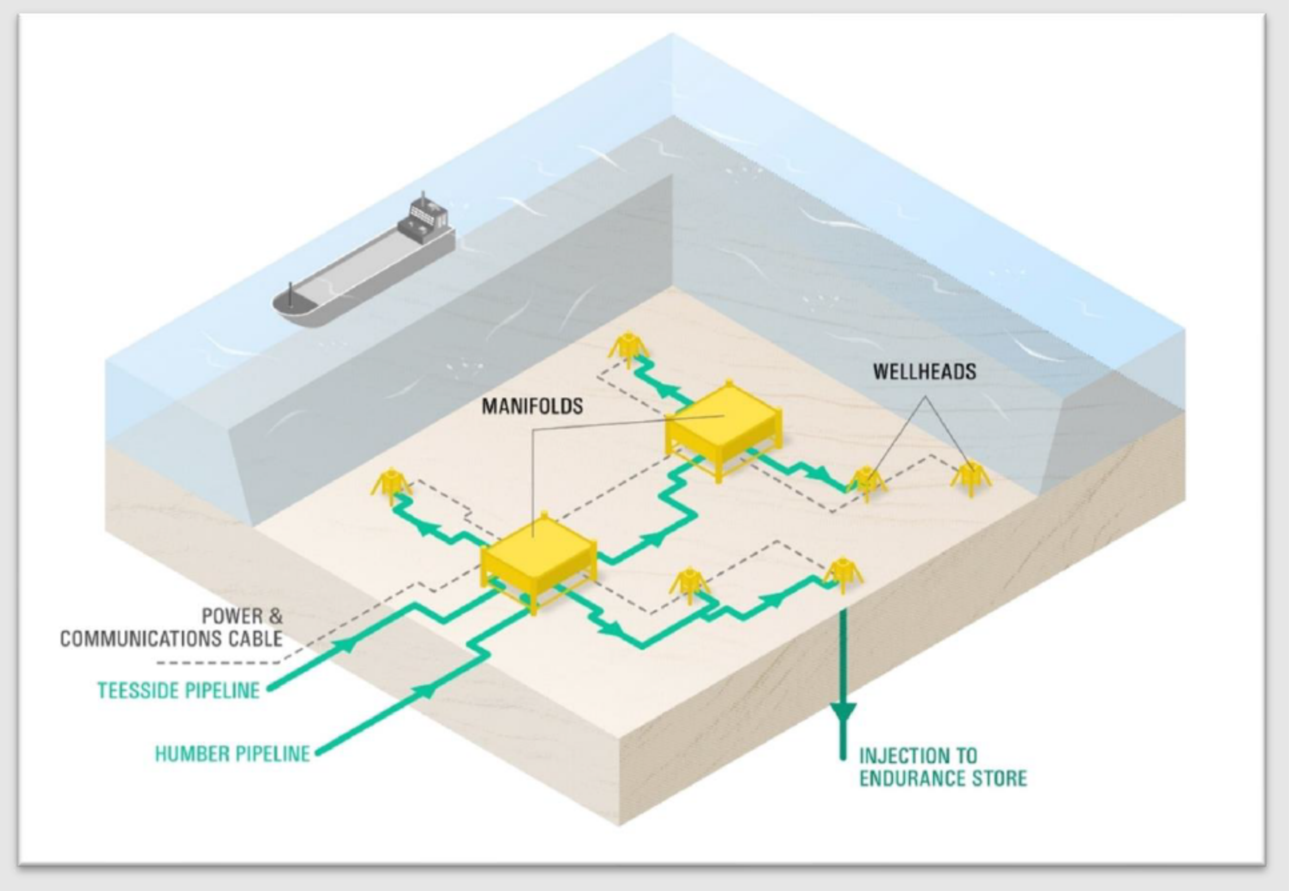


Figure 1: Schematic of Northern Endurance Partnership Initial Development Infrastructure (not to scale).

- Two long-distance transport seabed surface laid pipelines that route captured CO_2 from the shore-based carbon capture schemes (the Zero Carbon Humber and Net Zero Teesside projects) to the offshore CO_2 injection system (103 km and 145 km in length respectively), with one power/communications cable installed in close proximity to the pipeline from Teesside. The pipelines are currently estimated to have an external diameter of 28 inches.
- One manifold structure installed on the seabed that will combine the outlet of the two long-distance pipelines and enable the CO_2 to be distributed to three subsea CO_2 injection wells.
- One manifold structure that will initially be connected to two subsea injection wells with the potential to support two further injection wells in future.

- One buried pipeline to link the two seabed installed manifold structures that is currently estimated to be 8 inches in diameter with a power/communications cable installed in close proximity to the pipeline.
- Five 8 inch pipelines linking the seabed installed manifold structures to each subsea injection well.
- Five subsea CO2 injection wells plus a further single "observer" well drilled into the Northern Endurance saline aquifer, each complete with seabed installed Christmas trees and power/communications cables linking them back to the seabed installed manifold structures.

Potential Future Development Infrastructure:

- Further "in-field" pipelines and power/communications cables to link the initial development to future injection wells.
- Wells to enable highly saline water (brine) to be relieved from the Northern Endurance aquifer in the event that CO2 injection results in the aquifer becoming over-pressurised in future.
- A number of (predicted to be a maximum of four) small, normally unattended, platforms that would treat any brine released from the Northern Endurance aquifer prior to its release to the seabed environment.
- Pipelines linking the potential brine release wells to the brine treatment platforms.

2.2 Hornsea 4

Information gathered from the Hornsea 4 project is based on the environmental survey and other information provided by Ørsted. Selected information is listed below.

Hornsea 4 Site Parameters

Installation

- The total duration of the impact piling component of the installation campaign for wind turbine generator foundations is expected to be a maximum of 12 months with the installation of the transition piece, tower, nacelle and blades taking 24 months maximum.
- Wind turbines will be installed via a typical vessel such as a Jack Up Vessel (JUV) or barge carrying Wind Turbine Generator (WTG) components to site and installing them to pre-installed foundations / transition pieces.
- JUVs or barges will be supported by several vessels in field.

Wind Turbines

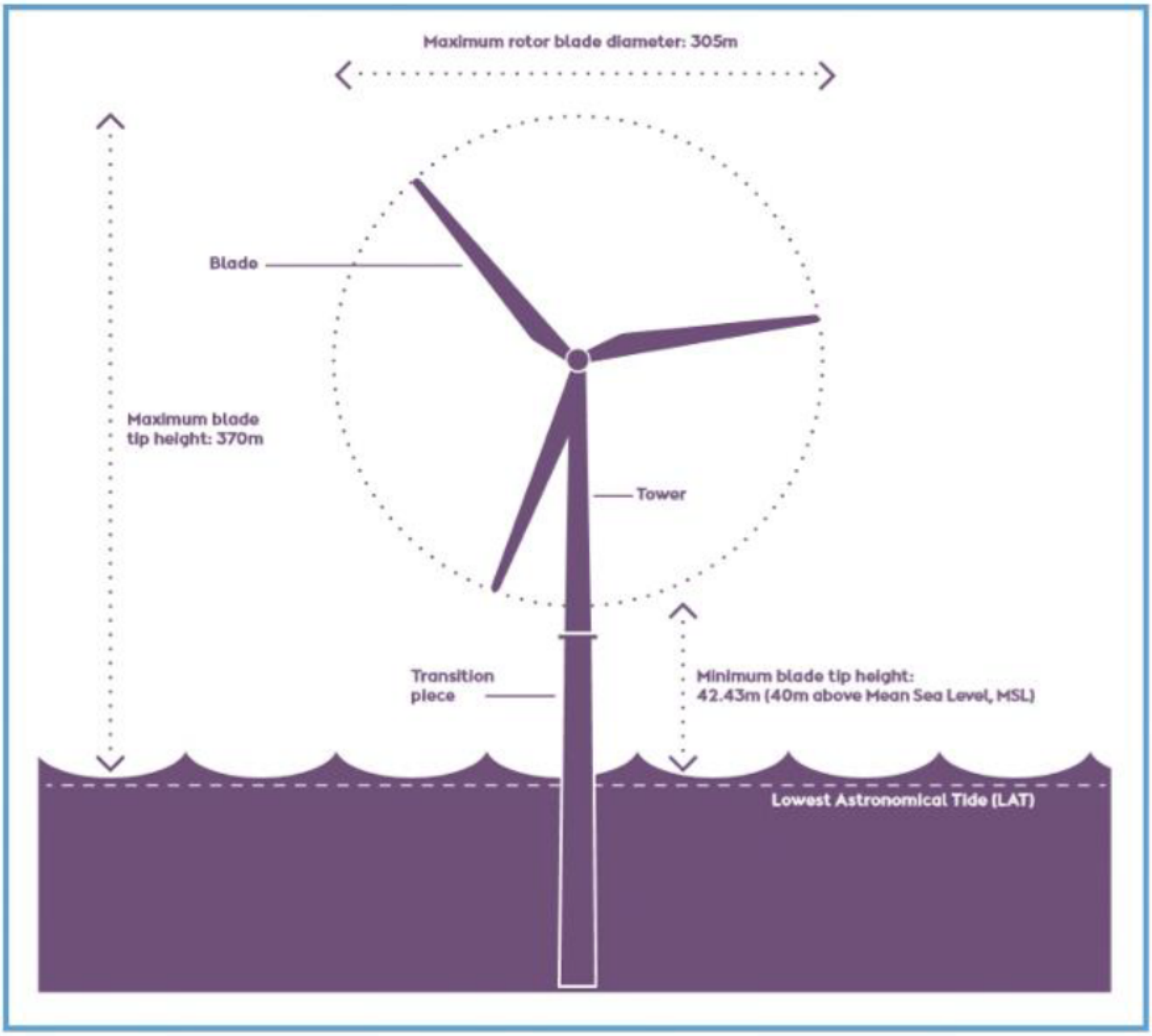


Figure 2: Overview of Maximum Parameters for Hornsea 4 Wind Turbine.

Parameters	Design Envelope
Maximum Number of Wind Turbine Generators	180
Power Generation (MW)	14 – 15
Minimum Height of Lowest Blade Tip Above LAT (m)	42.43
Maximum Blade Tip Height Above LAT (m)	370
Maximum Rotor Blade Diameter (m)	305

Table 1: Maximum Parameters for Hornsea 4 Wind Turbines.

Foundations

- Currently no foundation design has been landed on so all have been considered within this assessment.

Substations

- Either six small or three large separate offshore transformer AC substations will be installed within the Hornsea 4 area to support power production.
- Consideration given to HVDC export cables and HVDC converter stations.

Accommodation

- Offshore accommodation platform to be installed to accommodate up to 150 operatives for the storage of spares, tools and Operations and Maintenance (O&M) personnel.
- Service Operation Vessels (SOVs) have not been highlighted within the Hornsea 4 Environmental Survey but could be used as an effective means of carrying out O&M activities throughout the lifecycle of the project. A range of £20,000 – 27,000 per day for the hire of an SOV has been highlighted (including crew, fuel and consumables) however costs can fluctuate with demand and spot hires being as high as £45,000 per day in the last 5 years. A long term hire for the life of the O&M phase would ensure a competitive price at the lower end of the price range [4].

Offshore cables

- Array cables will link the turbines to the offshore transformer substations, 36 strings containing five turbines on a radial topology.
- The use of HVAC array cable technology (>100 kV)
- Total length of array cables is 600 km and maximum voltage 170 kV.
- Offshore interconnector cables may be required to interconnect the offshore substations to provide redundancy.
- Will consist of six circuits / cables, 90 km in length and maximum voltage 600 kV.
- Offshore export cable information is presented in Table 2.

Parameters	Maximum Design Parameters	
	HVAC	HVDC
Number of Circuits	6	4
Voltage (kV)	400	600
Maximum Number of Cables	6	
Length per Cable – including export cable within the Hornsea 4 array area (km)	109	
Total Length of Cables (km)	654	
Length of Hornsea 4 Offshore Cable Corridor (km) excluding array	99	
Width of Hornsea 4 Offshore Cable Corridor Temporary Works Buffer (km)	0.5	

Table 2: Maximum Design Parameters for Offshore Export Cables.

3 Measuring, Monitoring and Verification (MMV) Survey Interaction

This section looks to explore the primary subsurface characteristics of the Northern Endurance store and highlight MMV technologies that could be used to survey the store based on interviews with supply chain members and regulatory authorities. The end of this section highlights the noise generated by wind turbines individually and the risk posed by the turbine foundation's reflection on seismic acquisitions.

3.1 Subsurface Characteristics of the Northern Endurance Store

The Northern Endurance Structure was previously proposed as a carbon store by National Grid as part of the White Rose project. The following geological description of the Northern Endurance Structure is taken from the work completed by National Grid and partners [5].

Northern Endurance Storage Site

The Northern Endurance Structure is a four-way dip closure straddling blocks 42/25 and 43/21 in the UK sector of the North Sea, 60 miles east of Flamborough Head. The structure is a saline aquifer approximately 22 km long, 7 km wide and over 200 m thick. The aerial dimensions of the storage site are shown in Figure 3, with the crest of the reservoir located at a depth of approximately 1020 m below the seabed which closes at approx. 1460 m. Reservoir pressure and temperature are determined to be around 140 bar and 55.8 °C.

The Bunter sandstone formation, in which the Northern Endurance site lies, is composed of very fine to fine grained sandstone with generally high porosity and permeability.

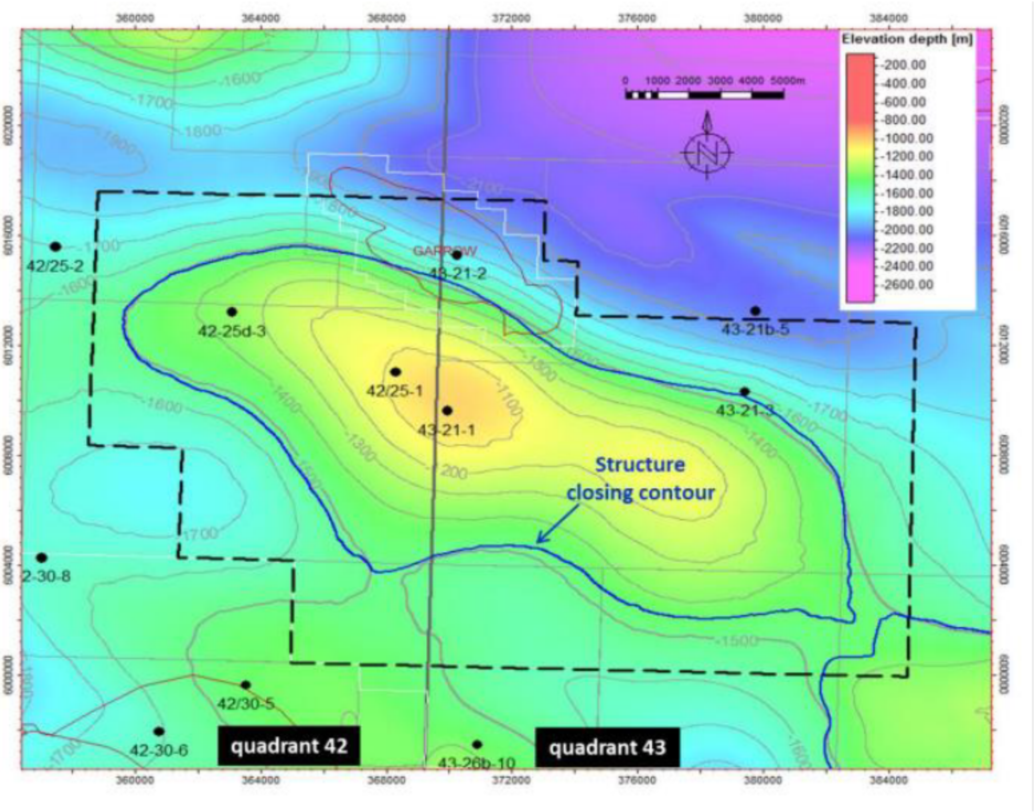


Figure 3: Depth Structure Map Over Northern Endurance Storage Site [5].

Lithologies above and below the Bunter Sandstone compose mostly of shales and evaporites and therefore are perceived to have good sealing quality (Figure 4). The Rot Clay, a layer of mudstone, provides the primary cap rock seal. This is overlain by more than 90 m of salt known as the Rot Halite which is thought to provide an additional seal.

The Upper Rotliegend is thought to provide a further basal seal. However, the base of this formation and the top of the underlying Leman Sandstone could not be resolved fully by the seismic data and are therefore mapped with lower confidence.

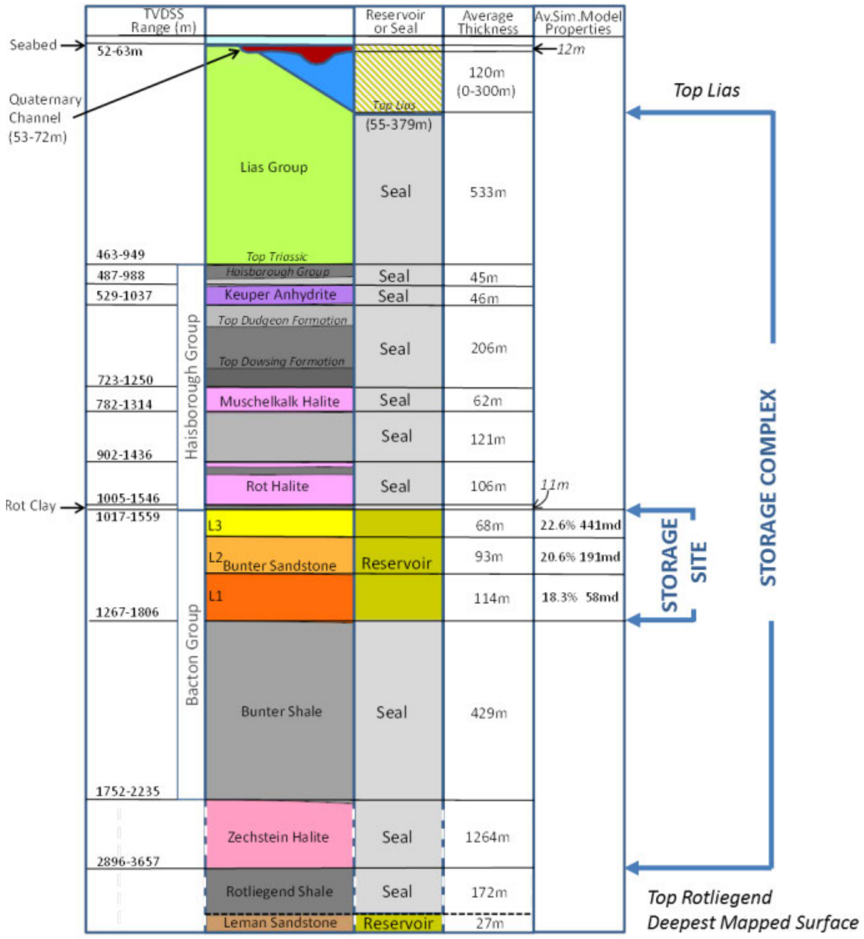


Figure 4: Lithology of Storage Site and Complex.

Available seismic images from 3D towed streamer, 3D OBC (ocean bottom cable) and 2D site survey data indicate that seismic imaging is good and able to image both reservoir and overburden (Figure 5). The gaps in the overburden imaging down to approx. 500 ms is due to insufficient spatial sampling of the seabed receivers.

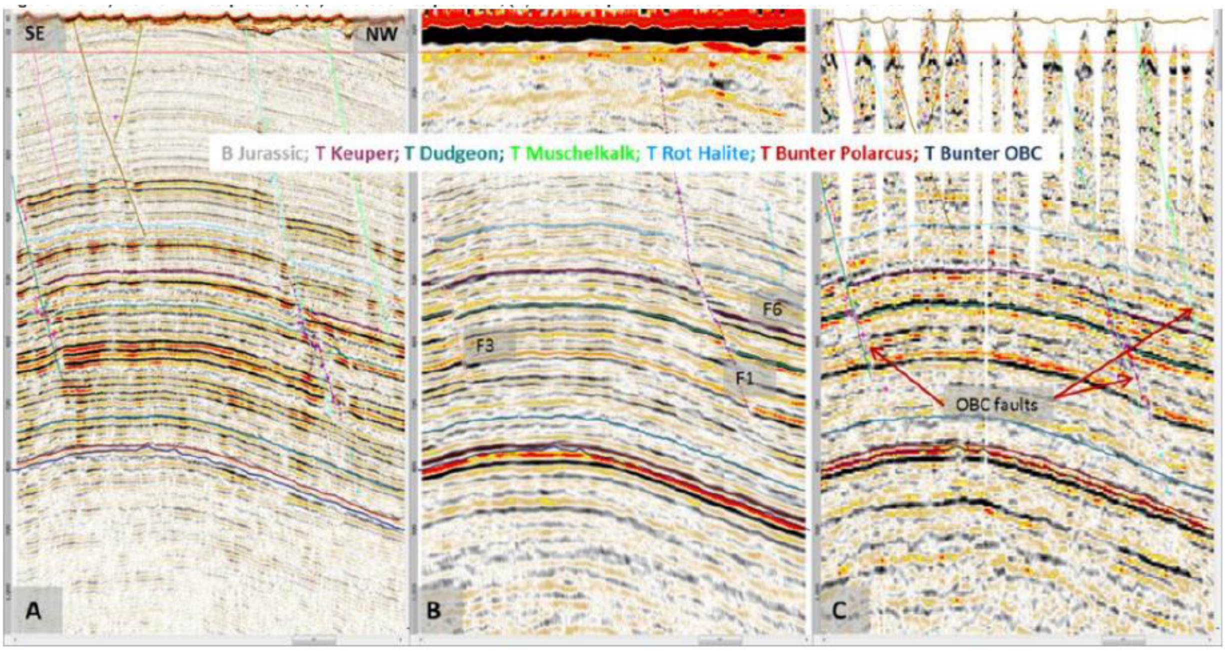


Figure 5: Examples of seismic data acquired over Northern Endurance Site. A) 2D tieline, B) Polarcus 3D, C) Ocean bottom Cable. Each show interpreted horizons and the OBC shows the impact of spatial sampling of receiver nodes on the imaging down to 500 ms (590 m TVDSS).

The presence of faults above the Northern Endurance structure has been interpreted from seismic (Figure 6). The faults do not penetrate through the Rot halite to the Bunter over the crest, but some faults penetrate close to the top of the Bunter sandstone on the south-eastern flank of the anticline. There is no evidence that these faults are open and therefore pose potential leakage pathways.

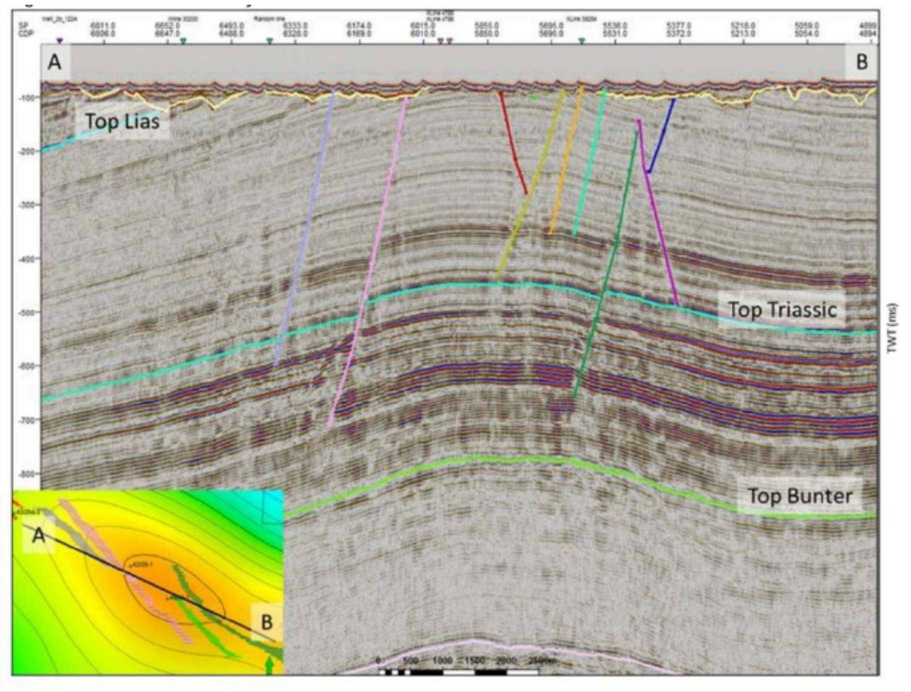


Figure 6: 2D site survey line showing fault interpretation across the crest of Northern Endurance storage site. Interpretation shows faults terminating before the Top Bunter.

3.2 Monitoring, Measurement and Verification (MMV) Plans

A monitoring plan is an essential component of the application for a CO2 storage permit. Monitoring is necessary to define a baseline, to ensure conformance to predicted behaviour and to verify containment of stored CO2. Based on the subsurface characterisation of the storage site, monitoring and measurement is designed to provide for early detection and recognition of irregularities to activate contingent actions.

The monitoring plan should describe the monitoring activities to be carried out by the licensees of the storage site and must include monitoring of the injection facilities and the storage complex, including where possible the CO2 plume and where appropriate the surrounding environment. The initial plan should describe monitoring activities throughout the asset lifecycle from baseline, through operation, and post closure of the storage site. The monitoring plan will be site specific, informed by the findings from site characterisation and risk assessment, and dependent on size, shape, and type of storage structure (depleted hydrocarbon or saline aquifer). Justification for not deploying monitoring techniques also needs to be documented.

Feedback from the monitoring plan is invaluable and allows history matching the dynamic simulation models to predict future behaviour of CO2 more accurately in the storage complex. The positive value of this monitoring can be quantified in terms of reduced operational costs (change/reduction in scope of monitoring plan) and avoidance of additional costs (including well interventions, additional wells or periods of suspended injection). Monitoring costs, which are a typically small fraction (<2 %) [6] of full-scale CCUS project costs need to be balanced against the benefits gained by ensuring successful and continuous CO2 storage operations. For further information on the requirements of a monitoring plan the reader is referred to Oil & Gas Authority Carbon dioxide storage permit application guidance [7].

Access or knowledge to the current MMV plan for the Northern Endurance site was not available in the public domain at the time of this report, therefore inference of likely activities will be based on a review of the MMV plan proposed for the White Rose project [8].

3.2.1 MMV Plan and proposed technologies

An MMV plan is typically divided into stages within the store lifecycle in which the requirements and capabilities of the technology are very different. In the case of Northern Endurance these are:

Injection – Active operational stage when CO2 is being injected. This stage is the highest risk to the integrity of the store and is the time when monitoring the impact of injection on the storage complex is at its highest.

Monitoring plume development from the injection wells is a key indicator of storage site behaviour. Measuring response at wells to update reservoir models and time lapse seismic are the main technologies capable of demonstrating conformance.

Post Injection – Average pressure in the storage site will start to decrease and therefore the risk profile will also reduce. With the high permeability the pressure is expected to decline rapidly and once the pressure response is known monitoring and measurement can be reduced.

The plume will continue to migrate after injection with time lapse seismic providing confirmation.

Post Closure – Wells are sealed and infrastructure removed, monitoring is limited to pressure measurements and checking for leakage of CO2 at the seabed. Time lapse seismic could be used to confirm the migration of the CO2 plume if required. If the storage site is behaving as expected arrangements are made to transfer responsibility from operator to responsible authority.

After Transfer – Monitoring and measurement tasks continue for 30 years to confirm long term stability in accordance with 2009/31/EC CCUS Directive.

A pre-injection stage could also be included for some of the MMV technologies where baseline surveys are required.

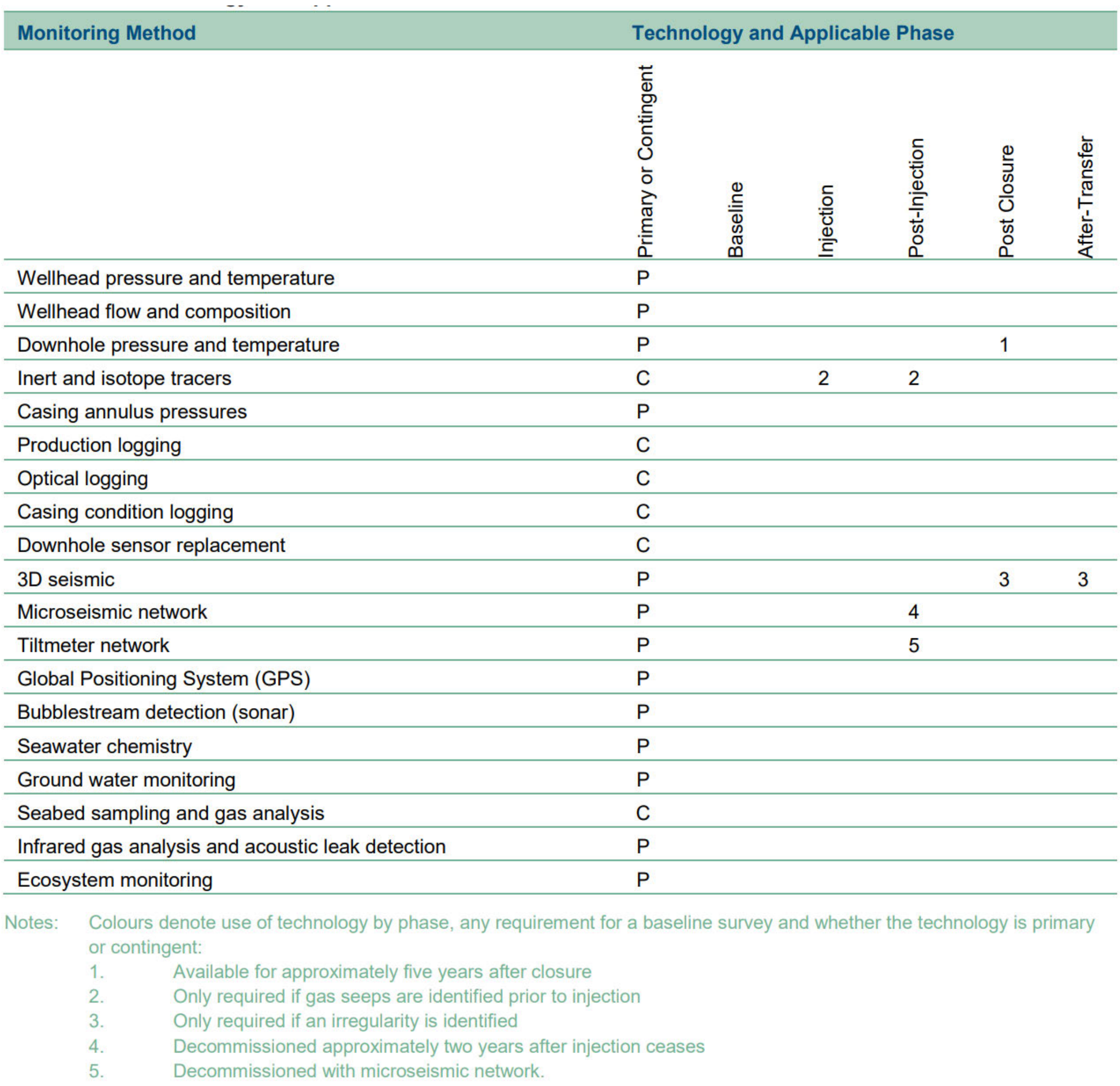
3.2.2 MMV Methods

Monitoring requirements can be grouped in terms of monitoring domain (injection well, reservoir, overburden and the marine environment) and their objectives (fluid saturation, fluid pressure, rock strain and environmental chemistry).**Error! Reference source not found.** lists the proposed monitoring methods for the White Rose development by monitoring domain while section 3.3 Current and Emerging MMV Technologies provides more detail on the subject.

Monitoring Domain	Monitoring Method
Injection well/Reservoir/Overburden	Wellhead pressure and temperature
	Wellhead flow and composition
	Downhole pressure and temperature
	Inert isotope tracers
	Casing annulus pressures
	Production logging
	Optical logging
	Casing condition logging
	Downhole sensor replacement
Reservoir/Overburden	2D seismic
	3D seismic
Overburden	Microseismic network
	Tiltmeter network
	Global Positioning System
	Bubblestream detection
Environmental chemistry	Seawater chemistry
	Ground water monitoring
	Seabed sampling and gas analysis
	Infrared gas analysis and acoustic leak detection
	Ecosystem monitoring

Table 3: Monitoring methods proposed for Northern Endurance Storage Site (K42).

Table 4 shows how these technologies will be used and applied across the various stages of the storage site lifecycle.



Monitoring Method	Technology and Applicable Phase					
	Primary or Contingent	Baseline	Injection	Post-Injection	Post Closure	After-Transfer
Wellhead pressure and temperature	P					
Wellhead flow and composition	P					
Downhole pressure and temperature	P				1	
Inert and isotope tracers	C		2	2		
Casing annulus pressures	P					
Production logging	C					
Optical logging	C					
Casing condition logging	C					
Downhole sensor replacement	C					
3D seismic	P				3	3
Microseismic network	P			4		
Tiltmeter network	P			5		
Global Positioning System (GPS)	P					
Bubblestream detection (sonar)	P					
Seawater chemistry	P					
Ground water monitoring	P					
Seabed sampling and gas analysis	C					
Infrared gas analysis and acoustic leak detection	P					
Ecosystem monitoring	P					

Notes: Colours denote use of technology by phase, any requirement for a baseline survey and whether the technology is primary or contingent:

1. Available for approximately five years after closure
2. Only required if gas seeps are identified prior to injection
3. Only required if an irregularity is identified
4. Decommissioned approximately two years after injection ceases
5. Decommissioned with microseismic network.

Table 4: Monitoring method and phase [8].

The co-location of a wind farm on the Northern Endurance Storage site is most likely to impact the proposed monitoring activities of 3D seismic the most. It should be noted that once installed, wind turbines may not significantly impact access and application of other monitoring methods at well or field scale, however during the period of installation noise and increased activity could have a significant impact on ongoing wellbore and field scale monitoring activities. The highest risk to the integrity of the store is during injection and this is when monitoring is expected to be at its highest. Sensitive downhole monitoring techniques (Distributed Temperature/Acoustic Sensing (DTS/DAS)) or permanent reservoir monitoring spreads could be severely impacted in their ability to monitor injection activities during the installation of turbine foundations where noise levels will be considerably more than during operation. This may cause monitoring, and more significantly injection, to stop. The impact of this on the economics of the store or condition of the wellbore would need to be considered depending on planned injection strategy and/or duration of turbine foundation installation activity.

In the 2016 MMV plan, towed streamer acquisition was chosen for the acquisition of time lapse seismic for the White Rose development. The use of ocean bottom cables or nodes was not proposed based on their higher cost compared to towed streamer acquisition, taking into account the data only provides confirmation of conformance and does not relate to containment or potential threats to containment.

Four monitor surveys were proposed over the lifecycle of the storage site based on the fact that plume development and migration of the CO_2 is not critical for the operation of injection wells. The first survey will be undertaken approximately four years after injection commences to ensure enough CO_2 will have accumulated to provide a clear image and 4D signal. The data from this will be used to calibrate dynamic reservoir models and plan frequency of future surveys. However, it is envisaged, based on model data, that future surveys would be carried out 12 and 18 years after injection commenced, and 3 years after injection has ceased.

With the potential co-location of offshore wind farms and CCUS sites the use of towed streamer acquisition for time lapse studies needs to be reconsidered. The repeatability and quality of the 4D time lapse signal is one of the biggest concerns with the overlap of wind farms and CCUS sites especially for towed streamer acquisition. The installation of the wind farm could make it difficult for the seismic vessel to navigate on the same acquisition geometry therefore compromising repeatability and introducing too much noise from differences in acquisition geometry, positioning or ambient noise.

3.3 Current and Emerging MMV Technologies

3.3.1 Reflection Seismic

Reflection seismic (towed streamer or ocean bottom nodes) in the form of 3D acquisition for time lapse studies is currently viewed as the most applicable and mature technology to monitor the impact of CO_2 injection on plume migration and assessment of store and well integrity. However, the cost of acquiring seismic data is high, initiating research into cost-effective solutions for monitoring CO_2 injection that minimise the use of marine seismic acquisition in the short term, and potentially replace seismic acquisition in the long term once the technology has been proven and matured.

Seismic has the advantage over other methods as it can image the whole complex area including reservoir, overburden and surroundings. Providing the reservoir characteristics are suitable the seismic response is sensitive to changes in fluids content, i.e. CO_2 replacing brine, and to significant changes in pore pressure. This makes the technique useful for monitoring storage site integrity and reservoir management over time.

Towed streamer is the most efficient and cost-effective method of gathering seismic data, especially over large areas like the Northern Endurance Storage Site. However, in the presence of wind farms this might not be the most appropriate acquisition method with the challenges outlined above.

Ocean bottom nodes have some advantages over the conventional towed streamer methods. The technique allows for greater flexibility where surface obstructions such as platforms and wind farms prohibit the use of vessels towing source and streamer arrays. In addition to the operational advantages ocean bottom surveys typically provide better data quality and imaging. However, these benefits need to be weighed up against the considerably higher cost of acquisition.

Cost of acquiring OBN seismic is approx. 10 times that of conventional 3D broadband data which is the current standard for towed streamer acquisition. Taking the total area of Endurance to be surveyed as approx. 400 sqkm, a cost of 3D towed streamer acquisition of $8,000 per km^2 and OBN (node on a rope) of $80,000 per km^2 [9], each 3D survey would cost $3.2 million and each OBN survey $32 million. Assuming four surveys over the asset lifecycle the difference between 3D towed streamer and OBN would be in excess of $100 million.

Advances in the speed of deployment and retrieval of ocean bottom nodes could reduce the cost of OBN acquisition, and the development of autonomous nodes [10] [11] could decrease this cost still further making it a viable alternative to towed streamer acquisition and significantly reducing the cost of ocean bottom monitoring for CCUS. These technologies are at a pre-commercial stage (Technolog Readiness Level (TRL) 5/6) and undergoing sea trials and therefore still need to be proven in an operational environment.

The ability to place geophones on the seabed also opens the opportunity to include stress and strain monitoring through the detection of microseismic events. While these measurements could be taken periodically at each monitoring survey, the most value would come from deployment as part of a permanent array (see section 3.3.4). Permanent arrays come at a significantly higher cost than deploying retrievable receivers therefore the cost to value of the data would need to be evaluated along with the expected level of rock strain. Depending on the level of expected rock strain, an alternative to a permanent array could be periodic deployment of retrievable receivers at the seabed before and during early phases of injection to characterise the background seismicity and to monitor injection induced rock strain.

However, one of the limitations of ocean bottom acquisition is the often degraded image of the overburden, Figure 7. Data gaps down to 500 ms are clearly seen on the section taken from ocean bottom cable data (pre 2012) acquired over Northern Endurance. This is a function of the spatial sampling of the receiver nodes and whilst this does not impact the imaging of the reservoir or storage site it severely impacts the imaging of the shallow overburden which could be important in the monitoring of CO2 conformance and containment.

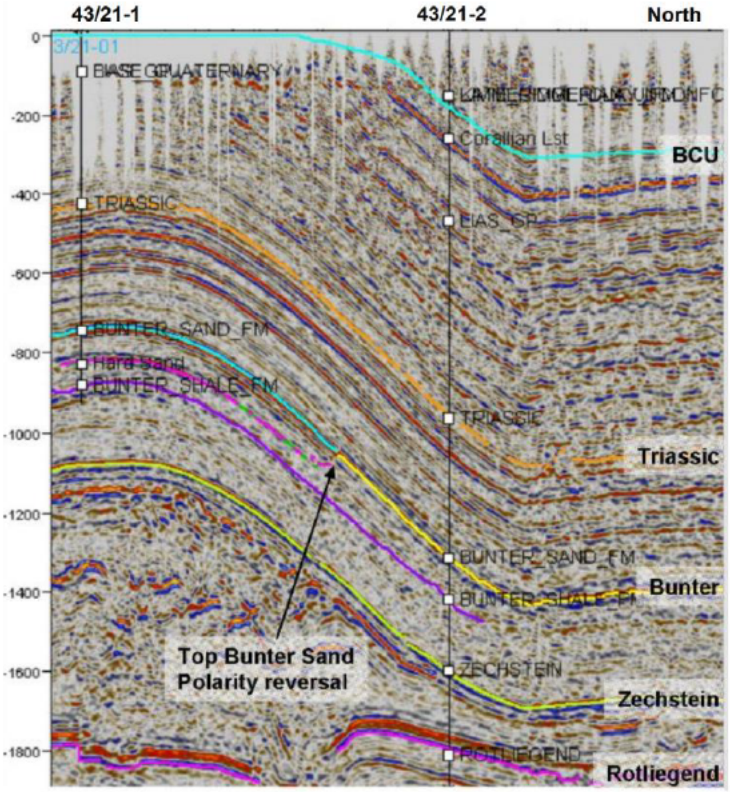


Figure 7: Section from 3D OBC data shows effects of insufficient spatial sampling of nodes on data quality.

This could be solved by implementing denser node spacing but this would result in higher costs so again the cost would have to be justified by the benefit to seismic acquisition results. Surface acquired seismic data would not be impacted by the issues of spatial sampling, however as previously mentioned there are challenges in turbine layout (spacing and often irregular pattern of turbine placement) that makes acquisition of surface seismic challenging. Increasing the spacing between turbines and arranging the turbines on a regular grid may open the potential for the use of short offset acquisition techniques like P-Cable [12], or conventional 3D arrays with shorter streamers to acquire conventional 3D towed streamer data within a windfarm. In the case of Endurance, the storage site is relatively shallow which may allow for a reduction in streamer length increasing the possibility of successful navigation and acquisition. Being able to acquire data on a standard grid pattern would also significantly improve repeatability and therefore time-lapse monitoring results. Before these techniques can be considered it is advised to carry out acquisition design modelling to look at potential sail configurations given the known challenges to understand what is possible in terms of acquisition and imaging, especially capturing the fluid effect of brine being replaced by CO_2.

Other technologies are emerging within processing of the seismic data that have the potential to allow sparse acquisition and therefore reduce costs.

Mirror Imaging [13]

Mirror imaging is another solution that may provide an alternative solution to improved imaging of the overburden without having to increase the number of nodes and cost. Using the down going wavefield the overburden can be imaged with improved incidence angle (near angles) giving improved resolution of the overburden allowing imaging of the shallow overburden and the seabed. Modelling would be required to verify if this approach would provide sufficient image quality for a given node spacing.

Compressive Sensing [14] [15] [16] [17] [18]

Compressive Sensing is a novel and innovative technology that is an enabler for sparse random ocean bottom seismic acquisition using reconstruction of the full azimuth wavefield. It has the potential to significantly reduce Ocean Bottom Node (OBN) survey acquisition time and the volume of data required. There is even the possibility of removing the requirement for repeatability which if proven true could dramatically reduce the cost and time of 4D surveys. This could be of particular value in the scenario where the baseline survey acquired prior to the installation of a wind farm could not be repeated with the same acquisition geometry.

In a special topics section of the SEG (Society of Exploration Geophysicists) publication The Leading Edge, ConocoPhillips reported that they were able to improve their acquisition productivity for land and marine by 5–10 times using ideas from Compressive Sensing (CS) that were initiated by the academic research Consortium SINBAD (the leader of this project) at the Seismic Laboratory for Imaging and Modelling (SLIM) from the University of British Columbia and now at the Georgia Institute of Technology [19].These results suggest that CS is a feasible technology that could deliver drastic improvements and cost reductions in seismic data acquisition with OBNs.

Full Wavefield Migration (FWM) [20]

Full Wavefield Migration, as proposed by PGS and other seismic service companies, is another processing technique aimed at significantly reducing and therefore cost of ocean bottom nodes. Using innovative acquisition geometries for imaging around obstacles this could also be a solution for acquiring seismic within a wind farm. To date the technique has been tested in deep water offshore West Africa but has yet to be tried in shallower water. Modelling to simulate applicability to shallow water and a process of verifying image quality would need to be carried out to understand if this method is suitable.

Gravity Field Monitoring

Gravimetry measurements offer direct measurements of density changes at relatively low cost and offer the potential for accurate monitoring of the plume and seabed deformation (as a by-product of gravity metre deployment). Gravity field changes down to ~2 mGal are currently detectable. Injection of CO2 will change the mass distribution and therefore density in the aquifer as the gas displaces the brine. This could be an applicable technology for saline aquifers where the density changes could be significant as the brine is replaced by CO2.

Gravity measurements have been used to great effect on the Troll and Ormen Lange fields to monitor water break-through [21].

Measurements are made at selected locations across the field by placing the gravimeter on the seabed usually on a concrete plinth. At a point source, gravity measurements give good vertical resolution but does not have the same spatial resolution. However, at a cost of approx. 10-15 % of a 3D seismic survey gravimetric measurements could be an alternative monitoring method depending on monitoring requirements.

At the current technology development level of gravimetric measurements and seabed positioning, gravity is currently considered as a valuable complement to a seismic monitoring programme [6].

Electromagnetism

Controlled Source Electromagnetism (CSEM) or Electromagnetism (EM) was not considered as an applicable technology for a MMV within a wind farm.

EM is most commonly used as a prospect de-risking tool used at the exploration stage and is acquired using a towed array so would have the same issues and challenges as acquiring surface seismic data within a windfarm. Vertical CSEM [22] offers an alternative to towed CSEM, however it is questionable if CSEM, towed or vertical, would provide sufficient resolution to monitor conformance or containment of injected CO2.

3.3.2 Permanent Arrays and Passive Seismic

Seabed nodes as part of permanent reservoir monitoring (PRM) systems offer both active and passive monitoring opportunities. Some of the benefits of a seabed array system are listed below

- Permanent passive seismic monitoring to identify storage integrity problems such as seismicity related to activation of faults that could act as leakage pathways for CO2 and fracturing of the overburden seal due to pressure build up. Monitoring could also be in real time using fibre-optic links.
- Active seismic acquisitions to provide high resolution monitoring of CO2 migration during injection. Acquisitions would only require a source boat, enabling more frequent monitoring according to the needs of the project.
- In the case of CO2 leakage to the overburden, the array could provide monitoring of site containment and detection of anomalies.

As with any technology there are important challenges to deployment

- Initial investment cost of a PRM is relatively large and may not offer sufficient benefit at an acceptable cost level

- The size of array would be based on models. If model prediction of plume development is wrong and the plume extends outside of the predicted area the array would lack the necessary coverage.

The potential use of the wind turbines as a seismic source was mentioned in few conversations and is an interesting concept that needs to be explored. A permanent source would remove the requirement for a source boat, reducing costs and any potential challenges of navigating the vessel and source through the wind farm. In conjunction with a permanent array, it could offer great flexibility in monitoring options for both conformance and containment.

Fibre optic cable and distributed acoustic sensing (DAS) was another option offered in discussions as a permanent seabed array and alternative to nodes. While fibre optic cable and DAS/DTS (distributed temperature sensing) is a rapidly developing technology for downhole and near wellbore studies, seabed or surface array application is still in its infancy. Further work is required to understand the size of array required and depth of penetration. Potential application in the near term could be for monitoring the shallow overburden for microseismic events.

Recent onshore CO2 storage projects in Australia at the Otway International Test Centre in Southwestern Australia [23] and at Quest [24] and Aquistore [25] test sites in Canada have shown the value of DAS/DTS to monitor plume growth. At these locations downhole DAS/DST has been used to record seismic data and demonstrate the value of time-lapse vertical seismic profiling (VSP) as a cost-effective method of monitoring plume growth.

Fiber optic monitoring techniques and technology are continually improving and with the cost gradually falling will continue to see increasing application in reservoir monitoring and management.

3.3.3 Optimised Monitoring Strategies

Based on the information gathered from the public domain on technologies in play today and those potentially available in the future below is a conceptual view on an MMV strategy where the location of a wind farm limits the use of towed streamer acquisition.

- Sparse PRM system focused on injectors and early plume area. This is the area where storage and operational risks are highest during the operation phase (injection)
- Sparse PRM will enable more accurate and frequent monitoring of reservoir units and overburden to demonstrate conformance and provide data to update models. The PRM system will offer both passive and active monitoring programmes and will minimise the requirement for towed streamer acquisition
- Design and frequency of repeat surveys would be adjusted as the project develops. Initial surveys would use a source boat, but this might get superseded in the future by being able to use the turbines as a seismic source signal
- With accurate and frequent monitoring, confidence in predicted to actual store behaviour would increase, allowing options like gravimetric modelling to be sufficient across the wider CCUS store

- PRM system will have a higher investment cost which may be challenging to the economics of the storage site. In the co-location scenario cost sharing of permanent systems could be considered to improve the economics
- PRM system may minimise the requirement for towed streamer acquisition, the aerial extent could still impact co-location and turbine installation and therefore may not be an applicable solution

Monitoring techniques and technologies are continually improving and their costs gradually falling, so MMV plans for future projects will be better placed to adopt emerging technologies as they mature and are proven. Figure 8, taken from [26] shows how a future CO2 monitoring strategy might look.

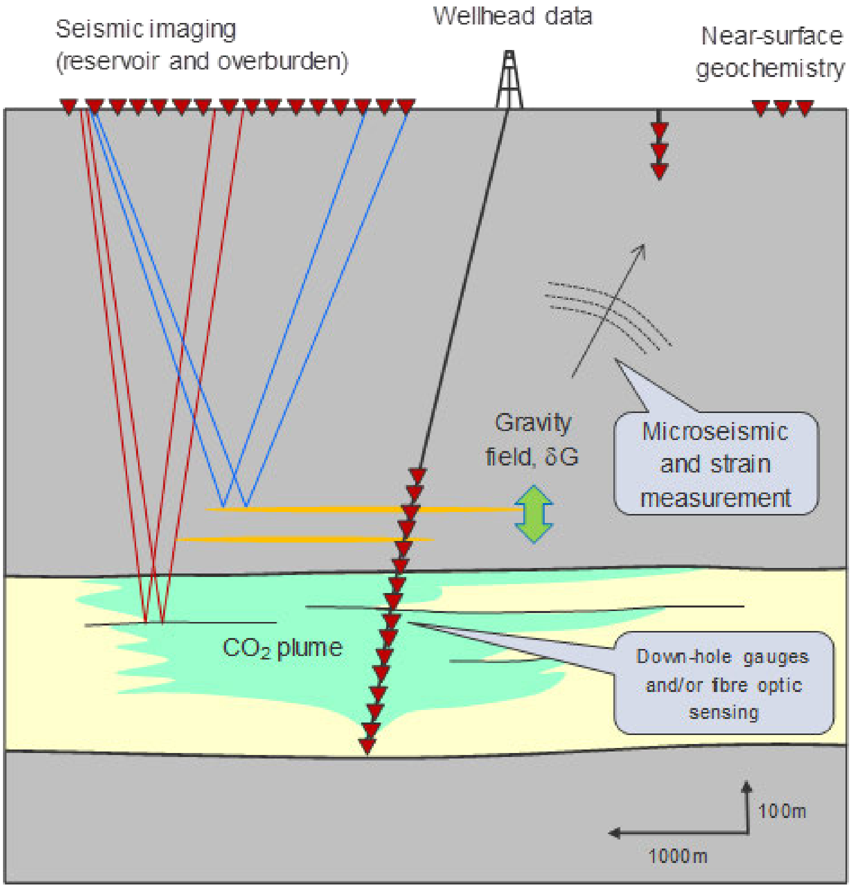


Figure 8: Conceptual picture of a future CO2 monitoring strategy.

3.4 WTG Impact on MMV Surveys

Due to the high cost and low TRL of many new seismic technologies, traditional towed streamers are still considered as the main technology to measure, monitor and verify CCUS stores by operators. With the risks associated with co-location, in particular towed streamers colliding with wind turbines, which was identified within Project Vulcan, this section looks to comment further on the research and case studies available.

This section focuses on possible forms of interference on seismic surveys due to wind turbine interactions such as;

- Turbine blades
- Mechanical noise and vibration generated by gearboxes
- Interference cause by reflection off turbine foundations such as monopiles and jacket piles

3.4.1 Turbine Noise

The construction and operational stages of a windfarm have been highlighted as stages that produce the most noise and possible impact on seismic surveys and marine life. The construction phase is the noisiest of the two but also the shortest. Construction noise is limited to increased marine traffic and piling foundations into the seabed with durations in the region of a year depending on the size of the site. The operational stage of a fixed offshore windfarm is quieter and is by far the longest stage and can last 25+ years. The typical noise that is generated from an operational turbine can be split into the swishing motion of the blades as they cut the air and the mechanically generated noise from the gearbox. It should be noted that not all turbines have gearboxes, some are direct drive and this noise generation is not applicable to all turbine manufactures and models. This section looks to review the research to date on these areas as well as review the case studies that have been carried out in the oil and gas and offshore wind sectors.

The Canadian Society for Exploration Geophysicists (CSEG) conducted land based geophysical research into noise affecting seismic surveys from onshore wind turbines concluding that the peak noise created is within the 4 – 16 Hz range [27]. The low frequency pulses are created as the blade interacts with the turbulent air around the tower structure at the 6 o'clock stage of its rotation. The amplitude of the air pulses is impacted by the following conditions as highlighted in Table 5.

Conditions	Descriptor
Higher Windspeeds	A higher windspeed allows the sound waves to travel further in the prevailing wind direction
Humidity	The higher the humidity the further the pulse travels
Wind direction	Sound waves converge in the prevailing wind direction
Multiple turbines	This increases the noise sources and increases the chance for constructive interference
Distance from turbine	Noise and amplitude decrease with the distance from the turbine.
Terrain	Flat terrain allows for sound waves to travel further without meeting barriers such as mountains, hills, trees, building etc.

Table 5: Conditions which impact the amplitude of air pulses.

The CSEG also carried out several tests using iSeis Sigma seismic reordering nodes and professional microphones to monitor the frequency and noise created by a single onshore wind turbine. This test was considered free from interference as there were no other turbines in a 7 km radius. Full results can be seen in Table 6, Figure 9 and Figure 10.

Test	Date, wind speed	Results
Test 1 – walkaway test from a single WTG	29th August 2019	No other turbines within 7 km – low interference of waves.
		10 Hz dominant frequency.
	Wind Speed – 18 km/h Wind direction – West	Recording at 550 m offset has an event that is a good estimate of the source wavelet (see red ellipse, Figure 10).
		Amp. at 1,800 m offset is about 1/3 the amp. at 550 m.
	Blade interval – 0.8 sec	Recording at 4,000 m offset still includes a small amount of seismic energy from the WTG.

Table 6: Test conditions and results [27].

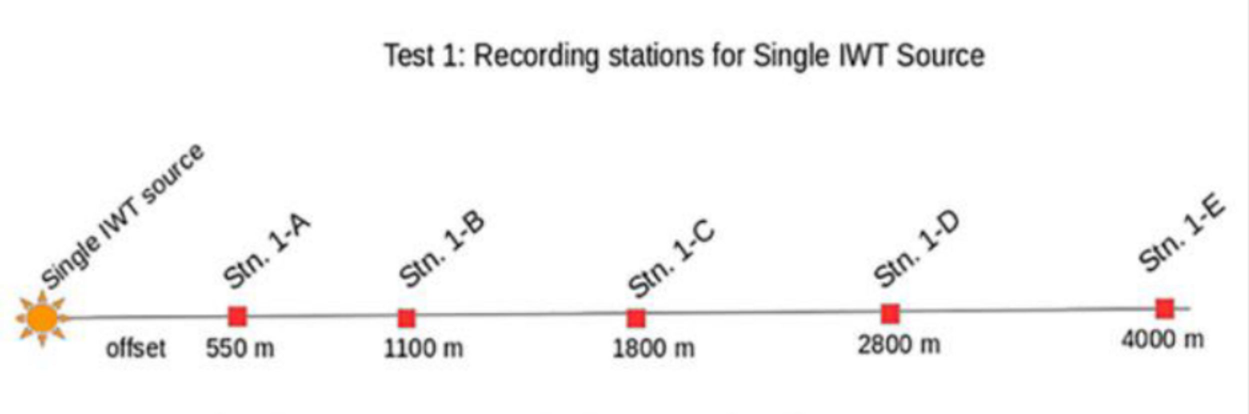


Figure 9: Map view of test 1, walk-away test seismic recordings for a single Industrial Wind turbine (IWT) source [27].

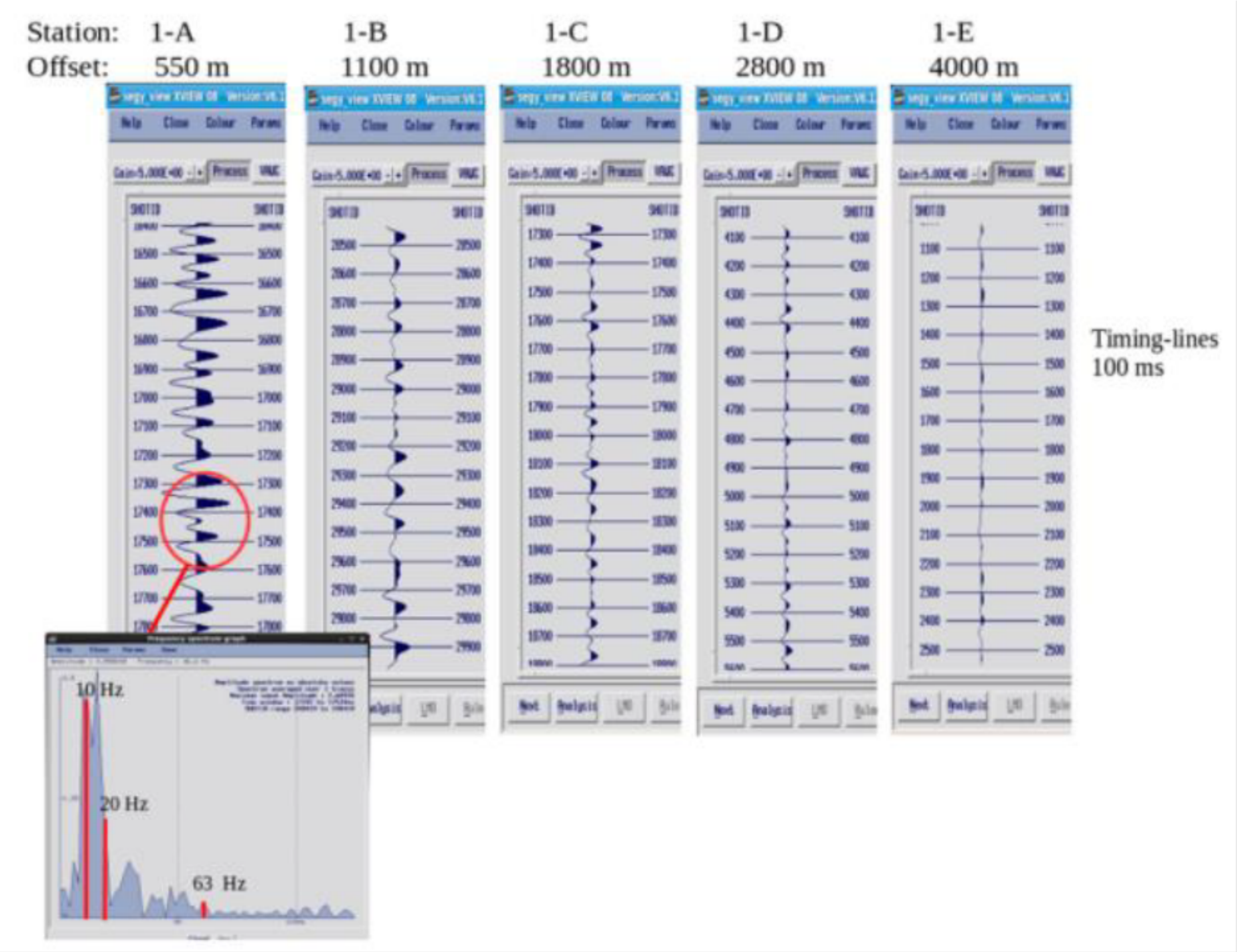


Figure 10: Time series from stations A-E, and the frequency amplitude spectrum of the estimated source wavelet (pulse, no filter) from station A [27].

The results show a low frequency noise generated by the wind turbine blades that diminishes with distance but is predictable and detectable on seismic monitors. While this shows that noise diminishes farther away from the turbines, the likelihood is that there will be a turbine within 1 km and so there will be constant level of noise from all directions.

The Collaborative Offshore Wind Research into the Environment (COWRIE) project, measured the noise created during construction and operation activities of offshore wind farms and looked to determine the effect that noise may have on several different marine mammals and fish populations [28]. Measurements were taken using Bruel & Kjaer hydrophones during pile driving construction activities at the following five offshore wind farms: North Hoyle, Scroby Sands, Kentish Flats, Barrow and Burbo Bank. The diameter of the monopiles varied from 4 – 4.7 m in diameter. These determined that the source level of noise at 1 m from the turbine varied from 234 – 257 dB with an average value of 250 dB. The transmission losses were characterised by values of geometric loss factor "N" of 17 – 21 and absorption factor of 0.0003 to 0.0047 dB/m.

During the operational section of the report, they assessed four wind farms - North Hoyle, Scroby Sands, Kentish Flats and Barrow – using the same Bruel & Kjaer hydrophones to measure sound throughout the windfarms. In general, the noise of an operational wind farm was found to be very low. The measurements highlighted an increase in 8 dB at North Hoyle, 3 dB at Kentish Flats, 1 dB at Barrow and no increase at the Scroby Sands site. The four sites varied slightly but in general in frequency ranges of 0 to 20 Hz, very little noise was detected and was probably limited to wave activity above the surface. Frequencies of 20 Hz – 120 Hz peaks in the spectra were detected and highlighted as distant shipping activities while finally frequencies from around 80 Hz – 100 kHz can be allocated to the wind and turbine noises.

The bandwidth or frequency that is used for the soundwaves in seismic surveys is in the range of 5 – 200 Hz and can be higher but depends on the depth of the reservoir and the clarity required. A lower frequency is required for deeper imaging as the higher frequencies are attenuated quicker. In this case, the Northern Endurance field is around 1,000 – 1,400 m depth [29] and is not as deep as some other reservoirs in the North Sea so it is expected the bandwidth to be around 5 - 80 Hz with about 50 Hz at the reservoir.

Very little work and studies have been carried out into the area of noise created by operational wind turbines. Most of the work has been carried out through the construction phases but aimed at understanding the impact that pile driving has on marine mammals and fish populations in the area. There is a consensus that the operation of a wind farm produced much lower levels of noise and does not affect the concentration or normal activity of the marine mammals and fish stocks. With the limited information available it has been highlighted that the noise produced by wind turbines through either mechanical noise or blade movement is quiet and low frequency noise that operates in the same band as seismic surveys. Although this sound can be removed through algorithms already used within the oil and gas (O&G) industry, this has not been carried out in a large-scale real-world example and more studies would need to be carried out before a conclusion is achieved.

3.4.2 Turbine Interaction

The writer is unaware of any studies that have been carried out looking at whether wind turbine foundations such as monopiles and jackets can interfere with seismic data. However, after engagement with Schlumberger (a seismic survey provider) and carrying out an interview on the issue, the phenomena of "rig reflection" or "rig noise" was discussed. This is when seismic acquisitions are carried out near an offshore oil and gas production or drilling rig. Interference can be created from the mechanical machinery on the rig or during drilling, reflection directly from a rig or pipeline and even from other seismic surveys ongoing in the area. There are a number of different approaches to removing unwanted signals from seismic acquisition such as denoising, shot-skipping and resplicing approaches [30]. Denoising is limited to seismic interference (SI) in the same direction to avoid potential strong signal loss and can't be applied to 2D.

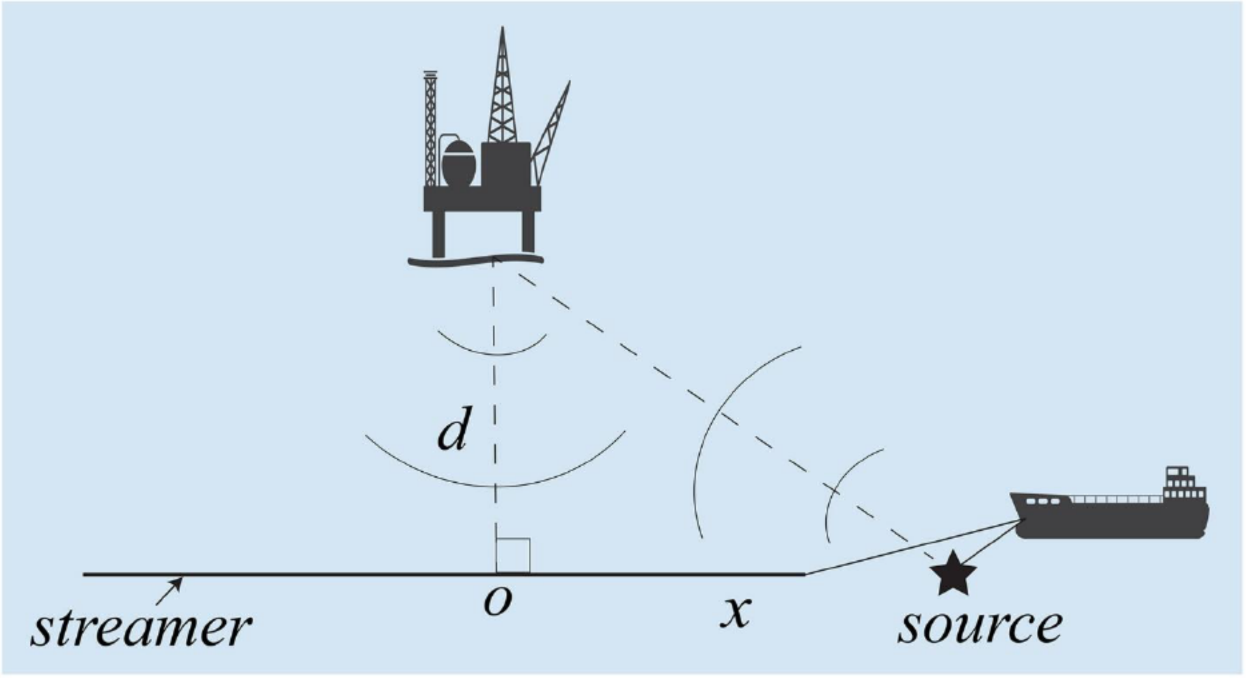


Figure 11: Rig Noise and How it Interacts with Streamers.

Shot skipping and resplicing approaches are better suited to the issues presented by "rig noise", noise generated from platform and SI. The shot skipping and resplicing method takes advantage of the fact that as the vessel takes consecutive shots the distance to the rig will change, and this approach looks to decrease the coherency of the rig noise. Shots gathered from the seismic are regrouped with another shot further along the seismic acquisition and merged. As the distance of the rig has changed a known amount, that will be reflected as the change between the two seismic shots. The denoising of acquisitions through shot skipping and resplicing relies on the time taken between each seismic shot to be accurate and the number of shots skipped should be kept to a minimum whilst allowing for clean seismic data to be collected along with the rig noise interference.

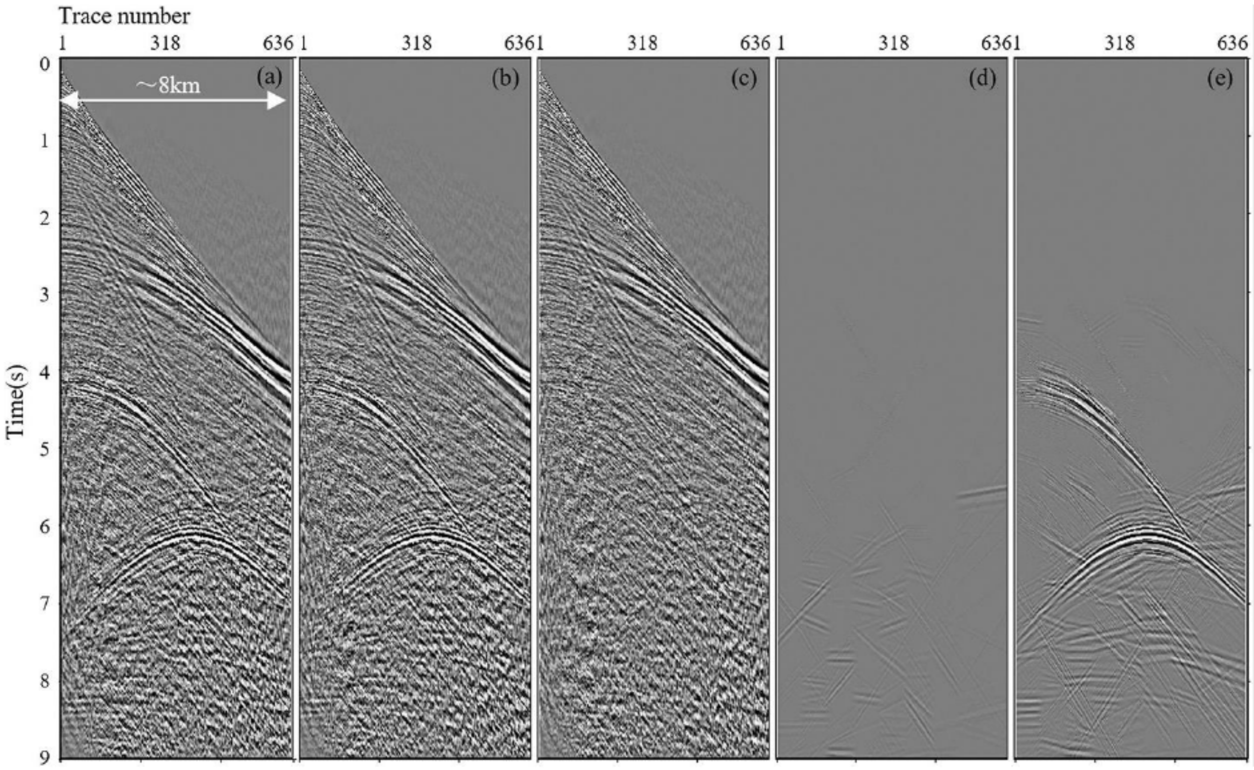


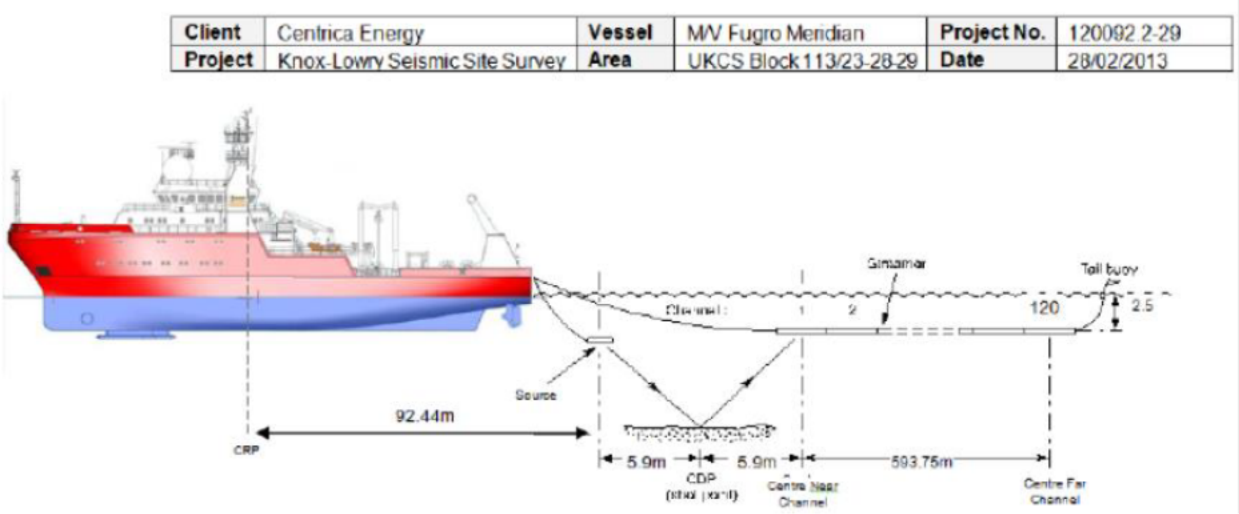
Figure 12: Visual representation of normal, shot skipping and resplicing approaches [30].

Figure 12 shows the results of denoising seismic acquisitions with (a) showing the results before denoising, (b) showing normal denoising methods without the shot skipping approach, (c) highlights the results of skipping 10 shots between acquisitions, (d) shows the difference between (a) and (b) and finally (e) shows the difference in results between (a) and (c).

It can be clearly seen that there is a distinction between denoising acquisitions with and without the shot skipping and resplicing method. This work can be carried out using processing algorithms and computer processing software to speed up the cleaning of data. It is felt that this approach could be used for wind turbine foundations if their location was known. However, field trials would need to be carried out against a wind farm as this example is of only one rig signal, and wind farms have several turbines and their foundations in situation.

3.5 Case Study

At the time of writing there has only been one seismic survey carried out through a wind farm. A 2D seismic acquisition was carried out by Fugro for Spirit Energy (formally Centrica Energy), through Vattenfall's Ormonde windfarm which consists of 30, 5 MW Senvion turbines on piled jacket foundations [10] in the East Irish Sea in 2013.



Client	Centrica Energy	**Vessel**	M/V Fugro Meridian	**Project No.**	120092 2-29
Project	Knox-Lowry Seismic Site Survey	**Area**	UKCS Block 113/23-28-29	**Date**	28/02/2013

Figure 13: Fugro Meridian courtesy of Spirit Energy.

As previously stated, Fugro carried out a 2D seismic acquisition which used a single towed streamer at a length of around 600 m. This differs from 3D seismic surveys which use multiple streamers in arrays that can be in the region of 1,000 m wide and can be towed at distances of 4,000 m – 8,000 m behind the vessel, allowing the efficient capture of data over large areas. The relatively shallow depth of the Endurance store could potentially facilitate the use of smaller seismic spreads (determined by acquisition design modelling), however smaller spreads require more sail lines, taking longer and costing more to capture data from the same amount of area.

Before seismic acquisitions could be carried out Apollo Offshore Engineering (Apollo) were contracted to look at the engineering and the risks associated with towing seismic through a wind farm, the following was considered, discussed and agreed by all parties.

1. Writing of procedures and documentation for the activity
2. Survey lines documented and agreed prior to entry as shown in Figure 14
3. Tow trials completed between the 'Fugro Meridian' and tug the 'Deilginis' as show in Figure 15
4. Drift trials undertaken and integrated into a computer modelling simulation to define environment window of operating conditions as show in Figure 16
5. Suitable weather window for acquisition within the wind farm based on modelled conditions as show in Figure 17

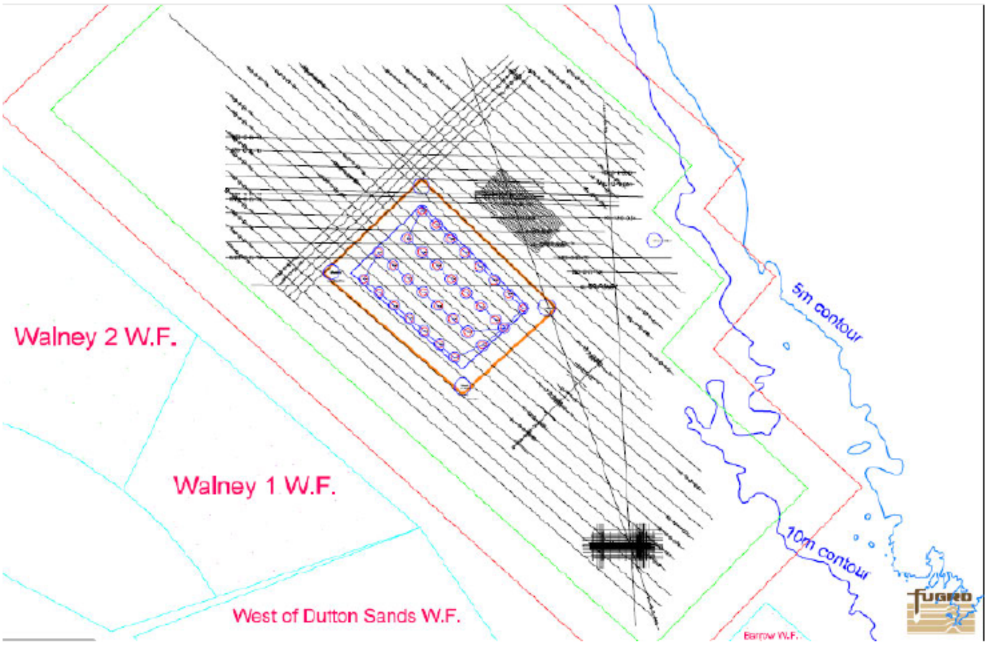


Figure 14: Fugro 2D seismic tow lines, image courtesy of Spirit Energy.

Figure 14 shows the proposed tow lines in black for the 2D seismic survey, a total of 17 tow lines were highlighted within the wind farm area.

Figure 15: Tow trials being carried out between the 'Fugro Meridian' and tug the 'Deilginis', image courtesy of Spirit Energy.

The tow trials were carried out as sea and witnessed by both a Vattenfall and Centrica Energy representative. The test was to demonstrate that the tug would be able to attach and secure the

'Meridian' in a number of real world examples with the worst case example being total main engine and thruster failure. This was achieved and the tug was able to recover and tow the 'Meridian' in under 4 minutes.

From this a number of additional assurances were highlighted in order to improve the safety of the operation.

1. Predesignated safe anchor zones highlighted within the windfarm
2. Safe anchor zones plotted and uploaded into the 'Meridian' navigation system
3. Vattenfall Turbine Rotor Brake System in place (3 minutes)
4. Vattenfall Turbine can be rotated (may take a prolonged period)
5. Vattenfall can de-energise in-field cables

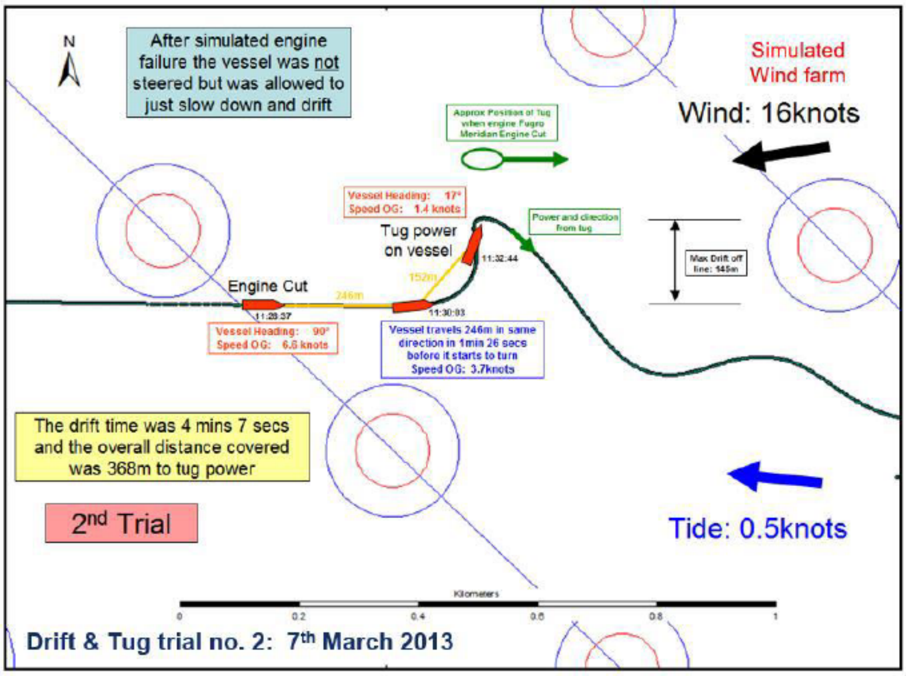
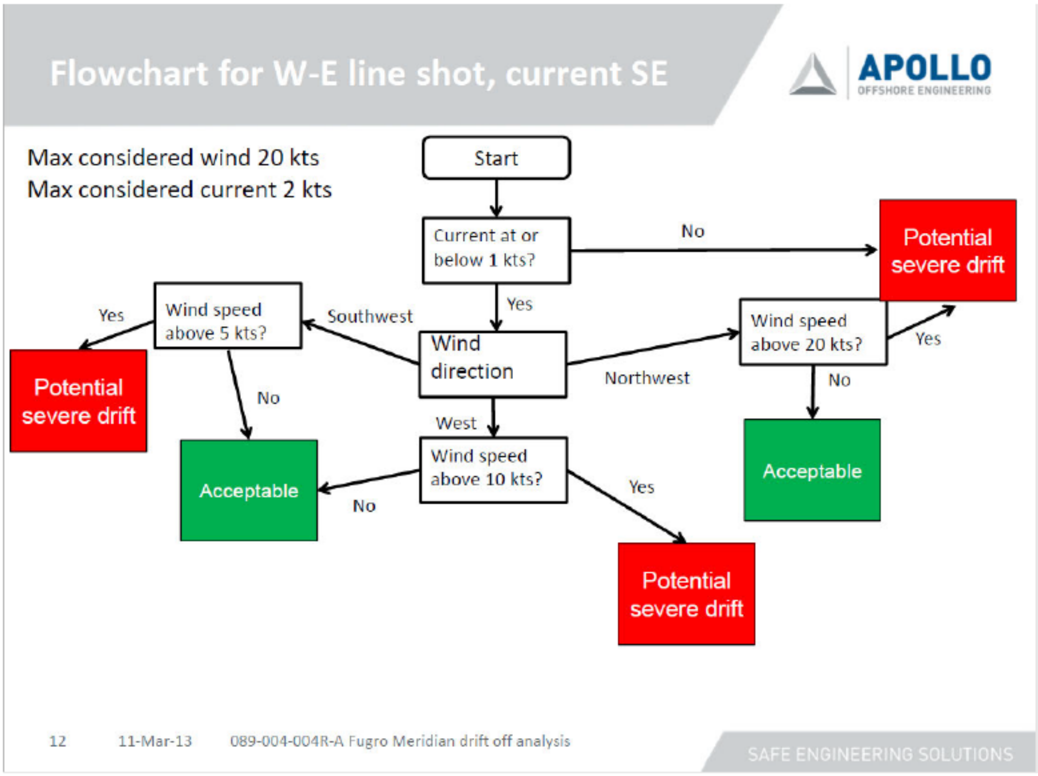


Figure 16: Example of drift and tug trial modelling, image courtesy of Spirit Energy.

In all the modelling scenarios undertaken, once there had been an engine failure it was assumed that there was no further intervention carried out on the vessel by the captain such as turning or thrusters. The model focused on two different scenarios of wind and tide direction, in the worst case scenarios the modelling concluded that a collision was likely with a turbine within a 5 minute window. Further modelling was carried out to determine the optimum environmental conditions in terms of wind and tide direction and speed and to provide a safety margin for the tug to intervene and secure the 'Meridian' in the event of a failure. Blue and red circles of 234 m and 112 m were highlighted by Vattenfall and Apollo around each wind turbine to ensure minimum safe working distances.



Flowchart for W-E line shot, current SE

APOLLO OFFSHORE ENGINEERING

Max considered wind 20 kts
Max considered current 2 kts

Start

Current at or below 1 kts?

No

Potential severe drift

Yes

Wind direction

Southwest

Wind speed above 5 kts?

Yes

Potential severe drift

No

Acceptable

West

Wind speed above 10 kts?

No

Acceptable

Yes

Potential severe drift

Northwest

Wind speed above 20 kts?

Yes

Potential severe drift

No

Acceptable

12 11-Mar-13 089-004-004R-A Fugro Meridian drift off analysis

SAFE ENGINEERING SOLUTIONS

Figure 17: One of the flowcharts identified for seismic operations, image courtesy of Spirit Energy.

A series of flowcharts for different environmental scenarios was developed from the modelling, this included clearly defined environmental conditions determined for both run directions and abort procedures. These were created to provide clear abort conditions if they changed on the run in lines.

There are limitations on the wind speed and swell direction within Figure 17 to accommodate the feather of the towed streamer. These were the environmental conditions assumed to be safe with a single towed streamer at 600 m of length. This 2D survey would have been significantly easier to control over the 1,000 m wide and 4,000 m – 8,000 m long towed streamers that traditionally carry our seismic surveys, where even a small change of 2 degrees to swell direction could move the array around 100m to one side due to the length of the streamer.

The operation was carried out with no incidents and Centrica were able to achieve the seismic information that they required. It was noted however that there was a 'Slight Noise' observed on the seismic data from the wind turbines for structural imaging. The impact of noise on amplitudes for reservoir characterisation is unknown at this time and would need to be examined in more detail.

3.6 Conclusion

The focus of this section has been to examine the impact of wind turbines on MMV activities especially away from the well and near wellbore.

Reflection seismic (towed streamer or ocean bottom nodes) in the form of 3D acquisition for time lapse studies is currently viewed as the most applicable and mature technology to monitor the impact of CO2 injection on plume migration and assessment of store integrity. However, navigating a 3D seismic surface array within a windfarm is not without its challenges. The cost of acquiring OBN data is high compared to towed seismic and image quality of the seabed and shallow subsurface can be significantly affected depending on the spatial sampling of the nodes.

New processing techniques like mirror imaging can help to improve the quality of the shallow subsurface imaging obtained from OBN acquisition, allowing sparse sampling and therefore helping to keep acquisition costs to a minimum. Compressive sensing is an exciting and potentially disruptive processing technology that has the potential to significantly reduce OBN survey acquisition time and the volume of data required. There is even the possibility of removing the requirement for repeatability which if proven true could dramatically reduce the cost and time of 4D surveys.

The only real-world example of a towed streamer survey being carried out within a wind farm was discussed in detail with all the lessons learned with this operation. This operation was a 2D seismic site survey with a single streamer at 600 m off the rear of the vessel. While the data acquired may give an indication of the impact of the wind turbines on data quality, the acquisition geometry is not representative of the type of survey required for MMV activities. Acquisition modelling and illumination studies should be used to determine survey geometry to capture imaging requirements and safe operational tolerances to the impact of wind, sea state and current on acquisition footprint.

Increasing the spacing between turbines and placing them on a regular grid could enable short-offset or a small 3D towed streamer array acquisition. Advances in the speed of deployment and retrieval of ocean bottom nodes could reduce the cost of OBN acquisition and the development of autonomous nodes could decrease this cost still further making it a viable alternative to towed streamer acquisition and significantly reducing the cost of ocean bottom monitoring for CCUS. Alternatives to seismic acquisition were also examined but these techniques like control source electromagnetism, distributed acoustic sensing, and gravity monitoring were either deemed to be inappropriate or were emerging technologies at a lower TRL which could be used currently to compliment seismic rather than replace it.

Permanent and passive arrays were considered. Seabed nodes as part of PRM systems offer both active and passive monitoring opportunities. Permanent arrays can offer some significant advantages especially in the early life of the storage site during the injection phase by enabling the operator to monitor and measure injection induced seismicity in real time. However, the initial investment cost of a PRM system is relatively large and may not offer sufficient benefit at an acceptable cost level.

Noise generated during the piling and construction activities of a wind farm have been documented at levels in the region of 250 dB and have been found to disrupt the normal marine activities of fish and marine mammals. Disruption from construction activities can typically last for several months to a year. It is unlikely that MMV requirements could be carried out during the construction phase of an offshore wind farm. Operational wind turbines have been found to generate quiet and low frequency noise in the region of 5 – 200 Hz and less than 100 dB and the duration of operational activities are in the region of 25 years or more. The noise range generated by an operational wind farm is similar in bandwidth (0-10 Hz) to the low frequency component generated by seismic surveys promoting the thought that this could somehow be used as a sound source for passive or active monitoring techniques or as an input to certain processing techniques.

This section also highlighted that although there haven't been any real-world examples of interference caused by WTG foundations, there are examples of oil and gas rigs and pipelines causing interference with seismic acquisitions and this has been given the term 'Rig Noise'.

The issue with 'Rig Noise' has been explored and the interference caused by rig or pipeline interference, along with noise generated from rigs or other SI have been resolved previously in practice. Denoising algorithms already used within the O&G industry such as shot skipping and re-splicing approaches have been proven to remove background information and provide clear seismic acquisitions and results. These approaches to denoising have not been carried out in real world examples next to a wind farm to date and this would be the next logical step in solving this issue.

Based on the information gathered from the public domain on technologies in play today and those potentially available in the future a conceptual view on a MMV strategy was presented that could be applicable in a co-location scenario.

- Sparse PRM system focused on injectors and early plume area. This is the area where storage and operational risks are highest during the operation phase (injection)
- Sparse PRM will enable more accurate and frequent monitoring of reservoir units and overburden to demonstrate conformance and provide data to update models. The PRM system will offer both passive and active monitoring programmes and will minimise the requirement for towed streamer acquisition
- Design and frequency of repeat surveys would be adjusted as the project develops. Initial surveys would use a source boat, but this might get superseded in the future by being able to use the turbines as a seismic source signal
- With accurate and frequent monitoring, confidence in predicted to actual store behaviour would increase, allowing options like gravimetric modelling to be sufficient across the wider CCUS store
- PRM system will have a higher investment cost which may be challenging to the economics of the storage site. In the co-location scenario cost sharing of permanent systems could be considered to improve the economics
- PRM system may minimise the requirement for towed streamer acquisition, the aerial extent could still impact co-location and turbine installation and therefore may not be an applicable solution

Monitoring techniques and technology are continually improving and the cost gradually falling, so MMV plans for future projects will be better placed to adopt emerging technologies as they mature and are proven.

4 Direct Physical Impact due to Co-Location

4.1 Helicopter Operations Review

The potential for interactions with helicopter operations when co-locating Hornsea 4 with the Northern Endurance Partnership CCUS project was examined from two perspectives:

- What the likely normal operating requirement will be for helicopter operations for CCUS projects; and
- What levels of access/clearance helicopters would need through an operational windfarm

4.1.1 Requirement for CCUS Helicopter Operations

Requirement for Helicopter Support During Initial Development

The plans for the initial CCUS project development are for it to be entirely subsea based and, as a result, there should be no requirement for routine helicopter operations associated with operating its infrastructure. Any requirements for inspection, maintenance and operation of the initial infrastructure will be carried out via a combination of marine vessel operations and autonomous underwater drones, which do not require helicopter support.

There will be a requirement for drilling rig operations during development of the project and, potentially, during operations. While drilling operations have been historically carried out with routine helicopter support to enable crew changes over extended drilling periods, there is potential for this support to be achieved using walk-to-work vessels as is becoming more widely used within the offshore wind industry. Indeed, this could be viewed as an opportunity to share the cost of such resources between the offshore wind and CCUS industries.

However, for both marine vessel support and drilling activities during operation, there may be a need for emergency evacuation of personnel in the event of a health emergency. This is also the case for marine vessels that support the operation of wind farm developments and is not considered to be a step change in the requirements for helicopter support for the offshore wind industry.

In summary, there does not appear to be a definitive case for the need for routine helicopter access during the construction, operation or decommissioning of the initial development of the Northern Endurance Partnership CCUS project.

Requirement for Support During Potential Future Development

The key difference between the initial development infrastructure for the Northern Endurance Partnership CCUS project and its potential future infrastructure is the addition of several small platforms for treating the brine that may need to be released from the Northern Endurance aquifer.

While these platforms are likely to be designed to be “normally unattended”, they will need periodic visits to perform fabric maintenance and to remedy potential operational issues. Within the North Sea oil and gas industry, this has classically been achieved by using helicopters to transfer crew to and from the platforms as required. However, there are several significant differences between the intent of these platforms and an oil and gas platform that need to be considered:

- Oil and gas platforms carry an inherent risk of hydrocarbon release resulting in potential harm to operations personnel, which leads to a preference for helicopter access to enable rapid evacuation from the platform in the event of an emergency (although it is noted that other escape routes such as lifeboats and "totally enclosed motor propelled survival craft" are typically provided as well as helicopter access). This is not the case with CCUS where the potential for harm to personnel from a leak would be relatively easily handled by appropriate personal protective equipment (e.g. breathing apparatus) being supplied to operations personnel.
- The cessation of oil/gas production from a normally unmanned facility typically results in significant and immediate loss in revenue for the platform operators leading to a requirement for rapid response to resolve any operational issues, which helicopter access can provide. The temporary loss of water treatment facilities on one of the platforms potentially required in future for the Northern Endurance Partnership CCUS project would not result in an immediate loss in revenue for the CCUS project and it is highly likely that the difference in response time between attending the platform by helicopter versus attending by a walk-to-work vessel (for example) would not make any material difference to the operating conditions within the saline aquifer. Put simply, there is not the same time pressure to respond to unforeseen operational issues.

Based on the above, there does not appear to be a case for the need for routine helicopter access to these potential future platforms. In the case of a medical emergency, the response time may actually be quicker with a walk-to-work vessel as it is on station at the platform during crew operations and would typically be equipped with an experienced medic.

In addition to there not appearing to be a case for routine helicopter operations, not equipping a normally unattended installation with a helideck will lead to a lower capital cost for the platform. The installation of a helideck on a platform requires a significant amount of associated support systems (increased power distribution, fire-fighting systems, etc.), which increases the capital cost of the platform. This in turn leads to a more expensive substructure (e.g. jacket) as it has to support more topsides weight. All of this leads to a helideck equipped platform requiring a higher capital cost than an equivalent platform without a helideck.

As with the initial development case, it is considered that there isn't a strong case for the need for helicopter support during normal operations, even with the extended infrastructure that may be required for the Northern Endurance Partnership CCUS project in future.

4.1.2 Helicopter Access/Clearance Requirements

There are very few regulations governing helicopter operations where offshore wind farms are co-located with existing offshore infrastructure. The only regulatory guidance that is available is outlined in Civil Aviation Authority's (CAA's) policy and guidelines on wind turbines document (CAP 764), which recommends a 9 nautical mile consultation zone be established around offshore helidecks. This consultation zone is not a prohibition on development within a 9 nautical mile radius of offshore operations, but a trigger for consultation with offshore helicopter operators, the operators of existing installations and exploration and development locations to determine a solution that maintains safe offshore helicopter operations alongside the proposed development.

In the absence of specific guidance, a range of interviews were held with helicopter operators (NHV and Bristow Helicopters) and independent helicopter operations specialists to determine what levels of access/clearance helicopters would require in the event that they need to access CCUS infrastructure through an operational windfarm.

The study did intend to consult with the CAA over this issue but, during the interview process, it was determined that the CAA does not currently have a director of operations for offshore helicopter flights due to staffing issues, so it wasn't possible to discuss the issues directly with a representative of suitable experience and authority.

The interview process yielded a range of opinions regarding potential interactions between helicopter operations and operational wind farms and produced the following common themes:

Emergency Response

There is a marked difference between the oil and gas industry and the offshore renewables industry in terms of helicopter response to emergencies. Over time, the oil and gas industry has established a commonly funded helicopter emergency response group with helicopter operators. This has enabled a standard set of "rules of engagement" to be developed and training to be provided to helicopter pilots involved in emergency response operations and has ensured consistency across the industry in terms of quality of personnel and what conditions operators can expect emergency support under.

In contrast, the offshore renewables industry appears to have relied on the UK Coastguard to provide emergency response services, although it is noted that there are some helicopter operators who have provided "medical" transport services to the offshore wind industry where there have been incident cases that are not life threatening. It is understood that there is increasing pressure on the Coastguard in terms of funding and availability of suitably trained helicopter pilots that could potentially lead to restrictions in their ability to react to emergency response situations.

With the advent of CCUS joining the offshore industries that may require helicopter emergency response, there was a clear desire and recommendation from the helicopter operating companies to extend the oil and gas funded emergency response scheme across all industries to provide a consistent level of support and relieve pressure on the Coastguard.

Even with such a common resource, there was a view across the people interviewed that emergency response would only be provided to an incident within a wind farm in a "life or death" situation and, even then, this may be restricted during low visibility conditions.

Accessing Helidecks Local to Wind Farms

There have previously been extensive case-by-case studies carried out where wind farms have been developed in proximity to existing oil and gas installations that have resulted in a wide range of recommended separation distances between the oil and gas installations and wind turbine generators (e.g. the wind turbines installed local to the Beatrice oil platform with a separation distance of 1.2 km compared to the recommended separation of circa 3.4 km between the Chiswick platform and the Hornsea 3 wind development).

For each previous case, a detailed review of operations was carried out for the specific helicopters, load conditions and environmental conditions that were expected at each installation combined with the oil and gas operator's appetite for limitations on the potential availability of their flight operations.

As a result, it is very difficult to arrive at a "catch all" recommended minimum separation distance between a wind farm development and a surface facility's helideck (whether that be for a CCUS installation or an oil and gas installation).

However, as mentioned previously, there doesn't appear to be a strong operational case for regular helicopter access to any of the items of infrastructure associated with the planned Northern Endurance Partnership CCUS project, so restrictions on regular flight operations are not likely to be a consideration for this case.

Navigating within Wind Farms

While it is understood that there are pilots within the offshore helicopter industry who are more experienced in operations within wind farms, there was a commonly held belief that many pilots are worried about operating within wind farms, particularly in challenging conditions (e.g. low visibility conditions).

The main problems identified during interviews with the helicopter industry representatives for navigation within wind farms were:

- Flying during low cloud cover conditions. The operators expressed the view that they would not usually support flight operations where the base cloud level was lower than the tip of the wind turbine generator blades. Flying in conditions with lower cloud bases was held to be a significant visual distraction to pilots in already challenging conditions.
- Issues with icing of helicopter rotors. The offshore helicopter sector in the North Sea has developed a number of special operations to enable flying in poor weather conditions that are not allowable onshore in the UK; one of these being the ability to descend to de-ice rotor blades on helicopters. The presence of wind turbines restricts the potential operational flying window for helicopters in this scenario as there needs to be a 500 ft clearance between the tip of the wind turbine blade and the level to which a helicopter can descend for de-icing for safety concerns. With increasing wind turbine sizes offshore, this limits the ambient temperature at which helicopters would be allowed to fly. It was noted that, while a proportion of the existing helicopter fleet is equipped with de-icing

equipment, this is only a fraction of the overall fleet and the design of the remaining helicopters makes it very difficult to retrofit such equipment. In addition, the development of new helicopters for the fleet equipped with such equipment is not currently being carried out and would require several years to go through development and accreditation.

- Lack of clarity over location of wind turbines. One issue that was repeatedly raised by helicopter operators was the lack of clarity over exactly where, and how large wind turbines are after they are installed. Their view was that the maps provided by offshore wind developers often do not relate to what is finally installed within wind farms and the lack of visibility of wind turbines to radar makes navigating within a wind farm especially difficult. There was a clear recommendation from this part of the discussions for the offshore wind industry to increase the accuracy of maps provided to authorities on completion of their projects, continuous engagement with the helicopter industry during development to ensure any changes are well understood (e.g. increase in height of turbines) and, finally, a clear recommendation to install instrumentation on wind turbine turrets to make them visible to radar detection.

Access Corridors

Following on from the above discussions, the potential provision of an access corridor through wind farms to any infrastructure equipped with a helideck was discussed.

It was noted that previous consultations between the wind industry and helicopter operators had established such corridors for projects with a typical path width of circa 1 km between the horizontal projection of wind turbine blades under all conditions (i.e. minimum of 1 km plus the diameter of the turbine blades). It was further noted that the access corridors proposed were frequently common to those proposed to enable drilling rig access to the same assets and, in those cases, the width of the access corridor was generally driven by the drilling rig requirements rather than the helicopter requirements.

4.1.3 Summary

In summary, discussions with the helicopter industry raised a number of concerns and potential areas of safety improvement across a number of subjects when considering helicopter operations in close proximity to wind turbines but, given the lack of a strong operational case for regular helicopter support being required for CCUS operations, it is not considered that these recommendations are specific to the situation where the Hornsea 4 wind farm would be co-located with the Northern Endurance Partnership CCUS project.

4.2 Drilling Rig Access

4.2.1 Requirement for Drilling

Any CCUS scheme will require drilling rig access to the proposed CO2 store area at the following stages of the project lifecycle:

- Assessment: Drilling of exploration and appraisal wells into the target reservoir for the CO2 store.

- Development: Drilling of injection and observer wells as part of the overall project CO2 storage plan.
- Operation: "Workover" of injection wells in the event of issues with the formation local to the injection location or issues with the well completion itself. Potential need to drill further injection / observer wells over time and, if the CO2 store becomes overpressurised, brine release wells. Also potential to have to drill intervention wells in the event the completions of wells start to leak CO2 to surface.
- Decommissioning: Plugging and abandonment of injection, observer and brine release wells to ensure that store is permanently closed.
- Post-decommissioning: Potential to need to drill intervention wells if plug and abandonment measures start to leak.

From what is currently understood about the Northern Endurance Project, the requirement for each of the above wells is as follows:

- Assessment: Exploration wells. Exploration wells have previously been drilled into the Northern Endurance reservoir and it is unlikely that further wells will need to be drilled.
- Assessment: Appraisal wells. Appraisal wells will likely need to be drilled over the next 2 years to enable the Northern Endurance store to be fully characterised. It is highly likely that these will be completed and abandoned (or completed to enable them to be used as future injection wells) ahead of the installation timeline for the Hornsea 4 wind farm.
- Development: Injection wells. The initial plan for the project is to drill five injection wells clustered around two manifolds.
- Development: Observer wells. The initial plan for the project is to drill a single observer well close to the "second" injection manifold.
- Operation: Injector and observer wells. It is likely that further injection and observer wells will be drilled during the operational phase given the projections for increases in CO2 injection rates over the life of the project. The project should define these locations prior to the operational phase through its appraisal drilling programme in the assessment phase.
- Operation: Brine release wells. There is an allowance in the overall project development plan for brine release wells needing to be drilled during the operational phase of the project. Whether these wells will actually be required will be examined in detail during the assessment phase of the project (after appraisal drilling) but won't be definitively ruled in or out until CO2 injection actually happens and the operators see how the reservoir responds.
- Operation: Intervention wells. While there is a risk that intervention wells will be required, it is considered to be a very low probability. With this project being a first of a kind CCUS project in the UK, there will be a lot of focus from government over the completion design of the wells, which will likely lead to them being designed to be "best in class". In addition, the shallow depth of the

reservoir and the low pressure and low temperature in the reservoir compared to the extremes of oil and gas developments indicates that the conditions around the well completion will be very well within the design experience of the offshore well industry. This all contributes to the assessment that the probability of the need for intervention wells to "correct" leaks from an operational injection well will be very low.

- Operation: Well workover. This is likely to be required for some of the wells during operation. There is potential for local damage or plugging of the reservoir sands during injection that would require workover and there is also potential for the wells needing to be re-worked to deviate and target different sections of the reservoir over time. As a result, an amount of well workover activities is expected during the operational phase of the project.
- Decommissioning: Plugging and abandonment. This will definitely be required and may be carried out for some wells while the bulk of the project is still in operation. As this project will be a first of a kind CCUS project in the UK, the design of the plug and abandonment works will be subject to close scrutiny from governing bodies, leading to it being likely that the techniques used will be best in class (likely to involve retrieving or milling through the well completions so that a CO2 resistant concrete plug can be installed "rock to rock" to minimise any chance of subsequent leakage).
- Post-decommissioning: Intervention wells. Given the above information regarding the "quality" of the design likely to be required for plug and abandonment, it is considered to be very unlikely that there will be a need to drill intervention wells following decommissioning. Even if such wells were required, their location would likely be similar to the potential intervention well locations during the operational phase of the project.

Taking all of the above information into account, it is evident that a clear pathway to enable drilling rig access will be required at all stages of the CCUS project's lifecycle, although it is noted that the probability of actually needing to access the wells during the post-decommissioning phase is considered to be very low.

Once a drilling rig is on station at a well, the required "exclusion zone" around the drilling rig is likely to be 500 m in all directions from the outline of the rig based on analogous oil and gas industry wells.

This defines the clear area that would be required at each well site to enable drilling operations. However, in addition to this access, pathways to the well sites will also be required to enable the drilling rig to be transported to the well site.

Based upon current understanding of the Northern Endurance Partnership drilling requirements, it is likely that the wells will be drilled by a jack-up drilling rig as the water depth is too shallow for a semi-submersible type of rig or drillships. It may be possible to perform the workover activities during the operational phase with a light well intervention vessel, but it is considered more likely that a jack-up drilling rig would be utilised for this activity as the water depth is shallow and may be at the lower limit of operation for light well intervention vessels.

4.2.2 Drilling Rig Transport Access

Discussions were held with one of the UK's most prominent drilling rig companies (Valaris) who operate 15 jack-up drilling rigs within the North Sea and have historically been responsible for the majority of drilling in the Southern North Sea sector of the UK continental shelf.

During the discussions, it became evident that Valaris have studied the potential access requirements for transporting drilling rigs to well sites through existing infrastructure, including wind farms and the majority of the information provided in this section is based upon the findings of their studies.

It was noted that, due to a downturn in demand and increasing costs for maintenance, the drilling rig operators are in the process of decommissioning their lighter, smaller drilling rigs and tending to consolidate their fleets to being comprised of heavy duty jack-up rigs that are suitable for operation in a wider range of water depths.

As a result, the studies that Valaris have completed have been based on their "Super Gorilla" heavy duty class of jack-up drilling rigs, which are suitable for operation in water depths up to approximately 107 m.

In general, three tug vessels are required to manoeuvre this type of drilling rig into position with each tug vessel attached to the rig via a 500 m tow line. This gives a "tow diameter" under still weather conditions of approximately 1,200 m. It would be possible to shorten the length of tow lines, but this would reduce the ability of the tug vessels to position the rig during significant weather conditions.

The access requirements for Super Gorilla rigs were examined for a range of scenarios with varying weather conditions, varying tug vessel sizes/capabilities and varying wind farm turbine spacings as shown in the figure below:

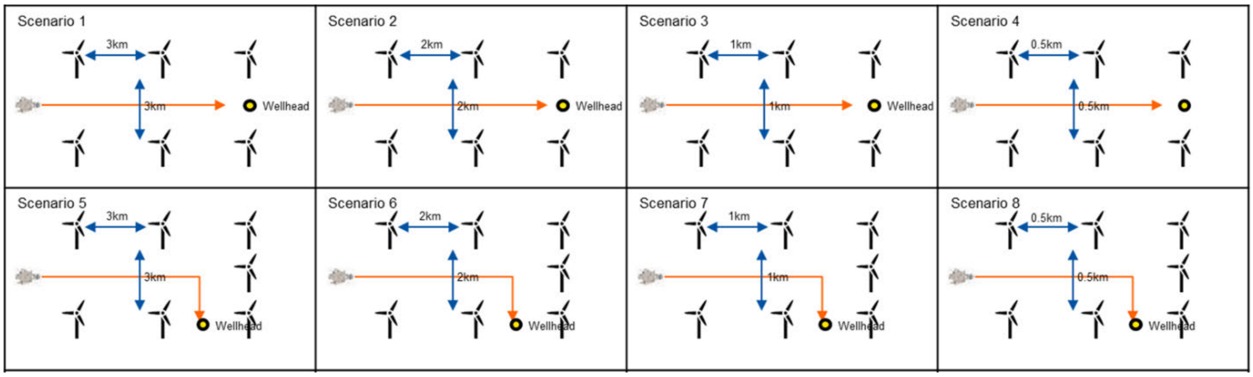


Figure 18: Jack-up rig access scenarios examined by Valaris.

All of the analyses assumed a nominal wind turbine rotor diameter of 300 m to represent an upper limit of current and foreseeable near future technology in this area.

The conclusion for the analyses were that a minimum turbine spacing of circa 2 km would be required for an access corridor through a wind farm to a subsea well. This width of corridor (arranged so that the tugs could pull into the prevailing wind direction) would enable rigs to be positioned with an average uptime across the year in the region of 70 - 85 % depending on the capability of the tug vessels, which was considered to be acceptable by Valaris. This uptime would be higher during summer and lower during winter, but Valaris did not provide this study with the variability in uptime although they did conclude that the calculated uptime would still be acceptable.

Given that the projected "worst-case" wind turbine blade intrusion into the 2 km corridor would be 150 m at each side (i.e. 300 m in total) and the still condition tug spread width is 1,200 m as mentioned earlier, this leaves approximately 500 m in total for drift during manoeuvring operations, which seems a reasonable recommendation.

Valaris did state that a turbine spacing of 1 km would require a "significant" reduction in deployed tow line length, which would have a knock-on effect on to the effective uptime for rig manoeuvring operations during more challenging weather conditions.

4.2.3 Summary

The following conclusions can be drawn from the above information:

- Access will need to be provided to the Northern Endurance Partnership CCUS project wells during all stages of the project's development, operational and decommissioning phases. While drilling rig access is theoretically required following decommissioning, the likelihood of it actually being required is very low.
- It is recommended that an access corridor be provided through the Hornsea 4 wind farm with a corridor width of approximately 2 km between turbines into the prevailing wind direction.
- A 500 m exclusion zone should be maintained around each of the CCUS wells to enable drilling rig operations.
- Clarity should be sought on the plans for future wells for the Northern Endurance Partnership CCUS project to ensure that the number of access corridors for drilling rigs is optimised within the overall Hornsea 4 development plan.

4.3 Saline Brine Displacement

Two documents were reviewed for the purpose of this section:

- A study commissioned by BP to model hypersaline brine discharge [31]
- A review of the Plymouth Marine Laboratories report commissioned by Ørsted [32]

The hypersaline discharge report assessed the impacts of large-scale disposal of produced water into the marine environment at two settings in the North Sea. The first location considered a deep water (>100 m) site (Goldeneye storage site) and the second in the shallower (<50 m) water depths of the Southern North Sea over the Northern Endurance Site.

Various brine release scenarios were created, defined by the rate of salinity and temperature changes. Other chemical characteristics of the produced water such as heavy metals using dilution were estimated using factors calculated from the salinity fields. From these scenarios an estimate of the potential impact from a range of scenarios and dispersion methods was calculated, including a combination of seabed, outcrop and sea-surface discharges, across different seasons with specific mixing characteristics. The scenarios are detailed in Table 7: Modelling Scenarios and geographical details of the Northern Endurance site scenarios shown in Figure 19.

Site	Release Rate Mt/a	Release Rate barrels/day	Salinity PSU	Temp °C	Release mode
Northern Test Concept	1.00	17,231	75	Ambient	Sea surface
			150		
	5.00	86,155	75		
			150		
Endurance	-				Baseline
	2.32	40,000	258	56	Sea floor
	9.29	160,000			Sea surface
Outcrop	-				Baseline
	0.116	10 x 2,000	258	56	Sea floor
	1.16	20,000			

Table 7: Modelling Scenarios

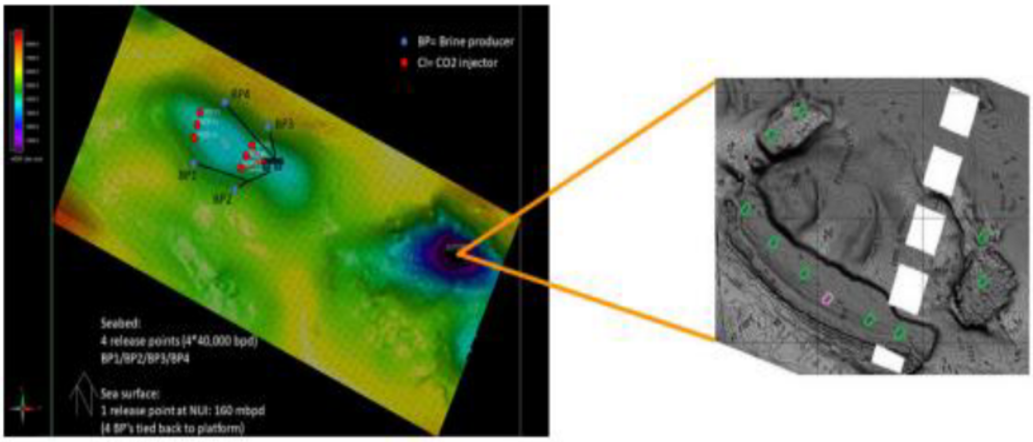


Figure 19: Northern Endurance release scenarios based on notional development plan on top structure map.

For the Seabed release, drilling and piping is required to the seabed. Single or multiple brine release points are considered as shown in Figure 19. The maximum advised discharge rate is 160,000 barrels per day spread evenly over 4 brine producers, giving 40,000 barrels per day each. As each producer is over 5.0 km from the other, the resulting plumes do not interact and a single point 40,000 barrels per day scenario was created. For the surface releases, this would require drilling and piping to the sea surface held by a rig, ship or other means, making sea surface releases a more costly mechanism. A scenario of a single surface release point for the full discharge rate of 160,000 barrels per day was therefore considered. Unmanaged seeps from the natural outcrop at a distance 25 - 30 km away from the injection site, seen in the right-hand side of Figure 19 was also considered as this is where the Bunter outcrops to the surface and could act as an outflow of hypersaline waters from the injection pressure, with the CO2 remaining in the reservoir. There is not enough information to determine what rate of seep could emerge from the outcrop, whether it comes out in a single point (worst case), or multiple locations. Scenarios of both have therefore been run, using a single seep point in the centre of the outcrop, and ten separate seep points spread equally. Estimated rate of seepage was suggested by the operator at 20,000 barrels per day.

The results indicate that over the Northern Endurance site the natural mixing process disperses the hypersaline plume rapidly over an area of 10 - 100s of metres in all directions. Where the brine is released has an impact on dispersion with disposal at sea surface giving quicker dispersion and a smaller footprint.

There is the possibility that sand waves on the seafloor, of which there is evidence on the seismic data, could reduce dispersal and increase the retention of brines over a small area, although salinity does not reach the strength of the original brine.

The report concludes that the disposal of brines into seawater will have a limited impact on levels of salinity and temperature in areas like the North Sea which are well mixed and have strong tidal forces.

The review of the report conducted by HR Wallingford focuses on the type of model used to model the hypersaline brine diffusion. They suggest that the model used is more appropriate for far-field plume simulations and therefore not suited to measure near to mid field spreading of the plume.

While HR Wallingford did not do any modelling based on their experience of discharges of brine at the levels detailed in the modelling study, they would expect concentrations to have reduced to within 5 % of the ambient salinity at 500 – 1,000 m from the discharge point. This is with the caveat that a brine diffuser is used to ensure high levels of near and mid field mixing. Their recommendation was to clarify the method of discharge proposed at the Northern Endurance site and whether it was planned to use brine diffusers.

Both studies suggest that the impact of hypersaline brine discharge will diminish over a short distance. With the available information on location and separation of discharge points and turbine foundations the effects of any discharge will have dispersed as the separation is approximately 1 nautical mile or 1,852 m

5 Infrastructure Blocking Seabed Access

This section looks to explore the risk of existing Offshore Wind (OW) or CCUS physical infrastructure limiting access for other parties in the same area. The technical implication of having a deviated injector or relief well focusing on directional drilling is reviewed as well as highlighting existing regulations for exclusion zones and safe working distances around CCUS and OW infrastructure, looking to make comment on minimum separation distances and how two projects might co-locate.

5.1 Deviated Wells

5.1.1 Introduction

One of the main areas where CCUS infrastructure may physically block access to the seabed for OW is the injection and observer wells that will be required as part of the CCUS project's development. Plus, the risk for future potential intervention wells that may be required in the event of a leak from injector / observer wells drilled as part of the development.

One factor that is key to understanding the risk and scale of wells blocking access to the seabed is whether there is flexibility in their placement. The wells will have specific target points within the saline aquifer reservoir proposed for storage, but that target can be reached via either a vertical well (where the well "tophole" location is directly above the reservoir target location), or a deviated well (where the well tophole location is offset from the reservoir target location.

A study was carried out to determine the maximum distance a deviated well could be offset from the reservoir target location. It should be noted that directional drilling plans can depend on many factors, but the main ones are:

- Geological formation: the well design and directional drilling capability is usually formation and pressure related
- Geometric factors: including wellbore kick-off point, target depth and dog-leg severity assumption

In total, four different well designs were considered with increasing complexity as below:

1. Vertical Well - Comparison Well
2. Option 1 Well: S Profile, terminating at a deviation angle of 0° (i.e. vertical) through the reservoir
3. Option 2 Well: S Profile, terminating at an angle of 19° through the reservoir
4. Option 3 Well: J Profile, building to a maximum deviation angle of 59° and holding that angle through the reservoir

The study was also aimed at assessing the complexity of each option and the relative cost of each well type. It should be noted, the costs should be considered Class 5 "Conceptual Planning" and as such have an accuracy level of -50 % / +100 %.

5.1.2 Well Design Options

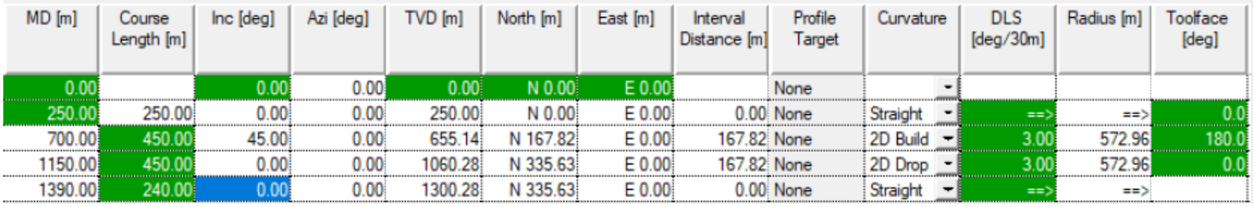
General Directional Design Assumptions

The same base directional design assumptions have been applied to each well. It should be noted that, in practise, these will differ depending on the seabed location and targets. The vertical well is for cost comparison purposes and won't be discussed here.

- Kick off point – 250 m total vertical depth below seabed. This means kicking off the directional work at a comparatively shallow depth in the Lias formation, which can be problematic to drill. However, to achieve any meaningful departure from the seabed location, a shallow kick-off is necessary
- Maximum dog-leg severity of 3°/30 m (a common assumption in directional planning)
- Top reservoir target at 1,020 m total vertical depth below seabed (1,060 m below the sea surface) into the top of the Bunter sandstone
- Bottom reservoir target at 1,300 m total vertical depth below seabed (1,340 m below the sea surface) into the Bunter shale

Option 1 Well: S Profile, 0° through Reservoir

This option builds the inclination to 45° prior to immediately dropping off at the same dog-leg severity (3°/30 m) until reaching top Bunter sandstone. This has the advantage of drilling vertically through the reservoir section. The seabed offset distance between the well tophole location and the entry point to the top of the reservoir is predicted to be ~335 m.



MD [m]	Course Length [m]	Inc [deg]	Azi [deg]	TVD [m]	North [m]	East [m]	Interval Distance [m]	Profile Target	Curvature	DLS [deg/30m]	Radius [m]	Toolface [deg]
0.00		0.00	0.00	0.00	N 0.00	E 0.00		None				
250.00	250.00	0.00	0.00	250.00	N 0.00	E 0.00	0.00	None	Straight	==>	==>	0.0
700.00	450.00	45.00	0.00	655.14	N 167.82	E 0.00	167.82	None	2D Build	3.00	572.96	180.0
1150.00	450.00	0.00	0.00	1060.28	N 335.63	E 0.00	167.82	None	2D Drop	3.00	572.96	0.0
1390.00	240.00	0.00	0.00	1300.28	N 335.63	E 0.00	0.00	None	Straight	==>	==>	

Table 8: Option 1 Well Profile.

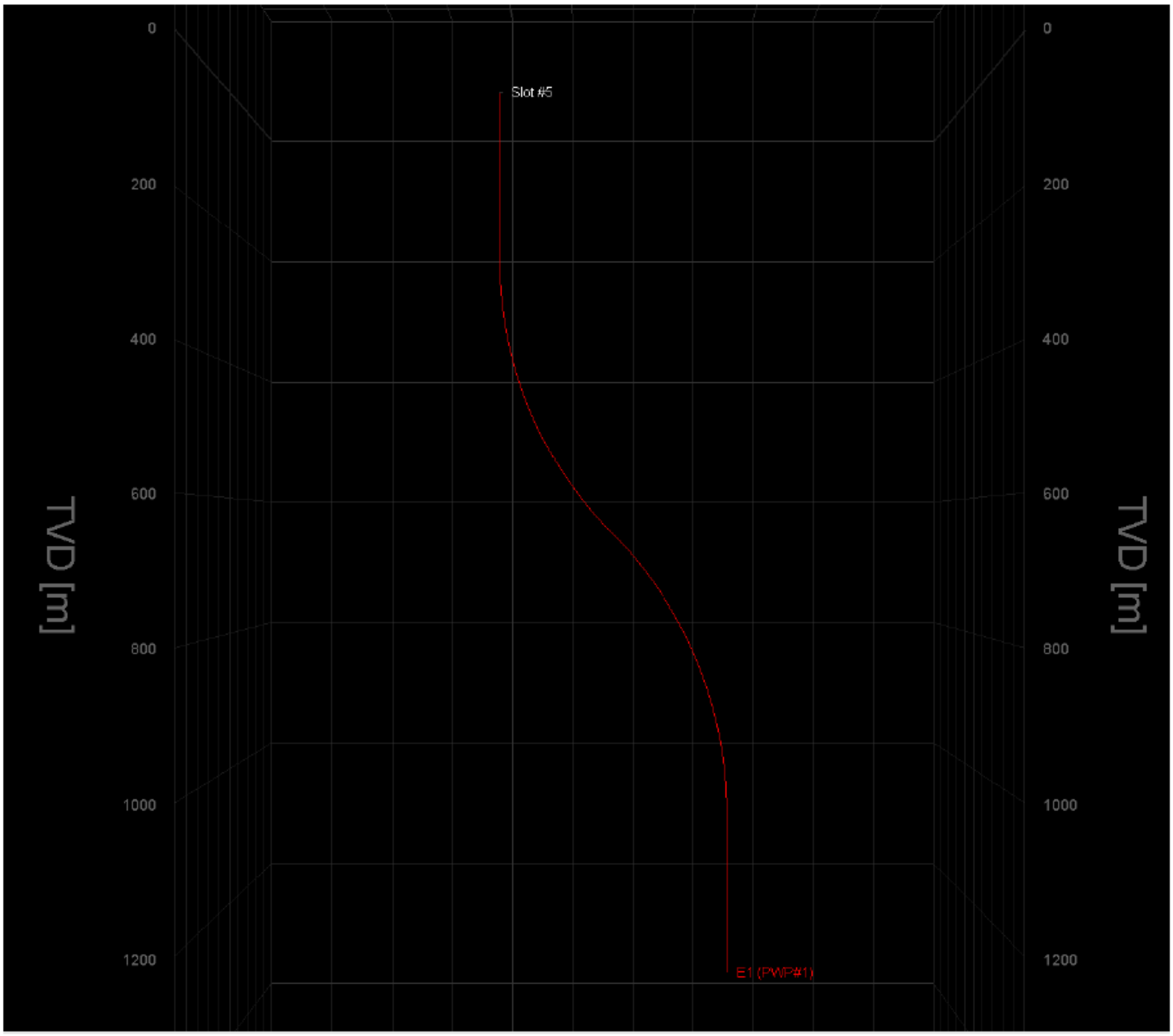
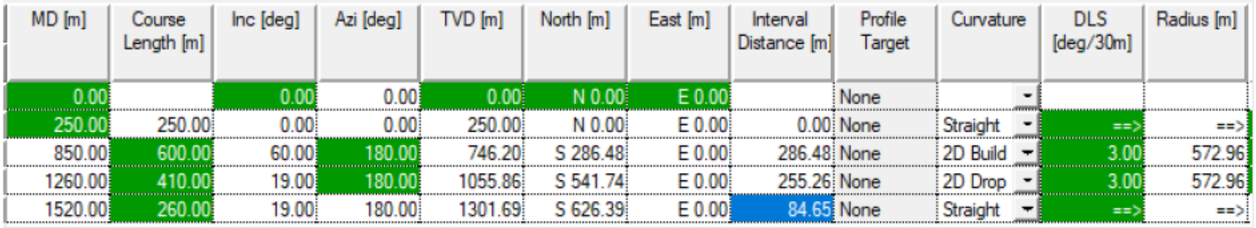


Figure 20: Option 1 Well Schematic.

Option 2 Well: S Profile, 19° through Reservoir

This option is similar to Option 1 with an "S" type directional profile but allows for a ~19° inclination through the reservoir. The offset distance achieved between the well tophole location and the entry point to the top reservoir is predicted to be greater than Option 1 at ~ 542 m.



MD [m]	Course Length [m]	Inc [deg]	Azi [deg]	TVD [m]	North [m]	East [m]	Interval Distance [m]	Profile Target	Curvature	DLS [deg/30m]	Radius [m]
0.00		0.00	0.00	0.00	N 0.00	E 0.00		None			
250.00	250.00	0.00	0.00	250.00	N 0.00	E 0.00	0.00	None	Straight	==>	==>
850.00	600.00	60.00	180.00	746.20	S 286.48	E 0.00	286.48	None	2D Build	3.00	572.96
1260.00	410.00	19.00	180.00	1055.86	S 541.74	E 0.00	255.26	None	2D Drop	3.00	572.96
1520.00	260.00	19.00	180.00	1301.69	S 626.39	E 0.00	84.65	None	Straight	==>	==>

Table 9: Option 2 Well Profile.

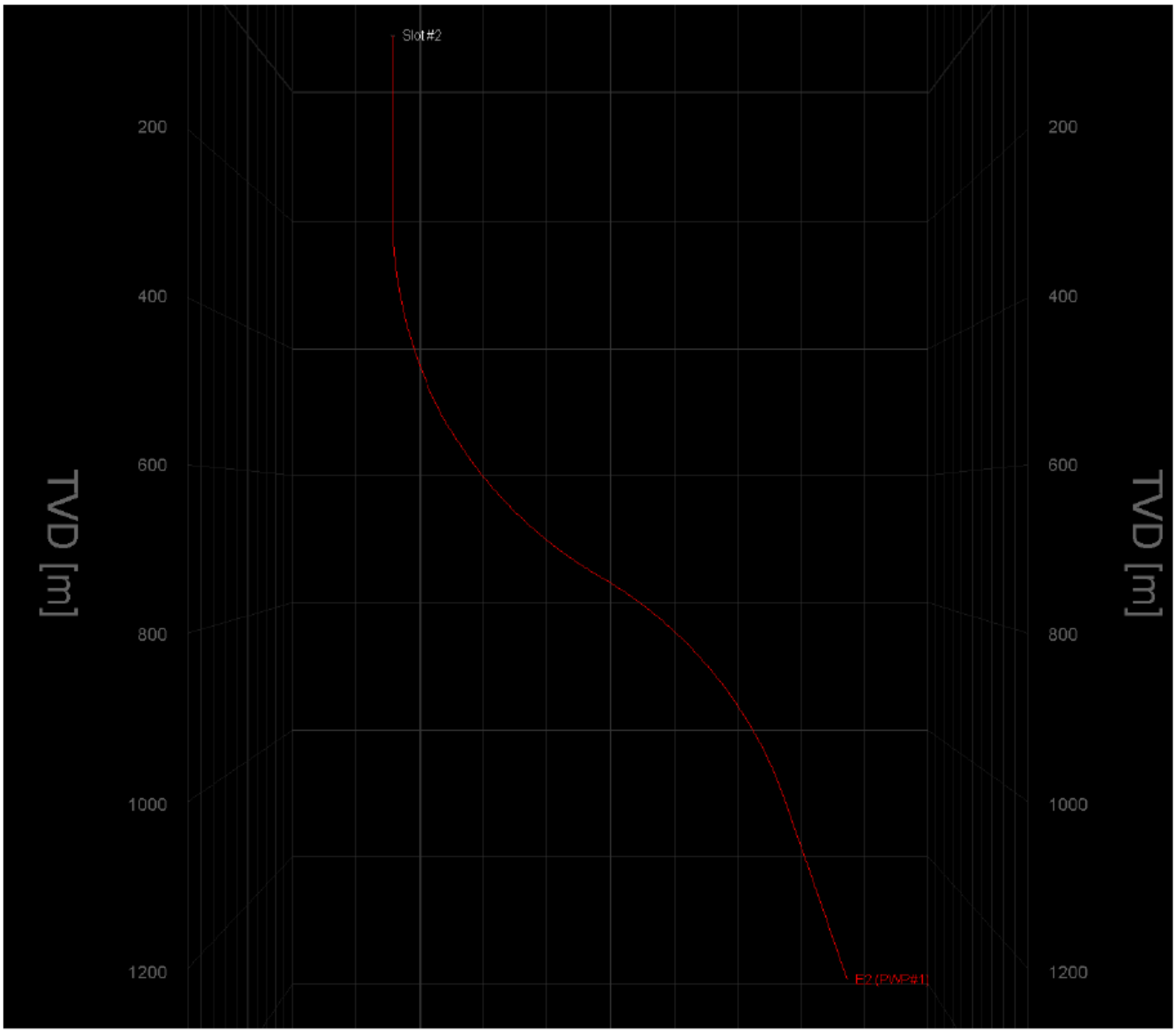
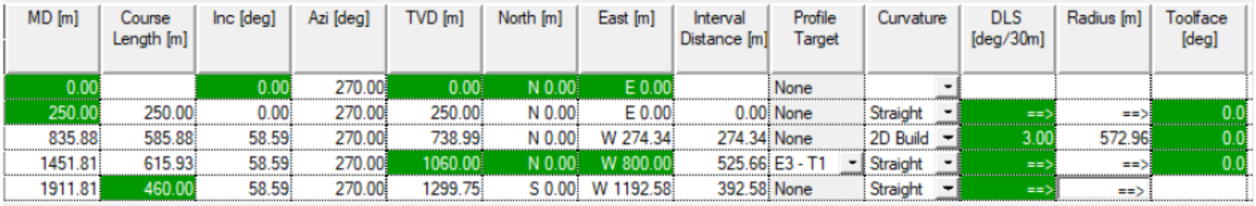


Figure 21: Option 2 Well Schematic.

Option 3 Well: J Profile, build to 59°, hold through Reservoir

This option builds inclination of 59° using a "J" type directional profile and holds this as a tangent through the reservoir. The distance achieved between the well tophole location and the entry point to the top of the reservoir is the highest of the three options at ~800 m. The disadvantage of this well profile is the higher well construction complexity and the high inclination through the reservoir. This higher inclination may not be ideal for fracturing and CO2 injection. To an extent, the angle could be decreased after hitting top reservoir, but this will have a limited impact on overall design.



MD [m]	Course Length [m]	Inc [deg]	Azi [deg]	TVD [m]	North [m]	East [m]	Interval Distance [m]	Profile Target	Curvature	DLS [deg/30m]	Radius [m]	Toolface [deg]
0.00		0.00	270.00	0.00	N 0.00	E 0.00		None				
250.00	250.00	0.00	270.00	250.00	N 0.00	E 0.00	0.00	None	Straight	==>	==>	0.0
835.88	585.88	58.59	270.00	738.99	N 0.00	W 274.34	274.34	None	2D Build	3.00	572.96	0.0
1451.81	615.93	58.59	270.00	1060.00	N 0.00	W 800.00	525.66	E3 - T1	Straight	==>	==>	0.0
1911.81	460.00	58.59	270.00	1299.75	S 0.00	W 1192.58	392.58	None	Straight	==>	==>	

Table 10: Option 3 Well Profile.

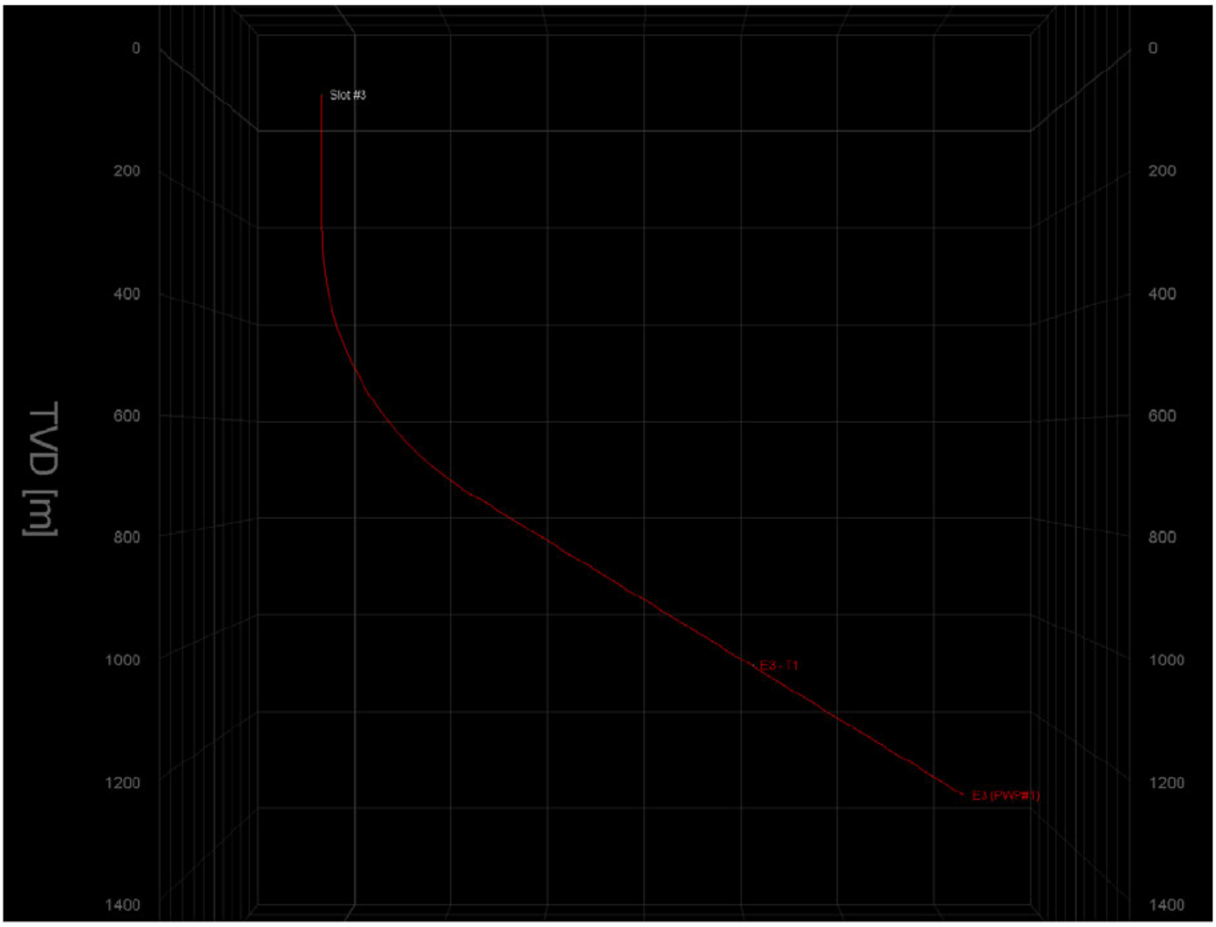


Figure 22: Option 3 Well Schematic.

5.1.3 Time and Cost Estimates

Introduction

Time and cost estimates were generated for each of the well profiles including the vertical well. Each directional well option was then compared to the vertical well to give some indication of differences in well construction cost.

To a large degree, well construction complexity is related to well length. The longer the well, generally the more complex given the same geological conditions. Time increases with depth due to the time it takes to make the many pipe runs during well construction. Costs also increase due to greater length costs for tubulars and other consumables. Lastly, well construction complexity generally increases with depth, which is reflected in a higher "Non Productive Time" (NPT) figure. However, drilling rate (metres drilled per day) generally increases with well length. The assumptions used to arrive at a comparison between the options is in the table below.

Well Type	Non-Productive Time & Waiting on Weather (%)	Drilling Rate (m/day)	Depth Cost Factor (%)
Vertical well	15%	80	1.00
Option 1	17%	85	1.07
Option 2	20%	90	1.17
Option 3	24%	95	1.47

Table 11: Well Comparison Cost Impact Assumptions.

Note: "Waiting on Weather" (WoW) represents downtime events related to weather factors. This has been assumed to be 5% for all options.

Cost Level Assumptions

The following tables present general cost assumptions for the vertical well. The assumptions for the other options only differ for the factors affected by well length and for brevity won't be repeated here.

Assumption		Cost Metric	Cost
Well TVD below drilling deck	1300 m	Preparation	£600 k
Depth to seabed below drilling deck	40 m	Rig and fuel	£180 k/day
Top target TVD below drilling deck	1060 m	Operational spread rate	£70 k/day
Bottom target TVD below drilling deck	1300 m	Personnel and supervision	£20 k/day
Top target well length below drilling deck	1060 m	Logistics	£80 k/day
Bottom target well length below drilling deck	1300 m	Formation evaluation	£1.2 million
Top hole time	7 days	Cement and fluids	£1 million
Drilling rate	80 m/day	Casing and tubing	£600 k
		Lower completion / perforation	£800 k
		Upper completion equip	£1 million
		Wellhead	£700 k
		Xmas tree	£1.5 million
		Interfield rig move	1.5 million

Table 12: Well time/cost Factors for Vertical Well Option.

Note: Rig rate including fuel assumed to be US$250 k/day

Cost Results

Operation	Depth (m)	Duration (days)	Rig Rate (£M)	Daily Rate (£M)	Fixed Costs (£M)	Total Cost (£M)
Mobilisation		7	0.18	0.17	2.1	4.6
Prepare for operation		2	0.18	0.17		0.7
Drill top hole & BOP	550	7	0.18	0.17	0.70	3.2
Drilling & casing	750	9.4	0.18	0.17	1.60	4.9
Formation evaluation		1.5	0.18	0.17	1.20	1.7
Lower completion & perforating		4	0.18	0.17	0.80	2.2
Upper completion		5	0.18	0.17	1.00	2.8
Install tree		2	0.18	0.17	1.50	2.2
Well commissioning		2	0.18	0.17		0.7
Demobilisation		2	0.18	0.17		0.7
Base well	**Total time**	**41.9**	**Total cost**			**23.6**
NPT	10%	4.2	0.18	0.17		1
Waiting on weather	5%	2.1	0.18	0.17		1
Overall well	**Total time**	**48.2**	**Total cost**			**25.8**
Total daily all-in spread rate						**0.53**

Table 13: Vertical Well Time / Cost Overview.

Operation	Depth (m)	Duration (days)	Rig Rate (£M)	Daily Rate (£M)	Fixed Costs (£M)	Total Cost (£M)
Mobilisation		7	0.18	0.17	2.10	4.6
Prepare for operation		2	0.18	0.17		0.7
Drill top hole & BOP	550	7	0.18	0.17	0.75	3.2
Drilling & casing	840	9.9	0.18	0.17	1.71	5.2
Formation evaluation		1.5	0.18	0.17	1.20	1.7
Lower completion & perforating		4	0.18	0.17	0.86	2.3
Upper completion		5	0.18	0.17	1.07	2.8
Install tree		2	0.18	0.17	1.60	2.3
Well commissioning		2	0.18	0.17		0.7
Demobilisation		2	0.18	0.17		0.7
Base well	**Total time**	**42.4**			**Total cost**	**24.1**
NPT	12%	5.1	0.18	0.17		2
Waiting on weather	5%	2.1	0.18	0.17		1
Overall well	**Total time**	**49.6**			**Total cost**	**26.6**
					Total daily all-in spread rate	**0.54**

Table 14: Option 1 Well Time / Cost Overview.

Operation	Depth (m)	Duration (days)	Rig Rate (£M)	Daily Rate (£M)	Fixed Costs (£M)	Total Cost (£M)
Mobilisation		7	0.18	0.17	2.10	4.6
Prepare for operation		2	0.18	0.17		0.7
Drill top hole & BOP	550	7	0.18	0.17	0.82	3.3
Drilling & casing	970	10.8	0.18	0.17	1.87	5.6
Formation evaluation		1.5	0.18	0.17	1.20	1.7
Lower completion & perforating		4	0.18	0.17	0.94	2.3
Upper completion		5	0.18	0.17	1.17	2.9
Install tree		2	0.18	0.17	1.75	2.5
Well commissioning		2	0.18	0.17		0.7
Demobilisation		2	0.18	0.17		0.7
Base well	**Total time**	**43.3**			**Total cost**	**25.0**
NPT	15%	6.5	0.18	0.17		2
Waiting on weather	5%	2.2	0.18	0.17		1
Overall well	**Total time**	**51.9**			**Total cost**	**28.0**
					Total daily all-in spread rate	**0.54**

Table 15: Option 2 Well Time / Cost Overview.

Operation	Depth (m)	Duration (days)	Rig Rate (£M)	Daily Rate (£M)	Fixed Costs (£M)	Total Cost (£M)
Mobilisation		7	0.18	0.17	2.10	4.6
Prepare for operation		2	0.18	0.17		0.7
Drill top hole & BOP	550	7	0.18	0.17	1.03	3.5
Drilling & casing	1362	14.3	0.18	0.17	2.35	7.4
Formation evaluation		1.5	0.18	0.17	1.20	1.7
Lower completion & perforating		4	0.18	0.17	1.18	2.6
Upper completion		5	0.18	0.17	1.47	3.2
Install tree		2	0.18	0.17	2.21	2.9
Well commissioning		2	0.18	0.17		0.7
Demobilisation		2	0.18	0.17		0.7
Base well	**Total time**	**46.8**			**Total cost**	**27.9**
NPT	19%	8.9	0.18	0.17		3
Waiting on weather	5%	2.3	0.18	0.17		1
Overall well	**Total time**	**58.1**			**Total cost**	**31.9**
					Total daily all-in spread rate	**0.55**

Table 16: Option 3 Well Time / Cost Overview.

5.1.4 Summary

A summary of the assessment of the maximum potential offset from the reservoir target for the Northern Endurance Partnership wells is shown in Table 17.

Well Type	Total Well Time (days)	Well Cost (£mm)	Well Depth (m TVD below drilling deck)	Cost Increase (delta and % increase)	Offset Distance (m)
Vertical well	48.2	25.8	1300	0 - 0%	0
Option 1	49.6	26.6	1390	£0.8 M - 3%	335
Option 2	51.9	28.0	1520	£2.2 M - 9%	542
Option 3	58.1	31.9	1912	£6.1 M - 24%	800

Table 17: Summary of Drilling Deviation Analysis.

While Option 3 is listed in the above table for completeness, it is considered to be significantly higher risk than the other deviated well options. As a result, it is recommended that Ørsted consider Option 2 (i.e. an offset distance of 542 m at an increased cost of £2.2 M per well) to be the maximum practical offset for a deviated well within the Northern Endurance Partnership CCUS project.

5.2 Hornsea 4 Planning

5.2.1 Exclusion Zones

An assessment of the current industry guidelines for separation distances in the UK have been reviewed and are highlighted below in Table 18. These distances are given as the radius from the centre of the asset and create a circle of diameter double the referenced radii. Distances for CCUS have been derived from historical O&G numbers as it is felt that they will be similar.

Industry	Asset	Separation Distance Radius (m)
Offshore Wind	Offshore Wind Turbines (Active Construction)	500 [33]
Offshore Wind	Offshore Wind Turbine (Partially Constructed)	50 [33]
Offshore Wind	Offshore Wind Turbine (Operational)	50
Offshore Wind	Subsea Cables	50
Offshore Wind	Subsea Cables Parallel Routing	50
Offshore Wind	Substation / Accommodation Platform	500
CCUS	Drilling Rig	500
CCUS	Cable	50
CCUS	Pipelines	50
CCUS	Wells (Injectors and Relief)	500
General	Submarine Cables (Telecoms, Power, Interconnectors and Export)	500

Table 18: Offshore Wind and CCUS Separation Distances.

From the information detailed in Table 18, the minimum separation distance of turbines has been reviewed in order for a rig to gain access to a wind farm and carry out drilling activities within.

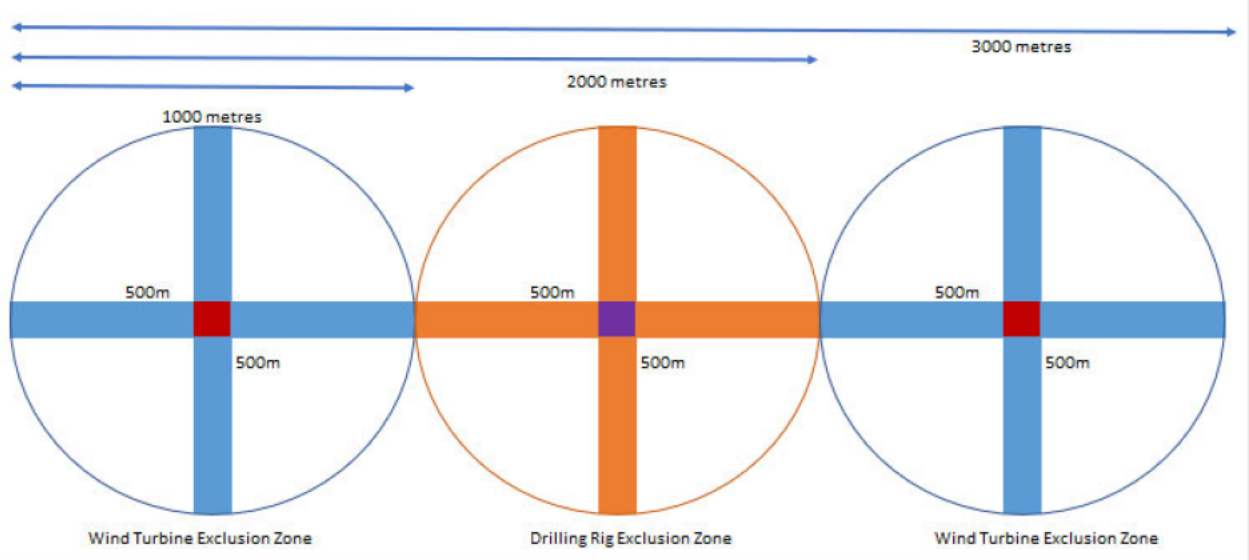


Figure 23: Minimum Separation Distance of Turbines and Jack Ups.

Figure 23 shows a theoretical wind turbine in red with a blue exclusion zone and a drilling rig in purple with an orange exclusion zone. This would be the minimum separation distance allowed between drilling rigs and offshore wind turbines but does not leave any room for movement or deviation for the drilling rig to operate within. The minimum separation distance of two turbines would be 2,000 m to allow for drilling rig access.

Ørsted have highlighted 3 turbines that could be used within the Hornsea 4 development.

Manufacturer	Model	MW	Rotor Diameter (m)	7 Diameters (m)	10 Diameters (m)
Siemens Gamesa	SG 14-222 DD	14	222	1,554	2,220
Vestas	V236	15	236	1,652	2,360
GE	Haliade-X	14	220	1,540	2,220

Table 19: Potential Turbines for Hornsea 4 Development.

Table 19 shows the range in rotor diameter is between 220 – 236 m, with typical wind turbine separation distances being between six to ten turbine rotor diameters in the direction of the prevailing wind with a lateral spacing width in the order of four to eight turbine rotor diameters [34]. In the previous assessment it was concluded that the minimum separation distance between turbines would be 2,000 m to accommodate a drilling rig and this is around nine diameters separation distance for all highlighted turbines. Depending on the layout of the wind farm it is possible for a rig to gain access to a wind farm and carry out drilling activities, however this would have to be carefully designed and drilling locations would also have to be known beforehand. This assessment does not consider cables and pipelines and has assumed that they would be run on the other side of the turbines or possibly at the 500 m exclusion zones of the turbines and jack up if pre agreed by Ørsted design team.

5.2.2 Cable Crossings

The Hornsea 4 environmental survey document states that there is expected to be 32 cable crossings already highlighted within the Hornsea 4 project. Where there are cable crossings and expected pipeline crossings (through CCUS) the best practise (DNVGL-RP-0360-2016) states that each individual case of crossings requires an individual assessment as it has its own physical characteristics that need to be addressed.

The agreement of a crossing must be decided by the owner/operator of the CCUS and Ørsted which outline a pre agreed safety zone, installation methods, liability and future maintenance. The best practise document DNVGL-RP-0360-2016 provides considerations of the location and design of the crossing and the design specification areas of requirement (i.e., coordinates of crossing, thickness of cover, inspection methods, installation of supporting structures and tolerance requirements).

6 Conclusion

This report is a follow-on study from the conclusions of The Crown Estate commissioned work Project Vulcan. The report looks to provide an unbiased opinion and some context to the high-level recommendations outlined in Project Vulcan by looking at the real-world scenario of the CCUS site Northern Endurance and the Offshore Wind project Hornsea 4.

Although the report provides context and answers to many of the original questions, the ETA has concluded that while there is information available on the individual aspects of CCUS and Offshore Wind there is a lack of literature on, and therefore understanding of, the impact of co-locating projects. This is specifically around the impact of turbine layout and noise on MMV activities and how to monitor plume development away from wells. Further studies are required before a definitive conclusion can be made. Until these issues have been addressed, a standard minimum square grid formation of one turbine every 2 km would need to be implemented. This relates to around nine diameters of the proposed turbines and would allow for rig access and opens the potential to use towed streamer acquisition for monitoring storage conformance and CO_2 plume development away from wells. This would be unless the cost of Ocean Bottom Node technology can be justified/reduced or a series of other MMV technologies can be compiled to provide full coverage. This layout would need to be investigated by the wind and CCUS operator to identify if this is feasible and economical for the project to continue.

Further areas of study are not limited to but include:

- CCUS operator to provide current MMV requirements for CO_2 plume monitoring for the Northern Endurance site
- Detailed independent study on MMV technologies based on current understanding of storage site characteristics and proposed MMV plan to understand viable options for co-location
- Real world study on the impact of offshore wind turbine noise on MMV survey activities

6.1 MMV Survey Interaction

The focus of this section was to review MMV activities that are mainly used to monitor CO_2 plume development and storage conformance away from wells and the near wellbore as this is the area that is perceived to be impacted the most in the scenario of co-location of offshore wind and a CO_2 storage site.

Reflection seismic (towed streamer or ocean bottom nodes) in the form of 3D acquisition for time lapse studies is currently viewed as the most applicable and mature technology to monitor the impact of CO_2 injection on plume migration and assessment of store integrity. However, there are challenges with acquiring towed streamer seismic within a windfarm due to the spacing of the turbines and the often irregular pattern of the turbine layout. Ocean bottom nodes do not have the same issues as towed streamer acquisition but the cost of acquiring the data is high, potentially up to ten times that of surface seismic, and image quality of the seabed and shallow subsurface can be significantly affected depending on the spatial sampling of the nodes.

Various acquisition and processing techniques were reviewed that could potentially enable towed streamer acquisition or reduce the cost of OBN acquisition.

Increasing the spacing between turbines and placing them on a regular grid could enable short-offset or a small 3D towed streamer array acquisition. Advances in the speed of deployment and retrieval of ocean bottom nodes could reduce the cost of OBN acquisition and the development of autonomous nodes could decrease this cost still further making it a viable alternative to towed streamer acquisition and significantly reduce the cost of ocean bottom monitoring for CCUS.

New processing techniques like mirror imaging can help to solve the image quality of the shallow subsurface from OBN acquisition allowing sparse sampling and therefore help to keep acquisition costs to a minimum. Compressive sensing is an exciting technology and potentially disruptive processing technology that has the potential to significantly reduce OBN survey acquisition time and the volume of data required. There is even the possibility of removing the requirement for repeatability which if proven true could dramatically reduce the cost and time of 4D surveys.

Alternatives to seismic acquisition were also examined but these techniques like control source electromagnetism, distributed acoustic sensing, and gravity monitoring were either deemed to be inappropriate or were emerging technologies at a lower TRL which could be used currently to compliment seismic rather than replace it.

Permanent and passive arrays were considered. Seabed nodes as part of permanent reservoir monitoring (PRM) systems offer both active and passive monitoring opportunities. These can offer some significant advantages especially in the early life of the storage site during the injection phase to monitor and measure injection induced seismicity. However, the initial investment cost of a PRM system is relatively large and my not offer sufficient benefit at an acceptable cost level.

Based on the information gathered from the public domain on technologies in play today and those potentially available in the future a conceptual view on a MMV strategy was presented that could be applicable in a co-location scenario.

- Sparse PRM system focused on injectors and early plume area. This is the area where storage and operational risks are highest during the operation phase (injection)
- Sparse PRM will enable more accurate and frequent monitoring of reservoir units and overburden to demonstrate conformance and provide data to update models. The PRM system will offer both passive and active monitoring programmes and will minimise the requirement for towed streamer acquisition
- Design and frequency of repeat surveys would be adjusted as the project develops. Initial surveys would use a source boat, but this might be superseded in the future by the ability to use the turbines as a seismic source signal

- With accurate and frequent monitoring, confidence in predicted to actual store behaviour would increase, allowing options like gravimetric modelling to be sufficient across the wider CCUS store
- PRM system will have a higher investment cost which may be challenging to the economics of the storage site. In the co-location scenario cost sharing of permanent systems could be considered to improve the economics
- PRM system may minimise the requirement for towed streamer acquisition, the aerial extent could still impact co-location and turbine installation and therefore may not be an applicable solution

The impact of noise and reflection of a wind turbine foundation on seismic acquisitions was investigated by reviewing literature and case studies of similar activities. The report found that there is a large increase in the noise generated during the construction activities of a wind farm due to the piling of the foundations into the seabed, however this is limited to around a year depending on the size of site. The operational phase of the wind farm which can last from upwards of 25 years produces minimal noise interference and is mainly produced by mechanical noises of the gearbox and the swishing noise of the blades at the 6 o'clock stage of their rotation. It should be noted that not all turbines have gearboxes, some are direct drive and this noise generation is not applicable to all turbine manufactures and models. The interference caused by the monopiles and even noise generated by the turbines can be compared to an existing problem called "Rig Noise" that has been solved within the O&G industry. Denoising of acquisitions through the shot skipping approach has been used to success within the industry to remove O&G platforms, drilling rig legs and noises and even other seismic surveys. Although this hasn't been carried out on a large scale, such as a full wind farm, results are promising and further studies should be carried out to investigate this.

The study into the impact of turbine noise threw up an interesting angle that hadn't previously been considered. The thought is that noise generated by the turbines could be a positive and act as a source for certain monitoring techniques. The bandwidth of turbine noise is in the range of 0-10 Hz which could be used in certain seismic techniques like full waveform inversion (FWI) which benefit from the availability of low frequencies which would otherwise be obtained through OBN, or long offset towed seismic data.

6.2 Direct Physical Impact due to Co-Location

Both helicopter and rig access were investigated in this section. Several helicopter operators from the industry were interviewed and a series of opportunities were identified for operations next to and within an offshore wind farm. However, after reviewing the current CCUS and OW operational cases for helicopters being minimal and an outage from either party not resulting in the same operational cost as O&G the project did not see a need to recommend the implementation of any industry recommendations currently.

Rig access was investigated, and it was highlighted that access will be required for drilling wells within the windfarm at all stages of the CCUS projects. After engagement with Valaris, an industry leader in drilling rig operations it was highlighted that 2 km corridors should be incorporated into the design of the wind farm to allow for drilling rig access. This should be planned in conjunction with the CCUS operator to ensure optimal designs. A 500 m exclusion zone should remain in place around the well sites and drilling rig while in operation.

Finally hypersaline brine discharge from a relief well was reviewed with the findings suggesting that the brine will have totally dispersed by around 1,850 m.

6.3 Infrastructure Blocking Seabed Access

Deviated wells and cable costs were investigated to provide an approximate cost associated with co-location and deviated infrastructure to accommodate for both projects. Three separate well profiles were analysed,

Option 1 – S profile with 0 ° through reservoir

Option 2 - S Profile, 19° through reservoir

Option 3 - J Profile, build to 59°, hold through Reservoir

Although Option 3 provided the greatest deviated distance of 800 m it had the highest cost of £6.1 million. It was also highlighted as the greatest risk profile, therefore option 2 was recommended which gives a 542 m maximum deviation at a cost of £2.1 million.

Lastly a cost of £154.55 per m for the array cables used within the wind farm was identified. This gave an initial assessment of the cost associated in relocation of the array cables which are not known at this time. However, cable crossings between projects during the different phases of project development was identified as one of the key focus areas in terms of risk and cost.

The issues presented within this report are the concern of the UK Government, The Crown Estate, Crown Estate Scotland as well as the Oil and Gas Authority (OGA) as they look to resolve challenges of co-location to maximise the seabed in order to meet legally binding net zero targets. This also presents a real challenge for the CCUS and OW operators as co-location adds a huge area of uncertainty into the development and operation of these projects. Lastly this offers a huge opportunity for the supply chain to rise to the challenge of creating cost effective and innovative solutions to the issues identified within this report.

If these parties cannot rise to the challenge of co-locating projects, there is a risk that an opportunity for developing co-locating projects in mutually beneficial high value areas is missed and that net zero targets are made harder to achieve by 2050.

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Hornsea Project Four

Position Statement between Hornsea Project Four and bp
Appendix 1.2: UK policy support for Carbon Capture, Usage and Storage (CCUS) and Offshore Wind

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Table of Contents

1 Executive Summary

1.1 On 14th December 2020 government published the Energy White Paper: Powering our Net Zero Future (EWP) [9]. EWP followed from the National Infrastructure Strategy [3] and The Prime Minister's Ten Point Plan of November 2020 [16], which sets out the measures that will help ensure the UK is at the forefront of a global green industrial revolution. EWP provides further clarity on the Prime Minister's measures and puts in place a strategy for the wider energy system. Since the publication of the Energy White Paper, not only has the UK hosted COP26, but further documents have been issued from Government and industry relating to the important roles of CCUS and offshore wind in achieving the aims of the UK's net zero commitment, namely:

- Adoption by government of the Committee on Climate Change (CCC) recommendation for Carbon Budget 6 (CB6, running 2033-2037);
- Issuance of the Draft revised suite of overarching and technology specific **National Policy Statements** for Energy (including EN-1 and EN-3); and
- A suite of documents setting out Cluster sequencing for the bringing forward of CCUS projects in the UK in the 2020s.

1.2 This paper summarises aspects of UK energy policy which have been relevant to CCUS[1] and offshore wind since the introduction of the **Climate Change Act 2008** (CCA2008) through to the most recent publications. The EWP is wholly consistent with the **National Infrastructure Strategy** (NIS) and with many of the recommendations made by the Committee on Climate Change (CCC) in their proposals for a sixth carbon budget (see following).

1.3 In summary, this paper demonstrates that both CCUS and offshore wind are of critical importance to both the UK's green recovery plan and the national need to meet Net Zero commitments by 2050. Government's policy position, based on absolute need and taking a conservative approach to planning, is not to prioritise either one or the other of these two critical technologies, but to progress both with equal vigour and drive to meet the United Kingsom's (UK's) strategic national climate aims.

2 The Low Carbon Transition Plan

2.1 Government, through CCA2008, made the UK the first country in the world to set legally binding carbon budgets, aiming to cut emissions (versus 1990 baselines) by 34% by 2020 and at least 80% by 2050, 'through investment in energy efficiency and clean energy technologies such as renewables, nuclear and carbon capture and storage' [1, Five Point Plan].

2.2 CCA2008 was underpinned by further legislation and policy measures. Many of these were first consolidated in the **UK Low Carbon Transition Plan** (2009) (LCTP) [1], and then in the **UK Clean Growth Strategy** (2017) [2]. Both CCUS and Offshore Wind can trace the policy support they currently enjoy back to LCTP. Both remain critically present in the **National Infrastructure Strategy** (November 2020) [3] and **Energy White Paper** (December 2020) [9]

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[1] CCS involves the capture, transportation and storage of carbon, primarily produced from industrial or power generation processes. CCUS extends CCS to include the possibility of using, rather than storing, the carbon which has been captured. Much of the infrastructure required for CCS is also anticipated to be required for CCUS, potentially excluding the ultimate storage site. This paper uses CCUS and CCS throughout, taking its lead from the primary text which is being referenced

and Government is supporting industry to make tangible developments in both important technologies during the critical 2020s.

2.3 LCTP, alongside other policies, included policy measures to show how generation of around 40% of electricity from low carbon sources, and a reduction in emissions from the power sector and heavy industry of up to 22% on 2008 levels, would both be achieved by 2020. [1, p52]

2.4 LCTP recognised that 'Renewable electricity, nuclear and carbon capture and storage will be needed in some combination', and government is therefore taking action to enable both to contribute as part of the mix. [1, p58]

2.5 In summary, LCTP acknowledged that delivering large increases in renewable electricity would be critical in decarbonising the power sector [1, p59], but also that fossil fuels 'remain important to ensure [UK] electricity supply is reliable and secure as [the UK] move[s] towards a greater dependence on intermittent renewable sources like wind'. Therefore, to enable the continued operation of gas fired power stations while respecting the Carbon Budgets established under CCA2008, CCUS was – and remains – critically important as a technological solution 'which has the potential to reduce emissions from fossil fuel power stations by up to 90%.' [1, p65]

2.6 In October 2018, following the adoption by the UN Framework Convention on Climate Change of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC) published a **Special Report on the impacts of global warming of 1.5°C above pre-industrial levels**. This report concluded that human-induced warming had already reached approximately 1°C above pre-industrial levels, and that without a significant and rapid decline in emissions across all sectors, global warming would not likely be contained, and therefore more urgent international action is required. The ambition against which CCA2008 was established had been extended, and the targets for carbon emissions reduction were tightened.

2.7 In May 2019, the CCC published **Net-Zero: The UK's contribution to stopping global warming** [17], which recommended that 'The UK should set and vigorously pursue an ambitious target to reduce greenhouse gas emissions (GHGs) to 'Net-Zero' by 2050, ending the UK's contribution to global warming within 30 years.' This recommendation was implemented into law in June 2019. One year later, in June 2020, the CCC reported to government that:

> *To reach the UK's new Net Zero target emissions … is likely to require outperformance of the carbon budgets legislated to date*. [4, pp52-53].

2.8 the importance of carbon abatement and renewable generation were both reiterated in the CCC's June 2021 **Progress Report to Government**:

> *Electricity generation should be fully decarbonised by 2035, while meeting a 50% increase in annual demand. This will require large-scale deployment of new low carbon generating capacity that is resilient to a changing climate [and] phasing out unabated gas-fired generation …* [19, p122]

3 The National Infrastructure Strategy

3.1 In November 2020, government published its **National Infrastructure Strategy** [3], rooted in the expert advice of the National Infrastructure Commission (NIC) and responding to its ground-breaking 2018 assessment of the country's infrastructure needs. NIS sets out the government's plans to deliver an infrastructure revolution 'to put the UK on the path to net zero emissions by 2050.' [3, p8]

3.2 NIS includes all points set out in the Prime Minister's Ten Point Plan (also November 2020), including:

- Significant investment in offshore wind and into modern ports and manufacturing infrastructure to expand the share of energy generation from renewables; and
- £1 billion to support the establishment of carbon capture and storage in four industrial clusters.

3.3 NIS also addresses current inequalities in infrastructure development and private investment across the Union. Government wants to use infrastructure to 'level up' the UK, including: 'creating regional powerhouses, making cities the engines of growth and revitalising towns' by 'backing new green growth clusters in traditional industrial areas, with carbon capture and storage, offshore wind, port infrastructure and low carbon hydrogen.' [3, p26]

3.4 CCUS and offshore wind are both valued by government as vital instruments in the regeneration of towns and communities:

> *The government's decarbonisation agenda will build the UK's capability in new green industries. Infrastructure investment in offshore wind capacity (40GW by 2030) and port infrastructure will create jobs in coastal communities. Further investment in Carbon Capture and Storage and in low carbon hydrogen will drive economic activity in post-industrial towns.* [3, p37]

3.5 Critically, current government strategy recognises that the energy ecosystem which will deliver Net Zero must be integrated, with cross-commodity, cross-vector technologies optimising energy generated while minimising both carbon emissions and energy wasted.

- Low carbon hydrogen (either green, or blue) is a potential (but increasingly seen as essential) alternative to fossil fuel heating in industry and buildings, for the storage ofenergy, as a source of power, and for some modes of transport. The UK Hydrogen Strategy [21, p10] states that, as a result of its geography, geology, infrastructure and capabilities, the UK has an important opportunity to demonstrate global leadership in low carbon hydrogen and to secure competitive advantage. The UK's *twin track* approach capitalises on the national potential to produce large quantities of both electrolytic (green) and CCUS enabled (blue) hydrogen.;
- CCUS is a lead technology to enable the decarbonisation of existing or new gas-fired electricity generation (to complement renewable generation when wind or solar levels are low), but also to capture emissions from industry, to enable the production

- of blue hydrogen, and to support greenhouse gas removal technologies to offset some of the hardest to reach sectors;
- Low-carbon electricity generation (with offshore wind at the vanguard) will generate electrical energy not only for traditional use, but also for the electrification of space heating and transport, and for the production of green hydrogen. [3, p48].

3.6 The North East of England has been identified in the NIS as an example of a place which 'could become a home of choice for companies delivering carbon capture and storage; making hydrogen power a part of daily life; and designing, building and maintaining offshore wind turbines' [3, p48] showcasing the dual importance of both CCUS and offshore wind not only to the country and our Net-Zero ambitions, but also to local areas in terms of jobs and community prosperity.

4 The Sixth Carbon Budget

4.1 The CCC's recommendations for a **Sixth Carbon Budget** (CB6), presented to the Secretary of State in December 2020 [10] provides insight into the level of policy support which may be required for CCUS, offshore wind and other technologies in order to 'reflect the goals and requirements of the Paris Agreement, recognising the UK's responsibility as a richer developed nation and its respective capabilities' [10, p17].

4.2 CB6 identifies actions which are required to expand low-carbon electricity supplies, and foresees in all scenarios that 'The largest contribution [to low-carbon electricity supplies] is from offshore wind, reaching Government's goal of 40 GW in 2030 on a path to 65-125 GW by 2050'. [10, p25]

4.3 Action is also needed to take-up low-carbon solutions: 'Industry must either adopt technologies that use electricity or hydrogen instead of fossil fuels or install carbon capture and storage' and 'Low-carbon hydrogen [must] scale up to 90 TWh by 2035 … produced using electricity or from natural gas or biomass with carbon capture and storage.' [10, p25]

4.4 All of the pathways explored in the CCC's Sixth Carbon Budget advice include CCUS as a critical and cost-effective means of meeting the UK's 2050 Net Zero target. The CCC state that the 'exclusion of CCS is likely to significantly increase cumulative emissions over the period to 2050' and is therefore not a recommended pathway. [10, Box 2.4]

4.5 The CCC scenarios indicate potential ranges of installed capacity for different generation technologies, each showing a significant increase for both offshore wind (as described above) and CCS. In each scenario, unabated gas generation is phased out between 2035 and 2040, and dispatchable (abated, i.e. with CCUS capacity) generation ranges between 50 GW and 65 GW by 2050 [10, Table 3.4a].

4.6 Further, it is foreseen (in line with current government policy support) that 'Infrastructures for CCS and hydrogen are deployed from 2025 in the pathway, starting near industrial clusters.' [10, p126]

5 Energy White Paper

5.1 The electricity sector is undergoing rapid and ambitious change and government's policy position will be reviewed, subject to the success of nascent technologies.

> *Our understanding of what is required from the electricity sector to support the delivery of net zero emissions will change over time. Our views will be informed by what we learn about the costs of decarbonising other sectors of the economy and by the costs and availability of negative emissions technologies … We are not targeting a particular generation mix for 2050.* [9, p42]

5.2 EWP presents Government's energy policy preferences before introducing legislation to put those preferences into effect. EWP is an important document which sets out current policy on energy and energy infrastructure and includes policy statements on both offshore wind and CCUS. [9, pp12,13]

5.3 In support of a key commitment to bring forward affordable clean electricity, government are targeting 40 GW of offshore wind, using highly competitive CfD arrangements to bring down the cost of generation. CfD Allocation Round 4 is ongoing at the time of writing, and a pot budget of £200m with no capacity cap has been allocated. [9, p45]

5.4 Further, offshore seabed leasing has also been announced by The Crown Estate and Crown Estate Scotland, the later awarding in January 2022 seabed leases to 17 projects totalling 24.8 GW of generation potential. These projects do not come without risk, however. Scottish Renewables recommended a 30% MW attrition rate for future potential projects leased under ScotWind in their 2018 publication **An industry view of the Draft Sectoral Marine Plan for Offshore Wind** in order to reflect the more challenging conditions in Scottish offshore waters relative to the rest of the UK, particularly regarding water depth, ground conditions and grid charges.

5.5 Additionally, a £160 million scheme with a competitive process for attracting funding has been launched to support the development of offshore wind manufacturing infrastructure through the development of major portside infrastructure hubs, strengthening UK offshore wind manufacturing.

> *By 2030 we plan to quadruple our offshore wind capacity so as to generate more power than all our homes use today, backing new innovations to make the most of this proven technology and investing to bring new jobs and growth to our ports and coastal regions.* [9, p56]

5.6 This narrative demonstrates that not only is it government policy for offshore wind to provide a significant amount of 'heavy lifting' required to combat climate change, but also that the offshore wind sector is well placed to deliver that heavy lifting. However development is not without risk. Schemes which are located on developable areas of seabed, and are well advanced in their planning and development cycles, are therefore valuable in relation to the lower risk contribution they have the potential to make in continuing progress in decarbonisation.

5.7 EWP confirms that gas-fired generation with CCUS can provide flexible, low-carbon capacity to complement high levels of renewables, therefore the deployment of power CCUS projects are expected to play a key role in the decarbonisation of the electricity system at low cost. The EWP therefore included commitments to support at least one power CCUS plant to come forward and be operational by 2030 in one of the major industrial clusters (Grangemouth, Teesside, Humberside, Merseyside, South Wales and Southampton). [9, p47&121]

5.8 Both EWP and government's **Industrial Decarbonisation Strategy** [18] present CCUS as fundamental to the decarbonisation of energy intensive industries such as steel, cement, oil refining and chemicals and set out how CCUS can help secure the long-term future of these industries and enable production of clean hydrogen at scale, and therefore why CCUS development is needed.

> *Our ambition is to capture 10Mt of carbon dioxide a year by 2030 - the equivalent of four million cars' worth of annual emissions. We will invest up to £1 billion to support the establishment of CCUS in four industrial clusters, creating 'SuperPlaces' in areas such as the North East, the Humber, North West, Scotland and Wales.* [9, p125]

5.9 EWP confirms that both offshore wind and CCUS hold critical positions in current GB energy policy and EWP includes government measures to support the increased deployment of each in the critical 2020s timeframe.

6 The National Policy Statements

6.1 An important part of streamlining the planning process and thereby accelerating the deployment of low-carbon infrastructure in the England and Wales was establishing **National Policy Statements** (NPS). The NPSs were established against obligations made as part of CCA2008. The overarching **National Policy Statement for Energy** (NPS EN-1) [5] sets out national policy for energy infrastructure in England and Wales. It has effect, in combination with NPS EN-2 (for fossil fuel electricity generating infrastructure) [6], NPS EN-3 (for renewable energy infrastructure) [7] and NPS EN-5 (for electricity networks) [8], on recommendations made by the appointed Examining Authority (ExA) to the SoS for BEIS on applications for energy developments that fall within the scope of the NPSs [5, Para 1.1.1]. NPS EN-2 covers applications for fossil fuel generating stations with over 50 MW generating capacity and NPS EN-3 covers those renewable technologies which, at the time of publication in 2011, were technically viable at generation capacities of over 50 MW onshore and 100 MW offshore. These NPSs, when combined with the relevant technology-specific energy NPS, provide the primary basis for decisions by the SoS. The NPS set out a case for the need and urgency for new energy infrastructure to be consented and built with the objective of supporting government's policies on sustainable development, in particular by:

- Mitigating and adapting to climate change, and
- Contributing to a secure, diverse and affordable energy supply. [7, Para 1.3.1].

6.2 The UK chose to largely decarbonise its power sector by adopting low carbon sources quickly, but remained cognisant of the advantages to the UK of maintaining a diverse range of energy sources so avoid dependency on a particular fuel or technology type. [5, Para 3.3.5]

6.3 NPS-EN-1 identified the need for CCUS as a critical enabler to decarbonise fossil fuel generation, and for offshore wind as a low-carbon and proven fuel source.

6.4 During 2020, Government determined that the NPSs should be reviewed and EWP, signalled a review of the existing National Policy Statements. Draft versions of NPS EN-1 and EN-3 were issued for consultation on 6th September 2021 [14, 15]. While the Draft EN-1 confirms that the 'Secretary of State has decided that for any application accepted for examination before designation of the 2021 amendments, the 2011 suite of NPSs should have effect in accordance with the terms of those NPS.' [14, Para 1.6.2] the same document also states that "any emerging draft NPSs (or those designated but not having effect) are potentially capable of being important and relevant considerations in the decision-making process" [14, Para 1.6.3]. This paper therefore contains a synthesis of the Draft National Policy Statements EN-1 and EN-3 in relation to both CCUS and offshore wind.

6.5 However the NPSs as issued in 2011 remain current until they are superseded, and they provide specific policy in relation to both CCUS and offshore wind development. The policies set out in NPS EN-1, 2, 3 and 5 therefore apply, and being unquestionably 'important and relevant', therefore should afford significant weight in any planning assessment.

7 The Draft NPS (September 2021)

7.1 Draft EN-1, published for consultation in September 2021, establishes the need for new nationally significant electricity infrastructure and CCUS.

7.2 To ensure that there is sufficient electricity to meet demand, new electricity infrastructure will have to be built to replace output from retiring plants and to ensure that increased demand can be met. Building out more capacity increases the margin between supply and demand. The larger the margin, the more resilient the electricity system will be in dealing with unexpected events, and consequently the lower the risk of a supply interruption, although unnecessary additional capacity may increase the overall cost of the system. [14, Paras 3.3.2&3.3.3]

7.3 A doubling of demand by 2050 (as is anticipated by CCC, the National Infrastructure Commission and National Grid ESO), may require a fourfold increase in low carbon generation. [14, Para 3.3.5]. A diverse mix of electricity infrastructure is therefore required to come forward, to deliver a secure, reliable, affordable, and net zero consistent system in

2050 for a wide range of demand, decarbonisation, and technology scenarios. [14, Para 3.3.8]

7.4 Offshore wind and CCUS are both critical elements of a diverse mix of infrastructure. Government analysis 'shows that a secure, reliable, affordable, net zero consistent system in 2050 is likely to be composed predominantly of wind and solar' [14, Para 3.3.21], a key driver for government's target of 40 GW of offshore wind by 2030.

7.5 Combustion power stations, which by their nature are dispatchable and therefore provide significant energy security and system operation benefits, are also currently incredibly important to the GB electricity system, but most produce residual emissions. All new carbon-emitting combustible power stations over 300 MW in capacity must be constructed to be ready for carbon capture. CCUS is therefore a critical enabler to the continued operation of dispatchable carbon emitting plant. [14, Para 3.3.32]

7.6 Although CCS has not been deployed in the UK to date, the barriers to deployment are considered to be commercial rather than technical, and the potential of CCS will become clearer once at least one power CCS plant is operational, as expected by 2030. [14, Para 3.3.37]

7.7 Hydrogen could be a low carbon alternative for natural gas if production of that hydrogen is coupled with CCS, or through electrolysis powered by low carbon electricity, demonstrating that the significant uptake of hydrogen in the UK electricity system will be critically dependent on either or both offshore wind and CCS.

7.8 The conclusion is that all generating technologies mentioned in the Draft EN-1 are urgently needed to meet the Government's energy objectives of delivering a secure, affordable and net zero energy system. Prioritisation of one technology over any other is not current government policy [14, Para 3.3.43] and this extends to CCUS.

> *New carbon capture and storage infrastructure will be needed to ensure the transition to a net zero economy. The Committee on Climate Change Committee states CCS is a necessity not an option.* [14, Para 3.5.1]

7.9 Government's view is that CCS is needed to enable domestic production of low carbon hydrogen from natural gas (blue' hydrogen) as well as unlocking the potential use of biomass for low carbon hydrogen production with negative emissions. Further, CCS is fundamental to the deep decarbonisation of energy intensive industries such as chemical and cement plants and refineries. Alternate methods of decarbonising industry are limited, and CCS is therefore essential. [14, Para 3.5.5]

7.10 A further technology-specific NPS (Draft EN-3, [15]) covers onshore and offshore renewable electricity generation, including offshore wind. No technology-specific NPS currently exists for CCS. EN-1 Para 1.3.3 makes clear that Draft EN-1 will have effect alone for CCS infrastructure, and therefore that the absence of a technology specific NPS for CCS should not be inferred as a lower level of need for the technology.

8 COP26: Uniting the world to tackle climate change

8.1 The UN Climate Change Conference of the Parties (COP26) was held in Glasgow on 31 October – 13 November 2021. COP26 brought parties together to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate Change. As the first COP since the first Nationally Determined Contributions (NDC)s had been published (post Paris Agreement), the run up to COP26 in Glasgow was a critical moment in the world's mission to keep the hope of limiting global temperature rises to 1.5°C alive [22]. Through the NDCs shared at and before COP26, international pledges could be reviewed and amalgamated, and for the first time a view of global commitments made towards limiting carbon emissions and adapting to climate change could be created.

8.2 COP26 achieved agreements on many themes, including: science and urgency; adaption; adaption finance; mitigation; finance, technology transfer and capacity-building for mitigation and adaptation; loss and damage; implementation; collaboration; and confirmation and developments of elements of the Paris rulebook.

8.3 Of greatest relevance to this Summary of UK Policy Support, specifically because collective progress to date to reduce emissions has not been sufficient, are the outcomes agreed at COP26 relating to mitigation: setting out the steps and commitments that Parties will take to accelerate efforts to reduce emissions 'to keep 1.5°C in reach'. Key achievements at COP26 under the theme of mitigation include [23]:

- Over 90% of world GDP and around 90% of global emissions are now covered by net zero commitments and 153 countries have put forward new or updated emissions NDCs, which collectively cover around 80% of the world's greenhouse gas emissions. Net zero is a global endeavour and the world is getting on board;
- The importance of action now to address the urgency of climate change and drive emissions down before 2030 was cemented in an agreement from all parties to revisit and strengthen their current emissions targets to 2030, in 2022;
- The role of clean electricity in delivering climate action, and the importance of driving down emissions from fossil fuel generators as well as increase capacity of renewable generators, was acknowledged in the negotiated agreement by 190 countries at COP26 to 'phase down coal power'. Further commitments to cease international coal finance and direct public support of unabated fossil fuel energy, by the end of 2021 and 2022 respectively, will free funds to be redirected for deployment in renewable energy;
- Accounting for over 10% of global greenhouse gas emissions, and around half the world's consumption of oil, road transport is a critical sector to decarbonise with pace. Agreement was reached by countries, cities, companies, investors and vehicle manufacturers to target all new car and van sales to be zero emission by 2040 globally and 2035 in leading markets, and ultimately to phase out fossil fuelled vehicles. Electrification of transport is inevitable, underway and accelerating. Low carbon electricity supply must keep growing to provide the energy to enable the rapid displacement of oil.

8.4 It is appropriate that COP26 was held in the UK, because of the significant leadership and progress shown by the UK through its climate actions and ambitious climate change targets. And as the COP26 Outcomes report reminds its readers: 'we must continue the work of COP26 with concerted and immediate global effort to deliver on all pledges' in order to keep alive the hope of limiting the rise in global temperature to 1.5°C.

9 Sector-specific policy

9.1 As stated in the NPS, The UK chose to largely decarbonise its power sector by adopting low carbon sources quickly, but remained cognisant of the advantages to the UK of maintaining a diverse range of energy sources so to avoid dependency on a particular fuel or technology type. [5, Para 3.3.5]. The nature and timing of activities which have required support has therefore evolved differently across the critical sectors of offshore wind and CCUS. The following sections describe many the important policies and implementation support actions across each sector, which have supported their progress through the last decade and will continue to support progress into and beyond the next.

9.2 CCUS

9.2.1 Government first set out its support for the development of CCUS in the UK and internationally in 2013[2]. In October 2017, government announced a new approach to CCUS in the Clean Growth Strategy, which was designed to enable the UK to become a global technology leader for CCUS and ensure that government has the option of deploying CCUS at scale, subject to costs coming down sufficiently. To progress this ambition, government has more recently: re-affirmed their commitment to deploying CCUS in the UK subject to cost reduction; progressed international collaboration on CCUS; and supported and funded CCUS innovation. The Carbon Capture Usage and Storage deployment pathway issued by Government in 2019 set out a vision for CCUS, recognising the huge opportunity for the UK to become a global leader in the technology due to its existing assets, geography and infrastructure.

> ***Our vision*** *is to become a global leader in CCUS, unlocking the potential of the technology and securing the added value which it can bring to our industrial centres and businesses all across the UK.* [13, p6]

9.2.2 One of the biggest challenges with CCUS at the time of writing the LCTP, was that while each stage – capture, storage and transport – had already been shown to work, it had never been tried at a commercial scale on a power station and never the complete process from start to finish. However deployment at commercial scale in the 2020s is considered by both the CCC and the Energy Technology Institute to be an essential prerequisite to keeping open an option to deploy at scale during the 2030s, and thereby continue deployment through to the 2050s in support of achieving the Net Zero 2050 legal commitment. [13, p14]

> ***Our ambition*** *is that the UK should have the option to deploy CCUS at scale during the 2030s, subject to the costs coming down sufficiently.* [13, p6]

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[2] https://www.gov.uk/guidance/uk-carbon-capture-and-storage-government-funding-and-support

9.2.3 In setting out this ambition, Government has supported CCUS by encouraging CCUS investment and innovation through competition and funding, as well as progressing a demonstration of the technology at commercial scale, whilst ensuring the UK was prepared for its eventual deployment. [1, p65]. In recognition of the importance of infrastructure and geography to the cost effective deployment of CCUS, Government therefore encouraged clusters of CCUS infrastructure and expertise, in key areas, including Yorkshire and Humber, and Tyne/Tees [1, p66], as well as requiring that any new fossil fuel power stations would have to be designed and built so that they could fit CCUS in the future. [1, p53]. This also supports the government 'levelling up' agenda by 'Supporting local industrial competitiveness, supporting our industrial centres and attracting new high-tech companies to their areas'. [13, p14]

9.2.4 Actions taken by government in support of CCUS development include the following.

9.2.5 Development Plans

9.2.5.1 A **CCUS Cost Challenge Taskforce** has been established to provide advice on the steps needed to reduce the cost of deploying CCUS in the UK. The Taskforce identified the need for a long-term supportive policy environment and viable business models to support the delivery of CCUS.

9.2.5.2 The **CCUS Advisory Group** (CAG) was established. This was an industry-led group which considered the critical challenges that face CCUS, and provided insight into potential solutions

9.2.5.3 The **UK CCUS Deployment Pathway** has set out the steps government and industry should take in partnership in order to achieve the government's CCUS ambitions.

9.2.6 Siting

9.2.6.1 Government has worked with ongoing initiatives, including in the North East of England, to test the potential for development of CCUS industrial decarbonisation clusters. Government's **Industrial Clusters Mission** (ICM), announced at COP24 in December 2018, identified CCUS as a likely vital component to the low carbon transformation of the UK's industrial base. The ICM set out the ambition to establish the world's first net-zero carbon industrial cluster by 2040, and at least one low-carbon cluster by 2030 [11, p9]. With the potential to store more than 78 billion tonnes of carbon dioxide (CO_2), the UK could become a world leader in CO_2 storage services.

9.2.6.2 The Ten Point Plan crystallised further government's ambitions to see CCUS deployed in the critical 2020s by bringing forwards the aims of the ICM. In May 2021 further clarity on the process of project sequencing was published with the aim of facilitating the deployment of 'Carbon Capture, Usage and Storage (CCUS) in two industrial clusters by the mid-2020s, and a further two clusters by 2030 with an ambition to capture 10 $MtCO_2$ per year by 2030' [24, p4].

9.2.6.3 In November 2021, HyNet Cluster (North West) and the East Coast Cluster (Humber and Teesside) were selected as the preferred Track-1 clusters for national CCUS sequencing.

9.2.6.4 The East Coast Cluster will be enabled by the Northern Endurance Partnership (NEP), which is developing the common infrastructure needed to transport CO_2 from emitters across the Humber and Teesside to secure offshore storage in the Endurance aquifer in the Southern North Sea.

9.2.6.5 The Endurance aquifer is located in the vicinity of the Hornsea Four seabed lease area. Hornsea Four, if developed, will provide a significant and vital contribution towards meeting the urgent national need for the delivery of renewable energy in the critical 2020s.

9.2.7 Financing

9.2.7.1 A 2019 consultation [11] reviewed delivery and investment models for CCUS in the UK to understand how the barriers to cost effective deployment could be reduced, and how the private and public sectors can work together to deliver the government's ambition for CCUS. Government's overarching parameters to guide the development of CCUS business models were that they should be:

- Market based;
- Attractive for investment;
- Cost efficient;
- Appropriate and fair in the sharing of cost and allocation of risk between the Government and CCUS developers;
- Able to evolve as the technology matures, with the potential of becoming subsidy free.

9.2.7.2 The consultation response, published in August 2020, reconfirmed the crucial role CCUS would play in both green recovery and net-zero 2050, as well as a vital role in levelling up the economy. Government support for ambitious delivery plans for CCUS in the 2020s remains clear, using consumer subsidies to support the construction of the UK's first CCUS power plant while continuing to develop business models for CCUS power, industrial CCUS and low carbon hydrogen production. Further details on the revenue mechanism which will encourage private sector capital into the new business models which are being created to support deployment of industrial carbon capture were clarified in January 2022 in BEIS' **Carbon Capture, Usage and Storage: An update on the business model for Transport and Storage** [25].

9.2.7.3 Significant private investment must be raised for the construction and delivery of the early phases of CCUS Transport and Storage assets which will be critical to enable CCUS to be a key technology in supporting the government to achieve its net zero targets. The further detail provided by BEIS in early 2022 on a regulatory investment model for Transport and Storage of CO_2 is a critical step in providing the conditions required to encourage such private investment to come forwards. As of 2017, government had invested over £130m in R&D and innovation support to develop CCUS in the UK. Further innovation programmes which made funds available to progress CCUS post 2017, included £100m for industrial decarbonisation and CCUS as part of the **BEIS Energy Innovation Programme**.

9.2.7.4 At the Spring 2020 budget, a new CCS Infrastructure Fund was established, initially to support the development of at least two UK CCS sites with the first operational by the mid-2020s and the second by 2030. Government also announced plans of support for at least one CCS gas power station by 2030 [12, p7]. Since the budget, government has raised its commitment from £800m to £1bn to facilitate the UK's deployment of operational CCUS in four industrial clusters by the end of the decade [9, p126].

9.2.7.5 Later in 2020, eligible organisations were invited by Innovate UK to apply for a share of between £10m and £20m each, up to a maximum of £131m, from the Industrial Strategy

Challenge Fund to implement plans for decarbonising an industrial cluster[3].

9.2.7.6 Projects within the clusters sequenced onto Track-1 will have the first opportunity to be considered to receive any necessary support under the government's CCUS Programme. Such support includes access to the CCS Infrastructure Fund (described above) as well as the development of new CCUS business models for Transport and Storage of CO2, power, industrial capture and, potentially, bio-energy with CCS (BECCS) to bring through private sector investment into industrial carbon capture projects.

9.3 **Offshore wind**

9.3.1.1 Initially, government action in support of renewable technology increased financial incentives for renewables developers through the Contracts for Difference instrument, streamlined the planning process and supported innovation in renewable generation technologies. [1, p53]

9.3.2 Siting

9.3.2.1 Offshore wind developments in GB are permitted only in zones which have been identified and allocated (under a Zone Development Agreement) to potential developers by The Crown Estate. In 2001, The Crown Estate announced the first UK offshore wind leasing round and since then has run three further leasing rounds in 2003, 2008 and 2021. At the time of writing this paper, National Grid ESO's **Transmission Entry Capacity Register** [20] lists thirty-six distinct UK offshore wind project connections with Project Status 'built'. The UK's strategy is to grow offshore wind farm operating capacity from current 11.4GW [20], to 40GW by 2030. The government's ambition for 40GW of offshore wind to be operational by 2030 was reconfirmed in the 2020 Energy White Paper [9, p3 et al] and The Ten Point Plan [16].

9.3.2.2 Round 4, the first leasing opportunity of this scale in a decade, created the opportunity for 8GW of new offshore wind projects in the waters around England and Wales. Round 4 winners were announced in February 2021 and The Round 4 Plan-Level Habitats Regulations Assessment (HRA) is now underway and is expected to conclude in Spring 2022[4].

9.3.2.3 Crown Estate Scotland announced in 2022 that 17 new offshore wind projects are to be awarded through the ScotWind leasing process, again subject to suitable environmental and habitats assessments.

9.3.2.4 In 2020, BEIS launched the **Offshore Transmission Network Review** (OTNR) [26], to look into the way that the offshore transmission network is designed and delivered, consistent with the ambition to deliver net zero emissions by 2050.

9.3.2.5 Offshore wind is expected to play an important role in delivering net-zero emissions by 2050, and a review of the framework for delivering offshore transmission connections is relevant in the context of current and growing ambitions for offshore wind generation capacities.

9.3.2.6 Importantly the OTNR is exploring options for the efficient connection of nationally important wind resources to customers and markets. OTNR's Medium Term workstream seeks to focus primarily on projects which have already been identified and are expected to connect to the onshore network after 2025 (such as Hornsea Four), by facilitating coordination of development in the short-medium term and assessing how centrally delivered, enabling infrastructure may facilitate the connection of increased levels of

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[3] https://apply-for-innovation-funding.service.gov.uk/competition/657/overview

[4] https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-leasing-round-4/

offshore wind by 2030.

9.3.2.7 The OTNR will help the UK's world leading offshore wind sector to increase capacity and achieve net zero whilst ensuring the cost to consumers is minimised.

9.3.3 Financing

9.3.3.1 Contracts for Difference were first awarded to offshore wind projects in 2014 in the first Investment Contract round. These prices were administratively set. Government has subsequently run three competitive Allocation Rounds (ARs), awarded in 2015, 2017 and 2019 respectively. CfD Allocation Round 4 (AR4), is ongoing at the time of writing, having opened for applications in 2021[5].

9.3.3.2 In its response to a consultation on proposed amendments to the CfD scheme issued in 2020, Government took the decision on an overall merits basis to implement a proposal to introduce a new, third pot for offshore wind projects ahead of the fourth Allocation Round. Government considered that this approach would allow auction parameters to be set in a way which better reflects project characteristics, recognising that offshore wind projects are generally much bigger in size and have lower costs than other renewable technologies. This would allow parameters to be set for each of the pots to reduce the risk of suboptimal auction outcomes (e.g. higher consumer costs than necessary) while minimising the potential loss of competition to offshore wind by separating the technology into a single pot. The Energy White Paper confirmed government's plans to double the capacity awarded in AR3 with the aim to deploy around 12GW of low-cost renewable generation through AR4, with offshore wind a 'key building block' of the future generation mix [9, p45]. AR4 includes a pot of £200M which has been established to bring forwards an uncapped capacity of offshore wind generation.

9.3.3.3 This policy approach recognises that offshore wind is increasingly competitive as an existing technology, partly due to cost reductions in manufacturing and installation of offshore wind infrastructure, and partly also due to the advances in wind turbine technology which have delivered an increase in the amount of electricity generated in a year from each unit of installed capacity.

9.3.3.4 In order to accelerate the deployment of low-cost renewable generation, in February 2022 BEIS increased the frequency of CfD allocation rounds to every 12 months (versus the previous c. 2 years cycle). Increasing the frequency of allocation rounds is anticipated to help to encourage low carbon electricity generation, which may also encourage investment in supply chains, and benefit the UK in the longer term not least by protecting consumers from potentially volatile global markets. More frequent rounds will also support the delivery of those renewable technologies, such as offshore wind, which are key to decarbonising the power sector, creating jobs and bringing even more investment to the UK's former industrial heartlands.

9.3.4 Funding

9.3.4.1 Offshore wind continues to receive other policy support, not only to accelerate the drive towards Net Zero 2050, but also to increase capability and resilience in the UK offshore wind supply chain, thereby progressing towards the 60% UK content ambition set out in the offshore wind sector deal and also deliver regional economic and social benefits while increasing export opportunities for the UK offshore wind industry.

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[5] https://www.cfdallocationround.uk/longest-timeline

9.3.4.2 For example, in October 2020, the Prime Minister announced the government's decision to allocate funding (distributed via the **Offshore Wind Manufacturing Investment Scheme**) towards the development of the offshore wind supply chain the UK. Allocation will be a competitive process for award of a sum expected to be up to around £70m, to enable delivery of a single large coastal manufacturing site for the offshore wind industry, able to generate manufacturing clusters where several large-scale producers can co-locate[6].

10 Conclusion

10.1 Government policy is clear insofar as CCUS and offshore wind are not considered as 'either/or' technologies, either nationally or locally, but both have essential benefits both for local communities and for the UK as a whole in achieving Net Zero, building a secure and affordable energy system and providing jobs and supporting a green recovery.

10.2 Government policy has supported the development and acceleration of deployment of offshore wind over the last decade, and continues to do so in a way which offers pathways to decarbonisation of the electricity sector while offering value for money to consumers.

10.3 Government policy has also supported plans to decarbonise industry and electricity generation, as well as support the production of green and blue hydrogen, through the development of industrial clusters in the UK.

10.4 In multiple cases, CCUS and offshore wind may be ideally suited to existing side-by-side in local communities and especially close to industrial clusters, gas and electricity networks, and the sea. Plans for up to four industrial clusters are now progressing with government support, alongside policy which will enable the delivery of ambitious UK offshore wind capacity targets.

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SUMMARY OF BP POSITION WITH REGARD TO THE IMPACT OF HORNSEA 4 ON THE NORTHERN ENDURANCE PARTNERSHIP PROJECT

CONTENTS

Annex

1. bp Technical Report
2. bp proposed protective provisions and plan

1. INTRODUCTION

1.1 BP Exploration Operating Company Limited (“bp”) is the operator of the Northern Endurance Partnership ("NEP"), which includes bp, Equinor, National Grid, Shell and Total. The NEP proposes to construct and operate a carbon dioxide (“CO2”) transportation and storage system that will enable CO2 from certain carbon capture projects on Teesside and the Humber (together known as the “East Coast Cluster” or “ECC”) to be transported to safe, secure offshore geological storage in the ‘Endurance’ saline aquifer, a geological reservoir below the Southern North Sea (“SNS”) seabed, consisting of water permeable rocks that are saturated with salt water (the “Endurance Store”).

1.2 A DCO application for the Teesside onshore elements of the NEP project has been made (the “Net Zero Teesside DCO”), which will be examined this year. Applications for the offshore elements of the NEP project (in particular for the Endurance Store itself) will be made later this year. The Humber onshore gathering system is currently being progressed by National Grid with a view to form a single transportation and storage network in line with Government requirements by 4Q 2022.

1.3 The purpose of this statement is to provide the Examining Authority ("ExA") for the Hornsea Four Project (“Hornsea 4”) DCO application by Orsted Hornsea Project Four Limited (“Orsted”) with information in relation to two of the principal issues identified in Annex C to the Rule 6 letter, namely (i) the relationship with and implications for other proposed major development including the Endurance Aquifer (defined above as the Endurance Store)[1] and associated carbon capture and transfer, and (ii) the cumulative and in-combination effects with other major development proposals. bp considers that the ExA is right to regard these as principal issues, and they should be regarded as both important and relevant matters pursuant to section 104(2)(d) of the Planning Act 2008 in any decision that the Secretary of State may make in respect of the Hornsea 4 DCO. This statement therefore considers the implications of the proposed Hornsea 4 for the use of the Endurance Store for carbon capture and storage as proposed in the NEP project, and more widely for the delivery of the Government's decarbonisation policy, if granted without the protective provisions proposed by bp (included at Annex 2).

1.4 The area of seabed in relation to the Endurance Store which is subject to an agreement for lease (“the Endurance AfL”) granted by The Crown Estate (“TCE”) to bp overlaps in part with an area of seabed which is subject to an agreement for lease granted by TCE to Orsted for Hornsea 4 (“Hornsea 4 AfL”) (such overlapping area referred to below as the "Overlap Zone"). The overlap between the respective AfLs is shown in Figure 3 below.

1.5 It was originally anticipated that it would be possible for the projects in relation to the Endurance Store and Hornsea 4 to co-exist in the Overlap Zone, and on that basis an 'Interface Agreement' was put in place between the relevant parties to facilitate co-operation in the development and operation of the two projects.

1.6 bp is supportive of the development of offshore wind. However, after extensive work and analysis, bp and its co-venturers in NEP have concluded that unfortunately co-existence across the entirety of the Overlap Zone is not feasible for delivering the ECC plan (see paragraph 2.2), and that in the event that the Hornsea 4 DCO is granted in a form which would allow wind infrastructure to be located across the entirety of the Overlap Zone, the Endurance Store could only be developed outside of the Overlap Zone (meaning that it

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[1] The terms store, aquifer and reservoir are frequently used interchangeably, and in this document the terms Endurance Store and reservoir are used.

would achieve only 30% of its potential capacity). This would render the ECC plans unviable.

1.7 bp is supportive of development of the Hornsea 4 project outside of the 'Exclusion Area' (an area which is shown in Figure 8 and is located within the Overlap Zone where the two projects would otherwise overlap).

1.8 This statement explains:

1.8.1 the basis of the technical conclusions bp and its co-venturers in NEP have reached and their impact on the viability of the NEP project, as part of the ECC plan; and

1.8.2 why there is a need for protective provisions in the Hornsea 4 DCO which would prevent the construction of wind infrastructure in the Exclusion Area.

1.9 The protective provisions proposed by bp would also disapply the Interface Agreement. This is necessary in the public interest to remove the risk that the terms of the agreement lead to an award of compensation to Orsted in relation to an adverse impact of the NEP project on the Hornsea 4 project which renders the NEP project unviable.

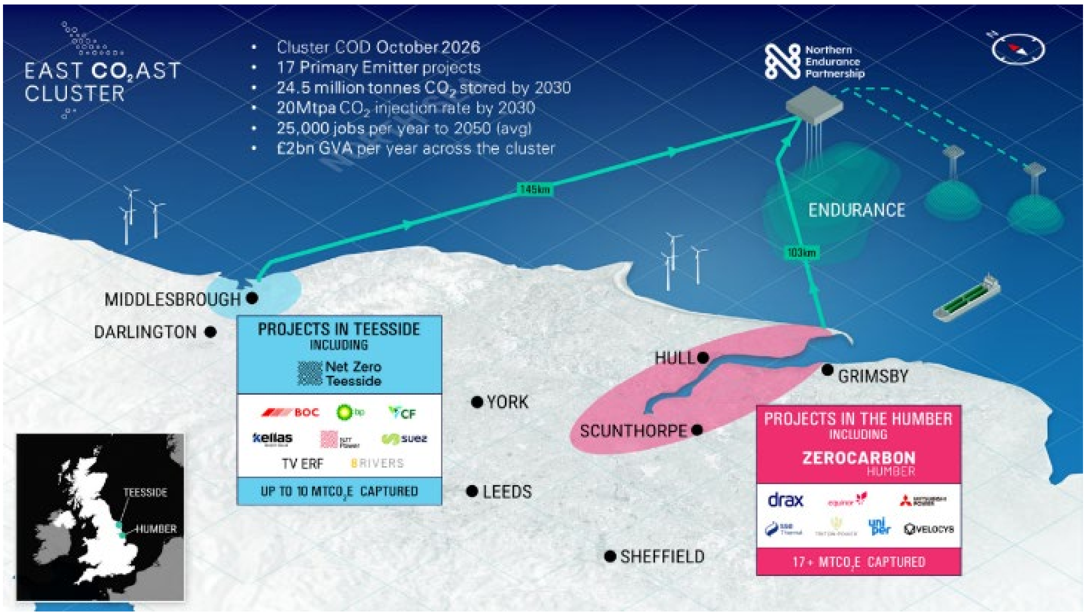
1.10 We recognise that the ExA will want to be provided with a detailed understanding of the Interface Agreement in order to consider the need for its proposed disapplication and to make a recommendation to the Secretary of State in this regard. We will continue discussions with TCE and Orsted with a view to providing the ExA with a copy of the agreement as soon as possible, along with a summary of its terms and a fuller justification of its disapplication.

2. THE EAST COAST CLUSTER (ECC) AND NORTHERN ENDURANCE PARTNERSHIP (NEP)

2.1 The ECC consists of multiple carbon capture projects across Teesside and Humber that are enabled by the NEP project, which will provide CO2 transportation and storage services as detailed below. The ECC has been selected as one of the UK’s first two carbon capture, usage and storage (“CCUS”) clusters following a successful bid to the Department for Business, Energy & Industrial Strategy (“BEIS”) in Phase 1 of the CCUS Cluster Sequencing Process.

2.2 Teesside and Humber represent almost 50% of the UK’s current industrial cluster CO2 emissions as defined by BEIS, and the proposed plan for deployment of CCUS by the ECC (“ECC plan”) by the mid-2020s will play a key role in reaching the UK’s target of net zero by 2050. The ECC plan aims to deliver 20 million tonnes per annum (“MTPA”) of CCUS capacity by 2030 across multiple emitters in both Teesside and Humber, with further expansion to 27MTPA of CCUS capacity by 2035. The ECC plan is only viable if the NEP project is permitted to develop to its full extent in accordance with the bid submission to BEIS which was premised on the Endurance Store achieving its full capacity.

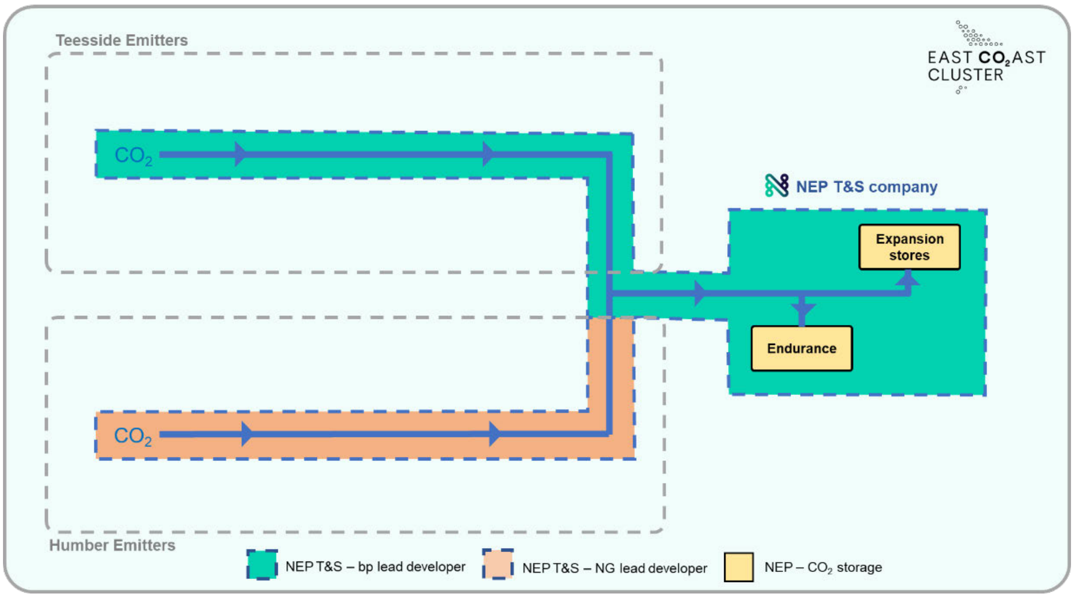
Figure 1: Location plan of ECC and NEP



2.3 The NEP project, as part of the ECC plan, includes developing an onshore CO2 pipeline network in each of the Teesside and Humber industrial clusters. CO2 will be captured and collected from individual carbon capture projects connected to each pipeline network. The captured CO2 will be transported offshore from a central gathering point located onshore within each industrial cluster. The NEP project will develop two offshore pipelines leading from each of Teesside and Humber to the Endurance Store. The NEP project is a First of a Kind ("FOAK") project in the UK.

2.4 The Endurance reservoir can store an estimated 450 million tonnes of CO2 at rates of up to 15MTPA. NEP intends to seek to develop additional CO2 stores using the Endurance Store as the hub, to provide increased storage capacity to enable NEP to reach rates of CO2 storage of 20MTPA by 2030. The CO2 will be transported through pipelines on the seabed and injected into wells into the Endurance Store approximately 1km under the surface to be stored in perpetuity.

Figure 2: Schematic depiction of ECC and NEP



2.5 The Net Zero Teesside DCO was accepted for examination by the Planning Inspectorate on 16 August 2021. The Net Zero Teesside DCO is based on a power generation project as the Nationally Significant Infrastructure Project (NSIP) but also includes the Teesside onshore CO2 gathering network, compression and landfall site elements, which comprise the onshore elements of the NEP project in Teesside.

2.6 The offshore CO2 export pipelines between both Teesside and Humber and the Endurance Store will be the subject of separate consent applications (e.g. store permit issued by the technical regulator, the Oil and Gas Authority, ("OGA")), including under the Energy Act 2008.

2.7 The NEP project builds on National Grid Carbon's ("NGC") 'White Rose' CCUS project, which was undertaken during the last government-sponsored CCUS competition. That project involved drilling of an appraisal well and completion of front-end engineering design (FEED) studies in 2016. That work produced important information about and understanding of the Endurance Store and its suitability for CCUS.

2.8 The appraisal well drilled as part of the White Rose CCUS project was located in the northwest quadrant of the Endurance Store, and the data that is currently available concerning the rock properties of the store is limited to that area. However, the final injection wells that will be used to inject CO2 will be positioned in the eastern and southern flanks of the Endurance Store, and additional information will be needed to determine where those wells will be positioned. In particular, seismic data and dynamic data obtained from injecting CO2 into the store and tracking the CO2 plume needs to be acquired and analysed.

2.9 Additionally, whenever CO2 is injected into the Endurance Store, it needs to be monitored in order to trace movement of CO2 within the store and confirm that where the CO2 is located (and remains) is consistent with the sophisticated dynamic modelling of how CO2 is expected to migrate within the Endurance Store.

2.10 Monitoring has to occur on a regular basis over the course of the NEP project's life (c. 20-25 years) and during an additional monitoring period (estimated to be at least 20 years) after decommissioning.

2.11 Acquiring (at regular intervals) seismic imaging and monitoring data that is consistently reliable is critical for: (i) modelling migration and producing an accurate initial seismic image; and (ii) active tracking and monitoring of where CO2 migrates and settles. This in turn allows progressive development of the store. Thus, NEP needs to (and will) deploy the best available technology for seismic acquisition for the Endurance Store and its features, namely vessel towed streamers (described in detail below in Section 6).

3. NEED FOR CCUS AND THE IMPORTANCE OF ENDURANCE

3.1 CCUS has been identified as one of the key components for decarbonisation in the UK and will underpin the UK's Clean Growth Strategy (October 2017), as well as more recent strategic aims set out in the 'Ten Point Plan for a Green Industrial Revolution' (Nov 2020), the 'Energy White Paper' (December 2020) and the UK's Net Zero Strategy ('Build Back Greener', Oct 2021).

3.2 The Government's CCUS target is for 20-30 MTPA of CCUS capacity by 2030 through the development of four industrial clusters, in line with the 6th Carbon Budget. It notes that the UK will need at least 50 MTPA by the mid-2030s.

3.3 In October 2021, BEIS announced that the ECC (based on the Endurance Store) and the HyNet cluster (based on depleted gas fields) will be the UK's first commercial CCUS projects and are expected to be operational by the mid-2020s.

3.4 There are three key areas of CO2 emission reduction that CCUS addresses:

3.4.1 Gas and biomass power generation with CCUS will provide reliable decarbonised electricity to complement intermittent wind and solar electricity generation;

3.4.2 Blue hydrogen requires CCUS to provide decarbonised hydrogen for heat and transport; and

3.4.3 Many industries such as cement, steel and fertilisers produce CO2 as part of their industrial processes. The capture and storage of these emissions enables decarbonisation of these industries and reduces imports of higher-emission products from overseas.

3.5 In contrast to the offshore wind industry, CCUS is still immature globally, with relatively small amounts of CO2 being sequestered annually and no operational projects in the UK. The offshore UK is expected to have high potential for CCUS but very few stores have been progressed through any subsurface exploration and appraisal analysis, with low proven storage volumes in accordance with the Society of Petroleum Engineers (SPE) CO2 Storage Resources Management Systems (SRMS) guidelines.

3.6 The SNS, where Endurance is located, has been identified by Government as a high priority for CCUS due to its proximity to the large industrial areas along the east coast of England and relatively short distance for transportation to CO2 stores.

3.7 Of the saline aquifer stores identified by numerous reports, the Endurance Store is the largest and best appraised store of this type in the SNS, with an estimated capacity of 450MT of CO2. It represents two thirds of the developable CCUS capacity in the UK today and would be significantly larger than other projects in the Norwegian sector of the North Sea such as Northern Lights, Snohvit, or Sleipner. The shallow water locale and geology in a very well-developed basin, plus its proximity to the Teesside and Humber industrial clusters, makes the Endurance Store a strategic, low risk and cost effective asset to the UK which is ideal to kickstart the nascent CCUS industry.

4. PUBLIC INTERESTS AND BENEFITS FROM NEP

4.1 CCUS is critical for decarbonising UK industry, providing mitigation against rising CO2 (carbon credits) prices, and protecting jobs in the Teesside and Humber regions. The ECC's decarbonisation plans for industry rely on maximising Endurance's storage potential to 15MTPA in order to meet the ECC's overall target of 20MTPA by 2030, and the ECC has the opportunity to develop the Teesside and Humber industrial clusters into a "SuperPlace" (a SuperPlace is defined by BEIS as an area where renewables, hydrogen, carbon-capture and industry come together to provide innovation and development of net-zero demonstrators to roll out across the UK and export-markets). The ECC plan combines a diverse portfolio of decarbonisation programmes using the NEP project as the integration system. The NEP infrastructure, and projects it enables, will organically facilitate synergies of wider low-carbon technologies across the Humber and Teesside regions. For example:

4.1.1 Installation of the hydrogen transmission/storage systems in Humber and potential expansion of hydrogen distribution/storage in Teesside;

4.1.2 Enabling a diverse portfolio of low-carbon projects/technologies including post-combustion capture, hydrogen fuel-switching, bioenergy with carbon capture and storage (BECCS) and bio-fuels across a variety of markets including power, industrial, heat and transport (road, rail, HGVs, maritime, aviation) applications;

4.1.3 Developing a range of ‘green products’ within the regions for export into an expanding green products market. These include, but are not limited to, ammonia, insulation, packaging, pigments and coatings, steel, bio-fuels; and

4.1.4 CO2 shipping to enable decarbonisation of other UK regions and import of CO2 from other countries.

4.2 The ECC plan will significantly support delivery of the UK’s CO2 emissions reduction targets. It will also have the potential to act as a catalyst for the government’s levelling-up agenda, with access to low-carbon infrastructure expected to:

4.2.1 drive inward investment across the Humber and Teesside regions creating an influx of people and wealth to support new low-carbon markets, supply-chains and jobs; and

4.2.2 create extensive social, environmental and economic opportunities throughout the 2020s, 2030s and 2040s.

4.3 Given the ECC relies on maximising Endurance’s CO2 storage potential to 15MTPA in order to meet the ECC’s overall target of 20MTPA by 2030, the NEP project is an enabler for the ECC and its many benefits.

5. BACKGROUND TO AND EVOLUTION OF THE OVERLAP BETWEEN ENDURANCE AND HORNSEA 4

5.1 On 6th November 2012, National Grid Carbon (via its affiliate Carbon Sentinel Limited, previously known as National Grid Twenty Nine Limited) was awarded the UK’s first carbon storage licence (CS001) (the "Storage Licence") and on 14 February 2013, the TCE granted the corresponding Endurance AfL over the Endurance Store in the SNS.

5.2 bp, Carbon Sentinel Limited and Equinor New Energy Limited are the current licensees to the Storage Licence, and bp is also the named party to the Endurance AfL.

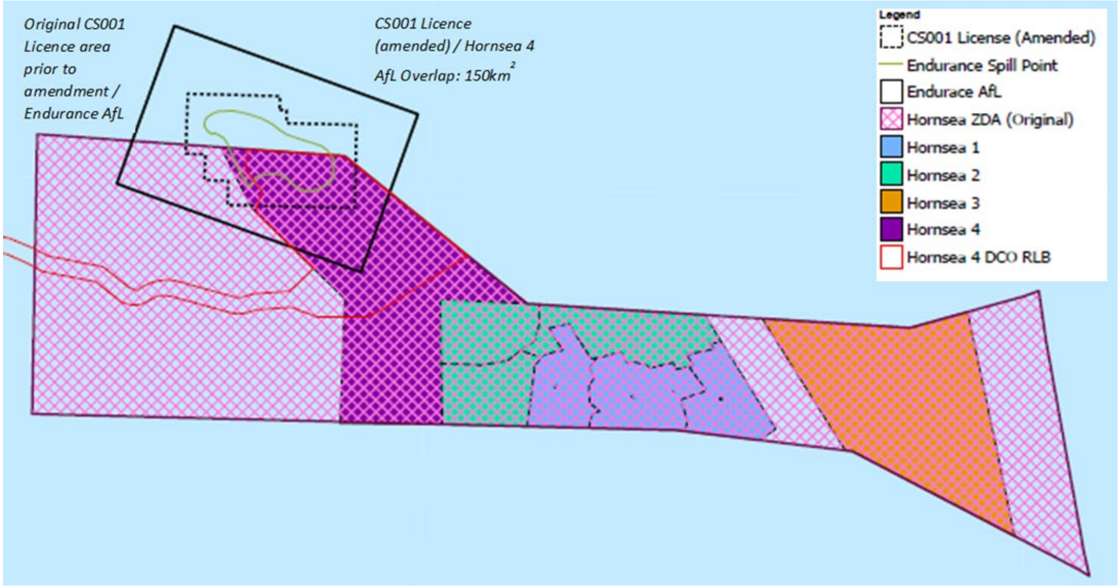
5.3 Orsted and TCE are party to the Hornsea 4 AfL in respect of, among other areas, part of the same area of seabed as the Endurance AfL.

5.4 The Hornsea 4 AfL area (shown in magenta in Figure 3) is ~845km2 and was selected from within the original Hornsea Zone Development Agreement (“ZDA”) area shown cross-hatched in Figure 3 below. The developable area within Hornsea 4’s AfL has been reduced due to concessions Orsted has made to other stakeholders over the past few years and the Hornsea 4 DCO redline boundary (“RLB”) as shown in Figure 3 now allows for ~465km2 of developable seabed area.

5.5 The area of overlap of the Hornsea 4 DCO RLB with the Endurance licence area (dotted black line in Figure 3) originally was 150km2 and has been reduced down to 110km2 due to (i) the latest environmental concession made by Orsted on Hornsea 4 causing a RLB amendment in July 2021 and (ii) optimisation of the seismic monitoring area as a result of technical collaboration between NEP and Orsted. The reduced overlap area represents ~24% of the developable Hornsea 4 AfL area (shown by the RLB).

5.6 However, this is still an increase from ~13% of the Hornsea 4 AfL area, and an increase from 3% of the original ZDA area.

Figure 3: Overlap between Hornsea 4 redline boundary and Endurance AfL



5.7 The wind farm and associated infrastructure covered by the Hornsea 4 DCO is in part proposed to be situated in the Overlap Zone, as seen by the Hornsea 4's DCO RLB in Figure 3 above.

5.8 An Interface Agreement (IA) was entered into in February 2013 between Carbon Sentinel Limited (as the "Carbon Entity"), Smart Wind Limited (as the "Wind Entity") and TCE.[2]

5.9 The IA was entered into to regulate how the respective projects would interact and co-exist with one another in the Overlap Zone. When the IA was agreed both developments were at the pre-feasibility stage and it was thought that co-existence in the Overlap Zone could be possible.

5.10 After entering into the IA in 2013, the relevant parties to the IA met quarterly, until early 2020 when the frequency of the meetings ramped up to monthly (and fortnightly since 1Q 2021) due to increasing project development activity for both NEP and Hornsea 4.

6. DEVELOPMENT OF THE ENDURANCE RESERVOIR

6.1 The Endurance reservoir was discovered in 1970. It has an estimated storage capacity of 450 million tonnes (MT) and injection capacity of 15 MTPA. Based on the current mapping of the aquifer boundaries, the reservoir stretches over an equivalent seabed area of 140 km^2 and is ideally located geographically to serve both the Teesside and Humber industrial clusters. It is the best appraised saline aquifer in the SNS, containing an appraisal well drilled in 2016 to sample the reservoir rock and fluids contained therein. The Endurance Store has over 1km of overburden (impermeable layers of rock above the sandstone reservoir, see Figure 4) up to the seabed, acting as a natural seal to contain for perpetuity

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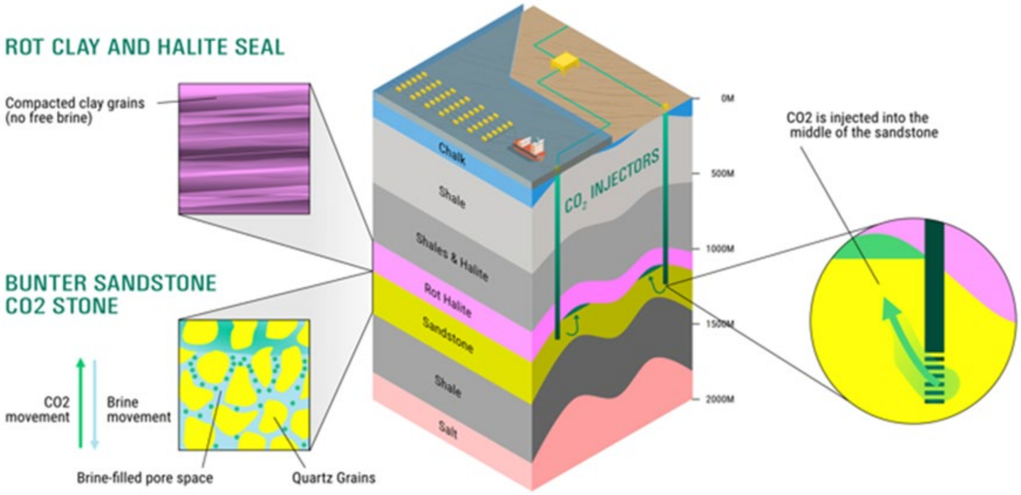
[2] The IA was varied and adhered agreement dated 12 September 2016 between (1) The Crown Estate Commissioners (2) Smart Wind Limited (3) Carbon Sentinel Limited and (4) Orsted and a Deed of Covenant and Adherence dated 10 February 2021 between (1) The Crown Estate Commissioners (2) Orsted, (3) Smart Wind Limited, (4) Carbon Sentinel Limited and (5) bp.

any injected CO2 (please refer to section 6 of the bp Technical Assessment in Annex 1 for a detailed description of the Endurance reservoir and the range of possible geological scenarios). Other saline aquifers in the SNS are either smaller or have not had any appraisal wells drilled into the reservoir to confirm rock properties.

Figure 4 - Cross section of Endurance Store in the SNS



6.2 The currently available data about the Endurance Store includes previously acquired seismic data and information acquired from 3 well penetrations with 5 to 7-inch boreholes at the reservoir sand face.

6.3 More data is needed in order to fully extrapolate the properties of the rock quality across the 140 km^2 reservoir. Additionally, CO2 has to be injected and the location of the injected CO2 in the Endurance Store identified and monitored through seismic imaging in order to confirm the reservoir rock quality and connectivity.

6.4 Developing the Endurance Store requires continuous appraisal activity and monitoring which involves regular and ongoing collection and analysis of data. This data comes from sensors at the injection wells and, crucially, seismic imaging from streamers towed by vessels.

6.5 Initial acquisition of seismic data of the Endurance Store enables a baseline image to be created. This is followed by repeating the seismic acquisition on a regular basis (planned to be every 5 years). This:

6.5.1 allows ongoing monitoring of where the CO2 injected in the store is located and the extent, and manner in which, the CO2 plume migrates within the store;

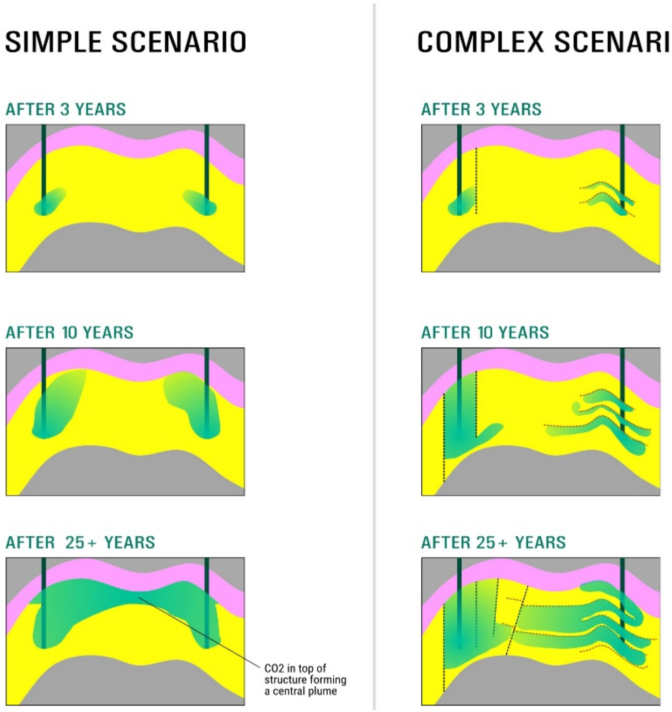
6.5.2 enables construction of a reliable time-lapsed four dimensional (4D) seismic image that will inform where the wells will over time be progressively located as the store is developed using actual, observed CO2 plume migration information (also known as ‘monitoring for reservoir conformance’); and

6.5.3 allows tailored technological solutions to be developed for any issues identified after CO2 injection operations occur.

6.6 Consistency in the methodology used to acquire seismic data for the Endurance Store is a critical part of creating a reliable 4D image, and each time seismic data is collected it needs to use the same technology and control parameters as that is the best and most reliable way of detecting and identifying the extent to which, over time, the location of the plume of injected CO2 is migrating.

6.7 If feedback gained over time (which involves carrying out, over 10-15 years, at least two to three time-lapsed 4D seismic images of the entire reservoir) conforms to desktop reservoir models, then subject to agreement with the technical regulator, the interval between seismic acquisition may be lengthened. However, if the reservoir behaves in a significantly more complex manner, then in order to mitigate any potential safety concerns it is vital to continue using high quality seismic imaging at least every 5 years to determine where CO2 is migrating within the reservoir. The simple and complex scenarios illustrated in Figure 5 below provide examples of how local compartmentalisation within a reservoir can result in a very different migration of a CO2 plume.

Figure 5: Examples of how the CO2 plume may behave in simple and complex scenarios



6.8 If there are local compartmentalisation effects in a reservoir, they may not be fully identified in the baseline image created from the initial seismic acquisition. However, 4D vessel towed streamer seismic acquisition is particularly effective in detecting compartmentalisation effects as seismic data acquired by this method detects density differences between the CO2 and salt water in the reservoir such that at each seismic acquisition interval the seismic images generated using the towed streamers will effectively “light up” where and how the CO2 plume behaves following CO2 injection.

6.9 As detailed in bp’s Technical Assessment (Annex 1) and discussed further in Section 7 below, various alternatives to using the 4D vessel towed streamer methodology to acquire seismic data in the area of overlap with Orsted’s Hornsea 4 AfL have been considered. However, none of the alternatives can produce the same high quality imaging that is needed in order to obtain a complete picture of how the Endurance Store performs (which in turn affects how the reservoir is developed). Furthermore, no other technology has an equivalent level of proven track record, particularly in shallow water and shallow geology like that of the Endurance Store in the SNS.

7. REASONS WHY SITING HORNSEA 4 INFRASTRUCTURE ABOVE ENDURANCE IS NOT PRACTICALLY POSSIBLE

7.1 In December 2021, bp shared a technical assessment report ("bp Technical Assessment", see Annex 1) with Orsted, TCE, BEIS and the OGA which summarised NEP's position on the feasibility and limitations of co-development between NEP and Hornsea 4, particularly within the Exclusion Area[3]. The report, which followed over 2 years of collaboration with Orsted, concluded that locating wind turbines on top of and near to the Endurance Store would not be feasible.

7.2 A summary of the key findings of the bp Technical Assessment is provided below. Please refer to section 7 of the bp Technical Assessment report for a detailed description of the key risks, options analysed, consequences and conclusions.

(i) Managing reservoir development

7.3 In order to safely and efficiently locate progressive injection wells in the Endurance Store, NEP will need to obtain reliable data concerning how the Endurance Store develops as CO2 is injected into the reservoir. Co-location involving fixed wind turbine structures on the seabed above the Endurance reservoir would prevent NEP from obtaining that required data (see paragraph 22 of bp Technical Report).

(ii) Adequate seismic imaging of the reservoir

7.4 Fixed wind turbine structures in the area of overlap also prevent the required 4D towed streamer seismic acquisition, which is needed to provide the quality of imaging data necessary to evidence CO2 migration and settlement (please refer to section 7.3 of the bp Technical Assessment report for further details, and 'Access Requirements 4' in Figure 6 below for an illustration of the minimum area required to conduct towed streamer seismic acquisition on the Endurance reservoir).

7.5 4D vessel towed steamer seismic acquisition has specific operational requirements and they set the boundaries of the minimum area required for safe monitoring of the Endurance reservoir, particularly in the Overlap Zone. Specifically, 4D towed streamer seismic acquisition is carried out using specialist survey vessels carrying long streamers in the water. The streamers are equipped with geophone receivers and nodes that send and receive sound waves. The processing of the sound waves enables the creation of a seismic image of all layers within the reservoir and when repeated towed streamer seismic acquisition is carried out over time, the collected data indicates how the CO2 migrates and settles within the reservoir during injection operations. The length of the streamers is dependent on the water depth and reservoir thickness, and the streamer length in turn determines the size of the safety corridor that is needed in order for the vessel to navigate safely. The presence of wind turbines in the Exclusion Area would prevent the survey vessel with streamers from sailing in the pattern required to collect the data and create a complete seismic image. This would leave significant blind spots that would prevent the imaging of CO2 across the whole reservoir.

7.6 Orsted have requested NEP to review the acceptability of hybrid monitoring technologies such as use of a combination of towed streamers and Ocean Bottom Node (OBN) seismic monitoring at the seabed. OBN replaces the geophone receivers utilised on the long streamers by using battery-powered individual nodes (each the size of a small box) which are installed on the seabed. This allows the streamers to be reduced in length. However, in order to mimic the operation that would occur using the longer towed streamers several hundred to several thousand fixed nodes would need to be installed on the seabed as a network. Additionally, each time that a seismic acquisition operation was required, the

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[3] Referred to in bp's technical assessment report (Annex 1) as "overlap area".

network of nodes would need to be installed at and retrieved from the seabed by manned survey vessels.

7.7 Such hybrid solutions are not proven technology for CO2 monitoring and do not provide a consistent, reliable and repeatable seismic image, particularly as OBN at the seabed in this location (which has large sand waves present) would be susceptible to tidal movement. This would ultimately prevent NEP from imaging the complete Endurance Store, which is something that needs to happen in order to enable adequate monitoring of the reservoir behaviour in a UK FOAK project.

(iii) Wells and drilling rig access

7.8 The safe and efficient development of the Endurance Store for CO2 storage requires a reasonable and practicable degree of separation from the Hornsea 4 wind turbines in order to access wells and drilling rigs. As described above in Section 6, the location and associated corridors of the wells can only be determined progressively over time as CO2 injection takes place, monitoring occurs and data is acquired concerning the migration and settlement of the CO2 plume.

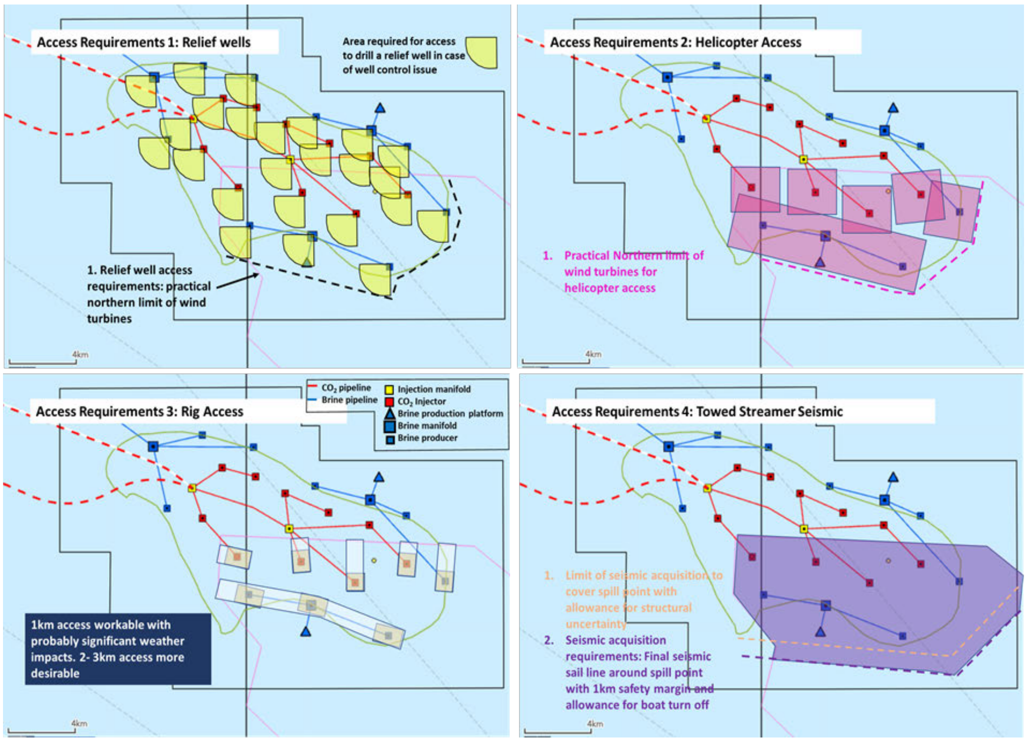
7.9 The challenges that exist in terms of ensuring adequate access for relief wells, helicopters and drilling rigs are summarised below (please refer to section 7.1 of the bp Technical Assessment report at Annex 1 for further details):

7.9.1 **Relief well access:** safety exclusion zones are required to allow for the drilling of relief well(s) in situations where well control issues arise. Well control issues could result in CO2 leakages from the well(s), which would require safe and rapid access, unhindered by the presence of wind turbines. If access were inhibited by the presence of wind turbines, extended wells outside the technical drilling envelope might be required. This could risk failure of any relief well operation, prolonged CO2 leakage and shutdown of all CO2 injection operations. Please refer to ‘Access Requirements 1’ in Figure 6 below.

7.9.2 **Helicopter access:** To ensure that Endurance is constructed and operated efficiently and safely, minimum safe distances for helicopter access are required to allow crew changes on drilling vessels and for search and rescue (“SAR”) operations. Maritime standards through the Civil Aviation Authority (CAA) dictate that in order for these flights to occur minimum safe distances, known as corridors, must exist between wind turbines. If marine vessels (rather than helicopters) are used for crew changes the amount of helicopter access can be limited to just SAR operations. However, there still would need to be the same required corridors between the wind turbines that would allow helicopter access for SAR operations and rapid evacuation of rig personnel in an emergency situation. Please refer to ‘Access Requirements 2’ in Figure 6 below.

7.9.3 **Drilling Rig Access:** corridors also are required in order to allow rigs to navigate between the wind turbines and to drill CO2 injector and brine producer wells. Based on notional well locations as shown in the images in Figure 6 ('Access Requirements 3'), it is vital that drilling rigs have enough space to be manoeuvred into position using tug boats operating within reasonable weather and sea state windows. If the CO2 migrated through the reservoir in a complex scenario (see Figure 5), the well locations would need to be adjusted to avoid the risk of localised overpressure from unforeseen internal compartmentalisation of the reservoir, which impacts safety. The consequence of the drilling rig not gaining access to the required well locations (including those that will be determined based on towed streamer seismic imaging) would be temporary or permanent cessation of injection to reduce reservoir pressure in one or more wells in order to prevent CO2 containment damage to the reservoir. This would be carried out through closure of valves in the wells (otherwise known as shut-in), causing disruption to injection operations and future performance.

Figure 6: Access Requirement for Endurance



8. REASONS WHY SITING HORNSEA 4 INFRASTRUCTURE ABOVE ENDURANCE IS NOT VIABLE FROM A REGULATORY PERSPECTIVE

(i) The importance of accurate imaging for NEP's licence to operate

8.1 Containment, conformance and confidence underpin the licence to operate ("LTO") for NEP. The use of proven technology to monitor the CO2 plume and Endurance Store development will be particularly important to the OGA given that NEP is a FOAK project and the need to ensure that there is confidence in the safety of its operations will be paramount. That is a principle enshrined in the Storage of Carbon Dioxide (Licensing etc.) Regulations 2010, which require the operator to prepare a monitoring plan and to update this every 5 years to reflect improvements in best practice and technologies available at the time. NEP's licence therefore compels use of the best available, proven technologies and techniques to mitigate the risks and any uncertainties arising during development of the reservoir.

8.2 In 2021 TCE, as part of Project Vulcan, commissioned a technical report to review the co-location challenges for CCUS and Offshore Wind. bp (representing the NEP project) participated in Project Vulcan. In response to bp's technical assessment report, Orsted commissioned its own report (prepared by the same entity that prepared the report in Project Vulcan). The report that Orsted commissioned was recently shared with bp in confidence. It reviewed a range of emerging technologies and the possibility of combining them to form a hybrid monitoring approach, both of which had already been discussed several times over a 2 year period through collaborative workshops with Orsted.

8.3 bp is in the process of reviewing the Orsted commissioned report, but the initial conclusion is that the analysis is consistent with and complementary to bp’s assessment (please refer to section 8 of the bp Technical Assessment report). In short, the emerging technologies are not yet at a stage where they can be relied upon for the purposes of the NEP project, but should continue to be matured. That is reflected by bp's ongoing investment in several of the most promising solutions.

8.4 The report also reinforces the fact that CCUS operations are temporal by nature, and the overlapping area of seabed could be released for offshore wind development after the site is closed and handover of the CO2 store to the Government has occurred.

8.5 Technology maturation of these emerging technologies could bring forward the point in time when the overlap area can be released for offshore wind development, but not at the timescales needed for the NEP project to be authorised and implemented. New technologies require extended field trials on an operational site to prove that they work and to generate the necessary data that will evidence suitability and confidence in replacing existing best available technologies, in order for them to be commercially deployable. The years it will take for new technologies to be commercially deployable within a clear regulatory environment is incompatible with the target final investment decision ("FID") of mid 2023 for the NEP project, combined with the technology uncertainty (which is compounded on a FOAK development like NEP where regulatory frameworks are yet to be finalised) which would prevent NEP from delivering the ECC plan as selected by Government.

8.6 The technical report commissioned by Orsted, referred to above, is not appended to this submission as bp does not have the right to disclose it without Orsted's consent. For the same reason its contents are not described here (or addressed) in any detail. However, in the event that Orsted discloses it or refers to parts of it during the remainder of the DCO examination, bp would wish to have an opportunity to respond in detail, as we consider that the Orsted report in fact is consistent with and complementary to bp's case[4].

(ii) The importance of accurate Endurance Store seismic imaging for liability transfer

8.7 Under the Storage of Carbon Dioxide (Termination of Licences) Regulations 2011 (the "Transfer Regulations") liability for the Endurance Store (including monitoring and corrective measures for leakages) remains with the transportation and storage company (NEP) until, among other obligations, it can be proved that the CO2 has remained contained and secure after closure of the storage site for a minimum of twenty years.

8.8 The ability to reliably image and identify where CO2 is stored within the Endurance reservoir throughout the injection phase and all the way to completion of post closure obligations underpins the ability of NEP to transfer long-term storage liability to the Government as provided for in the Transfer Regulations and BEIS's update to the CCUS business model, 'An update on the business model for Transport and Storage', released in January 2022. In order for liability to be transferred, stability of the CO2 in the reservoir has to be fully proven. Government and regulators will expect NEP to establish confidence in CO2 tracking and monitoring by demonstrating it using the best available technologies and drawing on the global expertise and experience of the co-venturers in NEP. bp and its NEP co-venturers have no confidence that the hybrid monitoring approach proposed by Orsted can be developed to be of equivalent quality as imaging provided by 4D vessel towed streamers, and in particular, bp and its NEP co-venturers have no confidence that this could occur within the necessary timeframe to achieve a FID on the NEP project which is forecast for 2023.

(iii) Regulatory Requirements in relation to Relief Wells, Helicopter and Rig Access

8.9 As explained in Section 7, there are regulatory requirements which necessitate uninhibited access to construct relief wells, and corridors for helicopter access and rig access. The ability to construct relief wells represent a low probability risk mitigation against well failure

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[4] Subsequent to finalising this submission, bp were informed that Orsted would be submitting this report to the examination as part of the Deadline 1 submission.

to demonstrate that this risk has been managed to As Low As Reasonably Practicable (ALARP) level. The principle of risk mitigation to ALARP would be part of the safety case, storage development plan and ultimately storage permit, which the OGA must approve under The Storage of Carbon Dioxide (Licensing etc.) Regulations 2010. Helicopter access is regulated by the Civil Aviation Authority (CAA) who have published guidelines on operating amongst wind turbines and standards for offshore helicopter landing on rigs (CAP 764, 437, 1145). Rig access corridors may be optimised by rig operators using their judgement but demonstration of safe operations would still be required by the UK Health and Safety Executive (HSE). Non-compliance with any of the above regulations may prevent NEP from obtaining approval of the storage permit within the FID timeframe of 2023. Should NEP be prevented from fully complying with the regulations included within the approved storage permit, the OGA has the power to revoke the storage permit at any point prior to and during injection operations.

9. REASONS WHY SITING HORNSEA 4 ABOVE ENDURANCE WOULD RENDER ENDURANCE UNFUNDABLE

(i) Summary of the principles of NEP funding

9.1 Unlike other low carbon industries such as offshore wind and solar, which have robust business models in place that have driven investment and growth, the CCUS industry is not yet established in the UK.

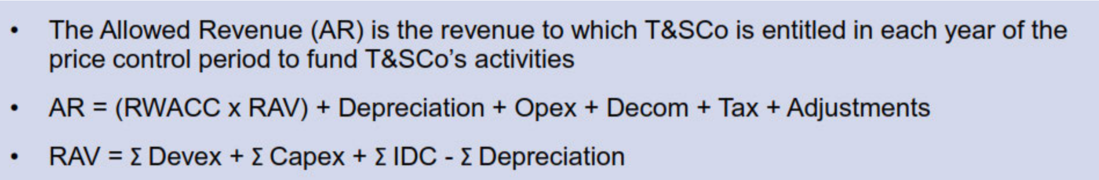
9.2 BEIS published the ‘Transportation and Storage Regulated Investment’ (TRI) model in 4Q 2020. The TRI model was last updated in 1Q 2022 and forms the basis for the NEP business case.

9.3 The proposed TRI model sets out a regulated framework which aims to provide visibility to investors through a transparent and predictable regime while ensuring value for money for users of the network.

9.4 The TRI model is built on the following principles which are typically used across regulated UK industries:

9.4.1 **Predictable Returns:** it is expected that the regulator will have a duty to protect network users from investors making excessive returns and so uses a building block approach to allow an investor to make sufficient revenue. The building blocks (see Figure 7) are designed to limit the upside to investors and maintain moderate, stable returns.

Figure 7: Extract from TRI model issued by BEIS



- The Allowed Revenue (AR) is the revenue to which T&SCo is entitled in each year of the price control period to fund T&SCo’s activities
- AR = (RWACC x RAV) + Depreciation + Opex + Decom + Tax + Adjustments
- RAV = Σ Devex + Σ Capex + Σ IDC - Σ Depreciation

where:

‘RWACC’ means regulated weighted average cost of capital,

‘RAV’ means realised asset value,

‘Opex’ means operating expenditure,

‘Decom’ means decommissioning expenditure,

‘Devex’ means development expenditure,

Capex’ means capital expenditure,

‘IDC’ means interest during construction.

9.4.2 **Economic and Efficient Costs:** the regulator determines which costs are economic and efficient for inclusion in allowed revenue calculations, directly driving the investor return. Any ‘disallowed costs’ are borne entirely by the investors from their cashflow which leads to reductions in the investor return.

9.4.3 **Financing:** Project financing is assumed under the TRI and NEP is likely to seek up to 70% in debt financing of its construction capital expenditure. Financiers require certainty that debts will be repaid and where risk is identified, measures such as reserve accounts and debt service coverage ratios are required to be put in place.

9.4.4 **Government Support Package (GSP):** the NEP's business model includes a GSP for certain high-impact, low-probability risks, including long-term CO2 storage liability. Under the Transfer Regulations this liability remains with the transportation and storage company (NEP) until it can be proved that the CO2 has remained contained and secure post closure of the storage site for at least 20 years.

9.5 The TRI model, investors and financiers require certainty of returns and acceptable risks in order to ensure the ECC plan can be developed as a viable project. Various financing difficulties associated with a proposal to construct Hornsea 4 above the Endurance Store are set out below.

(ii) NEP investors will not invest on the basis of reliance on unproven technologies

9.6 Research and successful development of novel and currently unproven technologies create the theoretical possibility of greater co-development of the seabed above Endurance, with offshore wind being possible in the future (but only if extended trials of any new technologies demonstrated their ability to produce consistent and reliable information and data that appropriately mitigated any uncertainties concerning development of the Endurance Store and resultant consequences as described earlier). However, even if trials of new technologies were implemented today, the requisite data that bp and its NEP co-venturers would need to receive and assess in order to have the necessary confidence in relying upon novel and currently unproven technologies will not be available by the time NEP is ready to trigger FID in 2023 (as required by the ECC plan).

9.7 There is also no guarantee that even after extended trials of novel and unproven technologies occurred, the trials would be successful and ultimately lead to a commercially deployable product. It is worth noting that technological solutions would need to be found not just to the approach to monitoring, but also to the issues of how to safely and efficiently locate wells progressively over time as reservoir understanding is developed, and to the regulatory issues around access for relief wells, helicopters and rigs.

9.8 Furthermore, even if such new technologies could be developed, the cost of such development and its deployment is likely to be much greater than the use of proven technologies that currently exist such as the use of 4D towed streamers. Accordingly, if NEP invested on the basis that in future it would be able to deploy some sort of new and as yet unproven technology, NEP would be taking the risk that any extra costs arising from its use of such technology would be 'disallowed' by the regulator under the TRI model (on the basis that these costs are excessive compared with existing proven technologies) and therefore such costs would end up being borne entirely by NEP.

(iii) NEP investors and debt funders cannot invest in or finance the NEP project if there is a risk that transfer of liability to Government could be frustrated

9.9 Section 8 outlined the risk that reliance on hybrid monitoring solutions could result in an inability to transfer long-term liability for Endurance to the Government. The possibility of this scenario, whereby NEP remains liable for Endurance for an extended period or perhaps in perpetuity, will be of significant concern to NEP investors and potential debt funders. It is therefore likely that NEP, as part of the ECC plan, will not be progressed if it were forced to rely on the development of new technologies and solutions which the bp Technical Report has concluded are unlikely to be deliverable (at least within the necessary timeframe for FID).

(iv) Debt funders will not have the necessary appetite for risk

9.10 NEP will be unable to attract debt financing if the risks attached to the project's financial viability are high. The perceived risks of providing debt finance to the project are likely to be higher in any event due to the fact it is a FOAK project. It will therefore be particularly important that the project is not seen to be relying upon uncertain and yet-to-be developed technologies – which could frustrate the project's full or timely delivery.

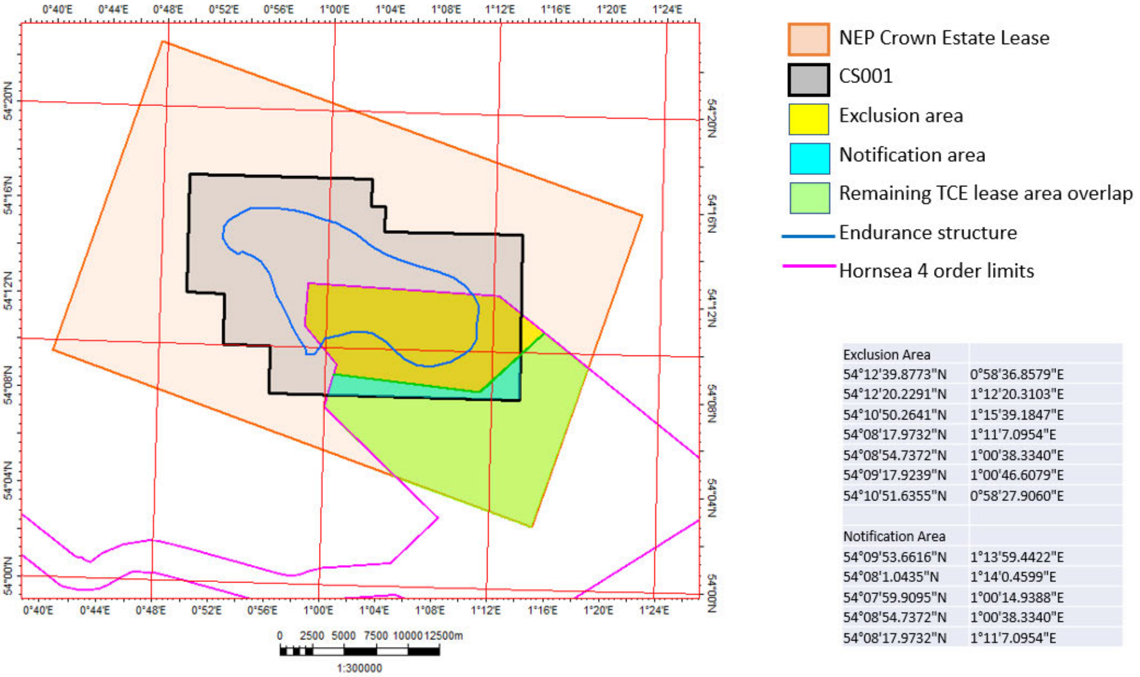
10. IMPACT ON ENDURANCE'S CAPACITY IF HORNSEA 4 INFRASTRUCTURE IS AUTHORISED TO BE CONSTRUCTED ABOVE ENDURANCE

10.1 Through regular technical collaboration with Orsted and reducing vessel turning circles and safety exclusion zones to the minimum permissible, NEP has been able to amend its 4D vessel towed streamer seismic monitoring design and reduce the overlap area down to ~110km2, a 27% reduction from the original layout. This collaborative effort over a span of 2 years looked at numerous technological solutions, resulting in the minimum criterion for full field Endurance reservoir development. Please refer to sections 3 and 7 of the bp Technical Assessment report (Annex 1) for further background on the collaboration history, process and constraints in arriving at the minimum criterion.

10.2 NEP's position is that further technical optimisation is not feasible or investable in view of the need to obtain reliable data to develop the reservoir, and the regulatory and commercial considerations discussed above and in the bp Technical Assessment report (Annex 1).

10.3 The minimum area over which Hornsea 4 infrastructure must be prohibited in order for Endurance to be delivered is shown as the 'Exclusion area' in Figure 8 below, which is the plan referenced in bp's proposed Protective Provisions (see Annex 2).

Figure 8: Protective Provisions Plan



Exclusion Area	
54°12'39.8773"N	0°58'36.8579"E
54°12'20.2291"N	1°12'20.3103"E
54°10'50.2641"N	1°15'39.1847"E
54°08'17.9732"N	1°11'7.0954"E
54°08'54.7372"N	1°00'38.3340"E
54°09'17.9239"N	1°00'46.6079"E
54°10'51.6355"N	0°58'27.9060"E
Notification Area	
54°09'53.6616"N	1°13'59.4422"E
54°08'1.0435"N	1°14'0.4599"E
54°07'59.9095"N	1°00'14.9388"E
54°08'54.7372"N	1°00'38.3340"E
54°08'17.9732"N	1°11'7.0954"E

10.4 Were Orsted permitted to build within the 'Exclusion area', this would prevent the full development of the Endurance Store, meaning 70% of the total storage capacity would be physically undevelopable. This is due to the inability of NEP to image the CO2 plume in all directions within the reservoir which would prevent the design of the brine production wells required to manage reservoir overpressure. Consequently, without comprehensive brine production facilities, only 30% of the estimated storage capacity within the Endurance reservoir may be safely utilised without risk of damaging the containment seal.

10.5 The ECC plan would be rendered unviable based on only 30% of the intended Endurance storage capacity.

10.6 Progressively building out the Endurance infrastructure using 4D vessel towed streamers might enable phased co-development of offshore wind from the mid-late life of Endurance, as over time development of the reservoir benefits from actual data obtained during live CO2 injection operations. Through investment in a number of technology ventures from concept level through to early field trials, bp is actively pursuing opportunities to accelerate future technical solutions that allow potential co-development of wind and CCUS. However, these solutions are at least 10-20 years away from commercial deployment. In the meantime, given development of the Endurance Store is at an early stage, the proposed Exclusion Area that has been identified is the minimum amount of space having no wind turbines installed that is required in order to enable NEP to make its FID decision and to ensure that the Endurance Store will be a safe and compliant CCUS development.

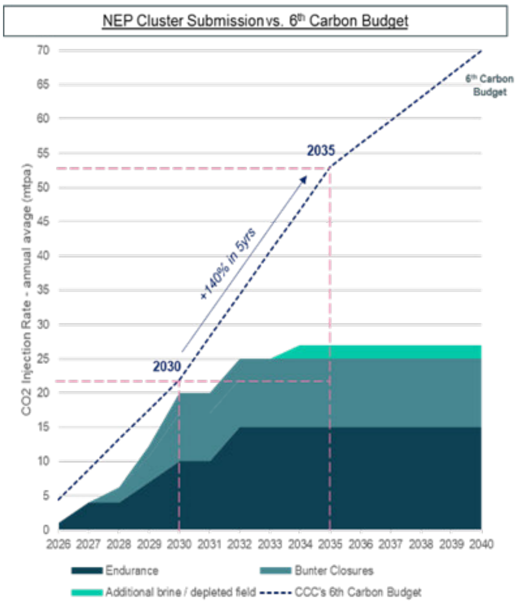
11. IMPACT OF PREVENTING ECC PLAN ON UK'S DECARBONISATION TARGETS

11.1 The prevention of the delivery of the ECC plan, as selected by government in October 2021, would represent the loss of the UK's largest CO2 store and a major obstacle to achieving the UK's CCUS requirements.

11.2 The ECC plan proposes that NEP transports and stores up to 20MTPA of CO2 by 2030 which represents more than 90% of Government's CCUS capacity targets and the 6th Carbon Budget.

11.3 Figure 9 below shows the Endurance Store's contribution to the CO2 storage capacity required by the 6th Carbon Budget.

Figure 9: NEP contribution to 6th Carbon Budget



12. RESTRICTIONS REQUESTED BY BP VIA PROTECTIVE PROVISIONS IN THE HORNSEA 4 DCO

12.1 The Protective Provisions that Orsted has proposed in the draft Hornsea 4 DCO assume that co-development is practically possible, and that NEP and Orsted will work together to find technical solutions to the challenges of co-development in the Overlap Zone.

12.2 As set out above, having assessed the extensive work that has been undertaken concerning possible co-development, NEP has concluded that due to the required technology for seismic monitoring (both to accurately monitor CO2 migration as well as possible leaks), rig, helicopter and well access requirements and the need for flexible locations of subsea infrastructure, co-location of the respective NEP and Hornsea 4 developments in the Exclusion Area will not be feasible for delivering the ECC plan. Orsted's proposed Protective Provisions are therefore inadequate as a means of protecting NEP's interests, and the public interest by frustrating the development of the Endurance Store. In view of the inherent unsuitability and inadequacy of those draft provisions, NEP has not commented further on any other issues associated with their nature and effect.

12.3 In order to preserve the deliverability of NEP and enable delivery of the ECC plan, bp (on behalf of NEP) has prepared draft protective provisions for inclusion in the Hornsea 4 DCO. The draft provisions and corresponding plan have been shared with Orsted and are included as Annex 2 to this submission. Specifically, they provide for:

12.3.1 an **'Exclusion Area'** within which Orsted may not construct any of the project authorised by the Hornsea 4 DCO. As set out in Section 10 above, this area has been optimised to represent the minimum possible area necessary to safeguard the delivery of NEP and represents a 27% reduction on the original NEP development footprint. It is not possible to reduce the area any further without compromising the deliverability of NEP; and

12.3.2 a smaller **'Notification Area'** within which Orsted may construct their project, but must first notify bp (as operator of NEP) and provide details of the works. This is a standard notification provision and is not intended to impede the Hornsea 4 in any way, but simply to ensure sufficient information is provided to bp to enable the safe and efficient delivery of NEP within the Exclusion Area.

12.4 The provisions proposed by bp are to apply unless otherwise agreed between the parties. This builds in the opportunity for certain aspects to be varied if appropriate (e.g. minor adjustments to the referenced co-ordinates and/or any of the collaboration or notification provisions to be edited if necessary); however, for the reasons set out above, the principles of the provisions proposed by bp and the need for separation of the Hornsea 4 and NEP project in the Exclusion Area will not change during the short to mid-life of the NEP project.

13. IMPACT OF THE RESTRICTIONS IN THE PROTECTIVE PROVISIONS ON HORNSEA 4

13.1 The Endurance Store is a fixed geological feature, with no ability to be relocated. In contrast, Hornsea 4 has some flexibility. The proposed creation of an Exclusion Area would still permit Hornsea 4 to deliver the same level of renewable generating capacity as proposed in the Hornsea 4 DCO. Hornsea 4 has the flexibility to relocate turbines into the remaining southern area of its Hornsea 4 RLB**.**

13.2 Figure 10 below shows the output from an independent third party forecast of the Hornsea 4 array, assuming no development constraints and that all 180 turbines (14MW capacity) are consented and constructed, providing 2.5 - 2.6GW of generation capacity. The forecast was created for NEP in 2Q 2021 by expert independent consultants in the offshore wind industry who were able to advise on the entire offshore wind value chain. The 180 turbines within the red line boundary submitted represents the maximum case within the Rochdale envelope. The actual build-out could be less, as evidenced by the Hornsea One and Two developments by Orsted currently in operation. The array in Figure 10 was forecast prior to the Hornsea 4 red line boundary amendment in July 2021, where a small area in the north-western corner was relinquished due to environmental sensitivities identified from bird surveys and consultation with special interest groups.

13.3 Figure 11 shows how all turbines from the northern part of the Hornsea 4 array can be relocated into the remaining southern area leaving the 'Exclusion Area' clear for CCUS development to its full potential. The total number of turbines remains at 180 as per Hornsea 4’s DCO, with an estimated 60 turbines requiring relocation to the southern part of the array area. Figure 11 also does not reflect the red line boundary change to the Hornsea 4 array in July 2021.

Figure 10 – Anticipated Hornsea 4 development scenario if all 180 consented wind turbines are constructed across the full area.

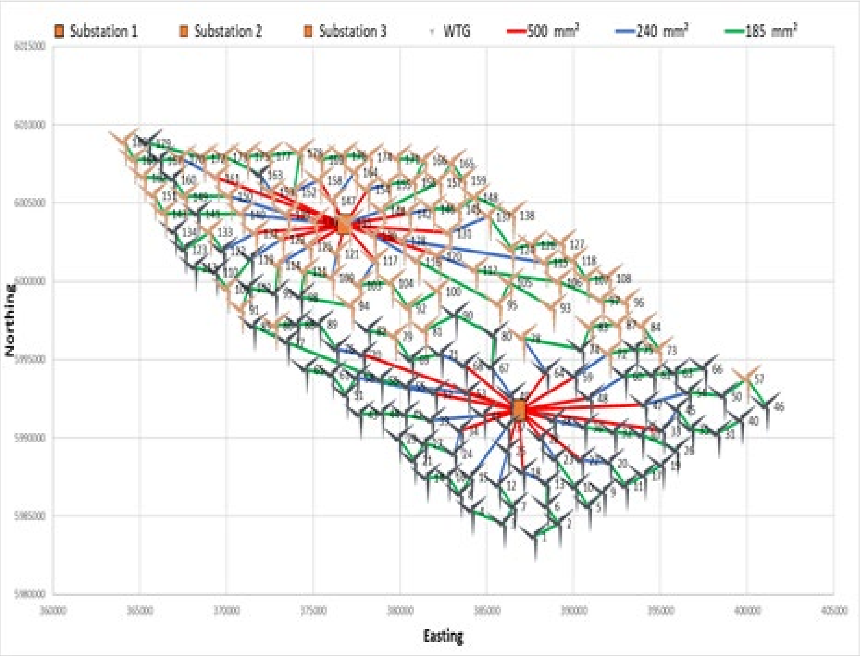
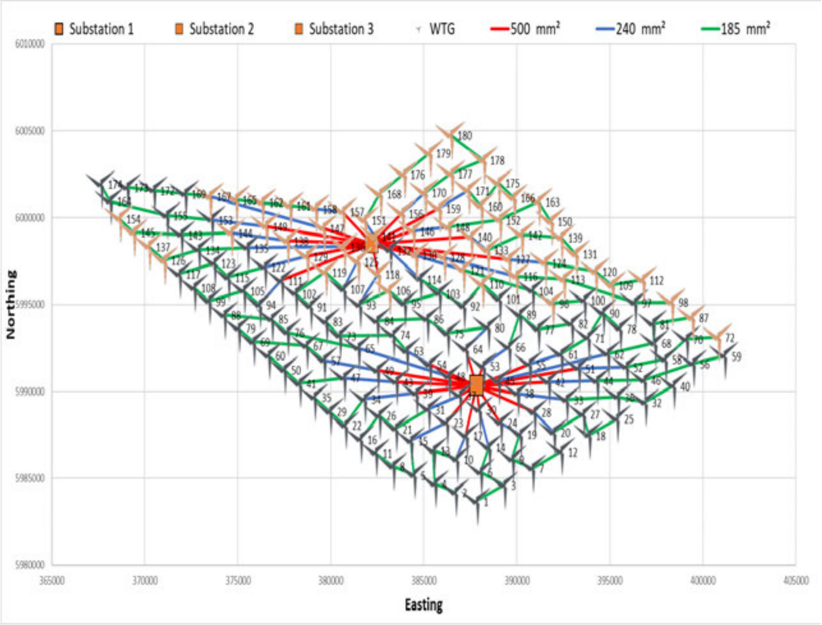


Figure 11 – Potential Hornsea 4 development scenario if all 180 consented wind turbines are constructed within the area outside the Exclusion Area



13.4 Estimates calculated by the independent consultants suggest that the increased density of turbines in the Figure 11 scenario could produce wake loss effects between 2.2 - 2.4% if the maximum number (180x 14MW) of consented turbines is constructed in the Hornsea 4 AfL area outside the Exclusion Area. Wake loss impacts arise from increasing the density of turbines in a specific area which reduces the power generation capacity of the turbines towards the centre of the array due to reduced wind resource. Condensing the turbines into a smaller geographical area may impact on their performance; however, it is considered this would only likely occur in the context of Hornsea 4 in circumstances where Orsted choose to build out the full 180 turbines for which consent is sought under their DCO. Were they to use fewer, larger turbines (as their DCO permits) then the same generating capacity could be achieved, without any such possible performance/wake loss impacts occurring.

14. IMPACT ON UK 6TH CARBON BUDGET OF CONSTRAINING OR NOT CONSTRAINING HORNSEA 4 AFL AREA VIA PROTECTIVE PROVISIONS FOR THE BENEFIT OF NEP

(i) Immediate impact of reserving the Exclusion Area for CCUS alone

14.1 Offshore wind is already on track to exceed its 6th Carbon Budget target of 40GW of generation capacity by 2030. With 52GW scheduled to be online by 2030 (11GW of operational capacity, 9GW of committed capacity and a further 32GW of capacity that is under development / pre-planning) and another 37GW of identified future leasing potential, offshore wind is set to exceed its 2030 target by 30%.

14.2 Losing the Endurance CO2 storage capacity due to the unviability of the ECC plan would result in a substantial loss of the UK's CCUS capacity (up to 20MTPA by 2030, greater than 90% of the 6th Carbon Budget target). This storage capacity will not be able to be sourced from other clusters in time to meet the target. There is therefore a very strong public interest case for ensuring that NEP, a FOAK and the largest proposed CCUS project in the UK, is not prevented, but allowed to help establish the CCUS industry and associated supply chain in the UK, Government CCUS targets and ensure that the ECC plan remains a viable development.

(ii) Potential for co-existence of offshore wind and CCUS in the Exclusion Area in future

14.3 For reasons explained elsewhere in this statement:

14.3.1 NEP’s monitoring plan requires that a baseline seismic survey occurs prior to development of the Endurance Store and injection of any CO2, followed by multiple repeat seismic surveys that will be undertaken at periodic times throughout the life of the project in order to track CO2 settlement and migration patterns;

14.3.2 the planned seismic acquisition (which needs to be undertaken using proven technology) will be done using 4D vessel towed streamers; and

14.3.3 the technological developments that would need to happen in order for NEP to use anything other than 4D vessel towed streamers will not occur before a FID decision has to be made in 2023 (see Sections 8 and 9 above).

14.4 Additionally, although (as NEP has indicated to stakeholders (BEIS, OGA, Crown Estate and Orsted) in theory the proposed Exclusion Area might become available for the offshore wind industry to develop in the future, it would be many years before any co-development could occur as:

14.4.1 once development of the Endurance Store begins, it would not be possible to switch from 4D vessel towed streamers and begin using any new (and proven) seismic monitoring technology for the Endurance Store until there has been adequate time to observe and understand the migration and containment of CO2 throughout the Endurance Store (and this will take at least 10 years);

14.4.2 any change to the technology being used for seismic acquisition and monitoring would need to be sufficiently proven and reliable that the relevant regulators (including the OGA) would need to agree to any proposed change (and at this stage, it is not possible to know how regulators might respond); and

14.4.3 the other challenges relating to regulatory requirements for access identified in Section 7 would need to be resolved.

(iii) Use of the Exclusion Area for offshore wind post-decommissioning of Endurance

14.5 CO2 injection and storage in the Endurance reservoir is limited by nature up to its economically developable capacity. At its estimated maximum injection rate and capacity, the Endurance operational and post closure monitoring lifetime could be less than 50 years from first injection, after which time the seabed could be reused for offshore wind development.

(iv) The importance of CCUS for energy transition to Net Zero

14.6 CCUS development is a necessary transitional technology for the UK to progress to Net Zero as it is a means of decarbonising industrial processes which renewable energy solutions cannot decarbonise. It can therefore support steady and reliable generation of low carbon power that complements the otherwise intermittent renewable energy generation from industries such as wind and solar, reducing pressure on the UK power grid and reducing costs to taxpayers and consumers.

14.7 CCUS also enables blue hydrogen production that can be used as a substitute to natural gas (methane) in industrial processes, providing a centralised carbon emissions source to capture carbon from, and produce a clean by-product for use as a raw material in many industrial processes, negating their carbon emissions and producing water as a by-product instead. Renewable energy projects cannot be developed quickly enough to provide sufficient energy to fully decarbonise the UK power grid and also to generate enough renewable energy required to enable green hydrogen to be produced from electrolysing water for use by industries in time to meet Government decarbonisation targets.

14.8 The development of Endurance now therefore assists with the energy transition at a crucial time in the process of UK and global decarbonisation, while also allowing for future development of offshore wind in the Exclusion Area in the longer term.

15. JUSTIFICATION FOR PROPOSED DISAPPLICATION OF THE INTERFACE AGREEMENT IN THE PROTECTIVE PROVISIONS

(i) History and purpose of the Interface Agreement

15.1 A further important consideration in the development of Endurance and its relationship to Hornsea 4 is the existence of the Interface Agreement ('IA'). As explained in Section 5, the IA was entered into in February 2013 between Carbon Sentinel Limited (as the "Carbon Entity"), Smart Wind Limited (as the "Wind Entity") and TCE. It is varied and adhered to by an agreement dated 12 September 2016 between (1) TCE (2) Smart Wind Limited (3) Carbon Sentinel Limited and (4) Orsted, and by a Deed of Covenant and Adherence dated 10 February 2021 between (1) TCE (2) Orsted (3) Smart Wind Limited (4) Carbon Sentinel Limited and (5) bp.

15.2 The IA was intended to regulate how the respective projects would interact and co-exist with one another in the Overlap Zone. It was originally put in place during the pre-feasibility stage of both developments, when it was considered that co-existence in the Overlap Zone would be possible. For the reasons set out earlier, this is no longer the case. Following detailed technical work, bp's position is now that co-existence in the Exclusion Area is not possible if the NEP project is to be delivered to meet the ECC plan.

15.3 In circumstances where it is possible for only one project to proceed in the Exclusion Area, the terms of the IA create the risk of significant financial liability being incurred by Orsted or bp.

15.4 The financing model for NEP (discussed in Section 9 above) means that NEP will have limited ability to cover additional exceptional costs (as would apply to such a compensation payment). An economic regulator for CCUS has not yet been appointed and no guidance has been provided on which costs will be allowable. However, it is noted that regulators use benchmarks from comparable industries to set the weighted average cost of capital and drive investor returns. Existing benchmarks include established regulated industries with low and stable returns that do not allow for large disallowances. In this context, it is quite possible that the regulator may 'disallow' any compensation payments bp, on behalf of NEP, was required to make under the IA. If the scale of such compensation payments were large it could render the project uneconomic. Certainly some of the project value losses that Orsted in discussions with bp has suggested might arise in respect of Hornsea 4 if the Exclusion Area were undevelopable for the Hornsea 4 project would render NEP unviable. The prospect of such costs falling to NEP investors (being disallowed by the regulator) may in itself stop those investors from progressing with the NEP project. Equally, the risk of such compensation payments arising is likely to deter debt funders. Additionally, further significant uncertainty exists concerning whether the Government would commit to all such costs (regardless of their scale) being recoverable as part of whatever regulatory system is put in place.

15.5 In summary, the IA is not appropriate in view of the present day reality, and its terms are now adverse to the public interest in the successful delivery of Government policy (the development of CCUS).

(ii) Why disapplication of the IA via protective provision is necessary rather than commercial negotiation of a replacement agreement

15.6 The focus of both projects has, until recently, been entirely on seeking a technical solution which would enable co-existence in the Exclusion Area.

15.7 It has now, however, become clear to bp through the results reported in the bp Technical Assessment report (Annex 1) that co-existence within the Exclusion Area is impossible.

15.8 It is also clear that the risks presented by the IA for the NEP project (and delivery of the UK's decarbonisation policy) are too high to bear, and urgently need to be resolved in the public interest.

15.9 It is for this reason that bp is requesting protective provisions which would disapply the IA. This approach, of disapplying the IA and replacing those of its provisions which remain relevant and appropriate with suitable protective provisions, gives the Secretary of State the power to grant a DCO for Hornsea 4 which enables both projects to be delivered viably side-by-side.

15.10 This approach affords Orsted, bp, the ExA, and any other Interested Parties the opportunity to work together through the course of the DCO examination to make any changes or additions to the draft protective provisions which are considered necessary to strike a balance between the needs of the two projects in the context of the wider Government policy, and the desirability that both projects are facilitated.

15.11 Whilst the disapplication of an agreement between parties under a DCO is novel, Section 120(3) of the Planning Act 2008 enables the Secretary of State to include any provision "relating to, or matters ancillary to, the development for which consent is granted" and so the ability to do is clear and fully justified in these unique circumstances.

(iii) The need to protect against liability for antecedent breach

15.12 bp's proposed protective provisions would also prevent the parties to the IA claiming for antecedent breach of the IA, following the coming into force of the Hornsea 4 DCO and the disapplication of the IA. This provision is important because should the DCO be granted with provisions which prevent Orsted from developing Hornsea 4 infrastructure in the Exclusion Zone, there is a risk that Orsted could take action against bp under the terms of the IA for bp seeking and obtaining such provisions (at a time when the IA existed and therefore was actionable, before its disapplication by the DCO). Therefore, should the Secretary of State be minded to disapply the IA via the protective provisions, it is important that its disapplication goes hand in hand with a provision which prevents action for antecedent breach. Without such a provision, there is a risk that bp's action in successfully putting forward protective provisions which restrict the Hornsea 4 project could give rise to significant liability for the NEP project. There is a risk that such liability could render the NEP project unviable, as part of the ECC plan. This risk would certainly deter essential investment in the project.

(iv) No adverse impact on The Crown Estate of disapplying the IA

15.13 Besides Orsted and bp, the other party bound by the IA is TCE. We do not consider there is any adverse impact on TCE through the disapplication of the IA given the limited nature of the provisions relevant to TCE in the IA.

(v) Disclosure of the IA to the ExA

15.14 We recognise that the ExA will want to be provided with a detailed understanding of the IA in order to consider the need for its proposed disapplication, and to make a recommendation to the Secretary of State in this regard. We will continue discussions with TCE and Orsted with a view to providing the ExA with a copy of the agreement as soon as possible, along with a summary of its terms and a fuller justification of its disapplication.

16. INADEQUACY OF HORNSEA 4'S ENVIRONMENTAL IMPACT ASSESSMENT

(i) Introduction

16.1 NEP and Orsted disagree about the extent to which their projects can co-exist in the Overlap Zone. This presents a particular complexity in respect of the assessment of the cumulative impact of the two projects, which Orsted is required to carry out pursuant to the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017. Specifically, what footprint should be assumed for each project when carrying out that assessment: (i) the complete overlap which Orsted believes is possible through use of technical solutions not recognised by NEP; or (ii) no overlap, instead development of the two projects in mutually exclusive adjacent zones (which would be the effect if the Hornsea 4 DCO were granted with NEP's proposed protective provisions). Currently, Orsted's EIA presents only an assessment of the former, and concludes that with the necessary mitigation in place the impact of NEP on Hornsea will not be significant. NEP considers this assessment to be unreliable and an inadequate basis for decision-making, for the reasons set out below.

(ii) Summary of Hornsea 4's approach to cumulative assessment

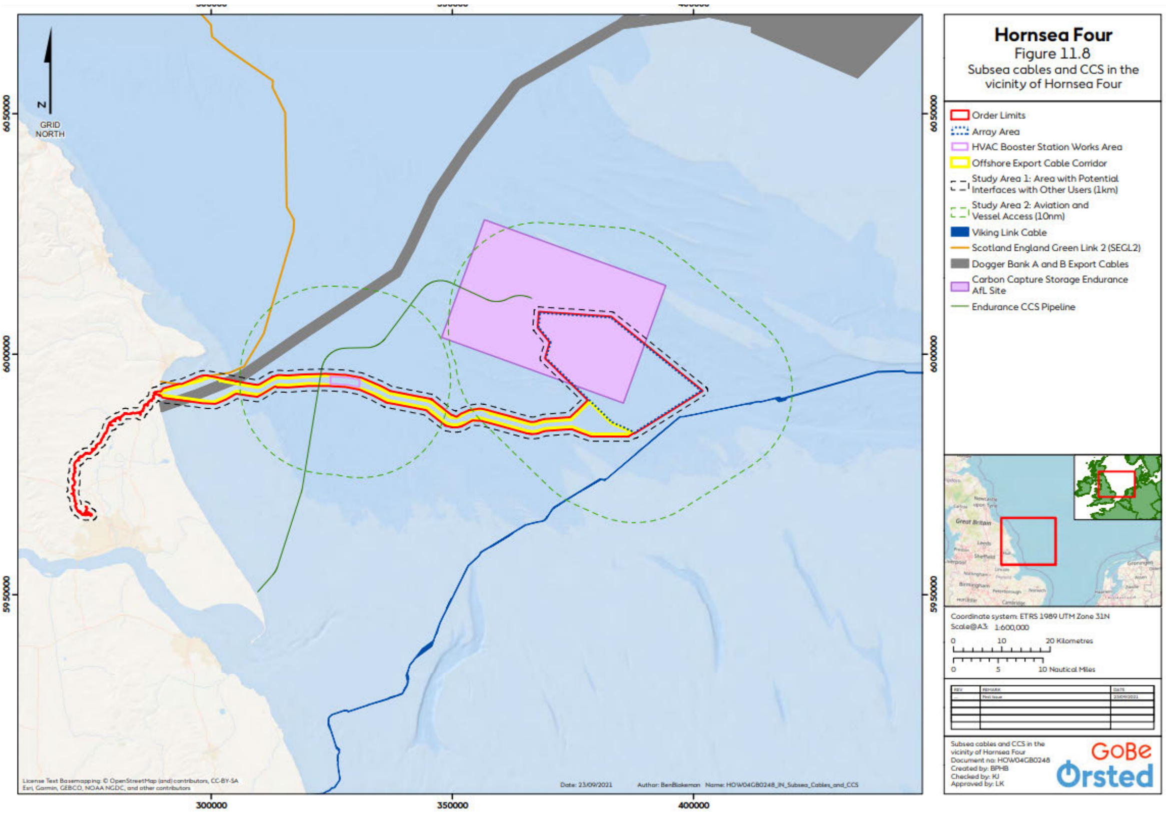
16.2 The Cumulative chapter of the Hornsea 4 DCO EIA states: "*In May 2019, Drax Group, Equinor and National Grid Ventures signed a Memorandum of Understanding committing to working together to explore opportunities for creating a zero carbon cluster in the Humber (now known as Zero Carbon Humber), utilising the Endurance reservoir as a potential carbon capture and storage (CCS) site. In parallel, in October 2019, the Applicant was approached by BP on behalf of Net Zero Teesside who are also looking to use the Endurance reservoir for CCS. Since then, consultation has been ongoing between the Applicant and both National Grid Ventures and BP regarding Endurance. At the time of writing, no offshore planning applications have been submitted for the Endurance project and only limited information is available for the purposes of the cumulative assessment*."

16.3 There is no other reference to the Endurance reservoir in the Chapter.

16.4 There is, however, a separate Chapter of the EIA (Chapter 11) entitled "Infrastructure and Other Users" which is provided expressly to consider the impact of Hornsea 4 on oil and gas and other offshore infrastructure.

16.5 The need for this assessment appears to be driven by the requirements of NPS EN-3, paragraph 2.6.179 of which states: **"***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 effect of the proposed development on such existing or permitted infrastructure or activities. The assessment should be undertaken for all stages of the lifespan of the proposed wind farm in accordance with the appropriate policy for offshore wind farm EIAs*". We note that this only refers to existing or licensed activities, but para 2.6.177 refers also to likelihood of future infrastructure including carbon capture.

16.6 At para 11.7.1.54 of Chapter 11, the Endurance reservoir is mentioned: "*There are currently two planned CCS projects that propose to make use of the Endurance reservoir, the proposed NZT and ZCH. In October 2020, it was announced that BP, Eni, Equinor, Shell and Total had formed the NEP, with the purpose of developing the infrastructure within the Endurance site to serve these projects. There is limited publicly available information available on the project proposed within the Endurance CCS site due to the pre-planning status of the projects. However, the NEP provided information to the Applicant on the proposed Endurance CCS site, with area of potential overlap shown in Figure 11.8. The Endurance CCS site may result in the Hornsea Four offshore ECC crossing the CO2 injection pipeline (Easington to Endurance) (see Figure 11.8).The project intends to gather and store CO2 generated from the Teesside and Humber industrial clusters with injection rates progressively ramping up from an initial 4 Mtpa (million tons per annum) starting in the mid-2020s up to 15 Mtpa over time"*



16.7 The assessment itself is set out in sections 11.11.3 (construction), 11.11.7 (O&M) and 11.11.13 (decommissioning), and does not identify any mitigation, but assumes that (i) with effective engagement it will be possible to identify such measures, and that (ii) with such measures in place, co-existence will be possible. In all three cases versions of the following standard text is included (the text below relating to the construction phase):

> *"The Applicant has engaged with the developers of the Endurance CCS site during the pre-application phase with regards to developing an understanding of the proposed CCS development activities and also establishing the principles and process for communication, collaboration and co-existence for the construction phase. This engagement is ongoing, and it is expected that Hornsea Four will:*
>
> - *Provide full details on the proposed construction activities and planned infrastructure that could impact on the CCS development activities to the developers of the Endurance CCS site to allow them to plan and design their projects accordingly;*
> - *Establish a set of working principles through an Interface Management Group comprising the project managers for the Applicant and the developers of the Endurance CCS site, establishing communication and liaison on planned activities (such as planned construction and development activities) so as to be able to plan and reduce or avoid adverse effects;*
> - *Establish the co-existence principles as the details of the Endurance CCS development site become more certain, on the basis of working together to minimise the effects on the Applicant's and the Endurance CCS development and maximise the opportunities for co-location and coexistence; and*
> - *Work together to plan development activities and to identify synergies and opportunities common to both the Applicant's and the Endurance CCS development.*

In addition to the above principles and processes, crossing and proximity agreements will be sought (Co107), particularly in relation to the Easington to Endurance CO2 injection pipeline. Such agreements will include the ability of a pipeline operator to access their infrastructure during Hornsea Four construction as far as practical."

16.8 As such, it appears that Hornsea 4's EIA assumes that there is a total overlap between two projects in the area shown on Figure 11.8 (copied above) and that co-existence will be possible. No analysis is presented to substantiate the assumption that the two projects will be able to co-exist in the Overlap Zone, and there is no explanation as to how this will or could be achieved. The residual impacts (assuming mitigation is possible to allow co-existence as Hornsea envisage in Chapter 11) is said by Orsted to be not significant. Prior to the application of such mitigation the impact is admitted to be 'moderate' or 'large' and therefore a significant adverse effect for the purpose of EIA.

(iii) NEP's position and relevance to the Hornsea 4 EIA

16.9 For the reasons set out in Section 7 of this paper, NEP's position is that no such mitigation could possibly render an overlap between the two projects viable for NEP as part of the ECC plan.

16.10 The mitigation relied upon by Orsted to enable co-existence to be successfully achieved in the Overlap Zone in Chapter 11 of the EIA is unspecified and undeliverable, and therefore their assessment is flawed. There is no circumstance in which NEP would be able technically or financially to carry out the NEP project as part of the ECC plan if development of Hornsea 4 infrastructure is allowed in the Exclusion Area.

16.11 bp suggests that the ExA therefore requests that Orsted provides a supplemental assessment, setting out the environmental impacts of Hornsea 4 in the event that NEP's protective provisions are adopted (preventing any activities by Orsted in the Exclusion Area), and a revised assessment of the effects in the absence of those protective provisions, addressing the flaws identified above. This will enable the Secretary of State, if he so chooses, to grant the Hornsea 4 DCO mindful of the effects of those protective provisions.

16.12 We are also puzzled by the absence of reference to the Endurance reservoir from the cumulative chapter of Orsted's EIA. Again, bp suggests that the ExA asks Orsted to provide a supplement to that chapter which takes account of the NEP project.

Annex 1

bp Technical Report

Carbon Capture, Usage and Storage (CCUS) and Offshore Wind (OW) Project Overlap Report

A Technical Assessment of the Endurance Reservoir and Hornsea Project Four Wind Farm

December 2021

The information in this document has been prepared by bp on behalf of itself and its partners on the Northern Endurance Partnership project for review by The Crown Estate (TCE) and Orsted only. While bp believes the information and opinions given in this report to be sound, all parties must rely upon their own skill and judgement when making use of it. By sharing this document with The Crown Estate (TCE) and Orsted, neither bp nor its partners on the Northern Endurance Partnership project make any warranty or representation as to the accuracy, completeness, or usefulness of the information contained in the document, or that the same may not infringe any third-party rights. Without prejudice to the generality of the foregoing sentences, neither bp nor its partners represent, warrant, undertake or guarantee that the outcome or results referred to in the document will be achieved by the Northern Endurance Partnership project. Neither bp nor its partners assume any liability for any loss or damages that may arise from the use of or any reliance placed on the information contained in this document.

Contents

Glossary of Terms

AfL: Agreement for Lease

AUV: Autonomous Underwater Vehicle

BEIS: Department for Business, Energy and Industrial Strategy

CCC: Climate Change Committee

CCS: Carbon Capture and Storage

CCSA: Carbon Capture and Storage Assocation

CCUS: Carbon Capture, Usage and Storage

CfD: Contract for Difference

CNS: Central North Sea

CO_2: Carbon Dioxide

CS001: Carbon Storage Licence 001

DCO: Development Consent Order

DECC: Department of Energy and Climate Change

ECC: East Coast Cluster

EIA: Environmental Impact Assessment

IFR: Instrument Flying Rules

FEED: Front End Engineering Design

FOAK: First Of A Kind

GW: Gigawatt

Hornsea 4: Hornsea Project Four

HR: High Resolution

JU: Jack Up (drilling rig)

Kv/Kh: Ratio of Vertical Permeability over Horizontal Permeability

MMV: Measurement, Monitoring, and Verification

MT: Million Tonnes

MTPA: Million of Tonnes Per Annum (average)

NEP: Northern Endurance Partnership

NGC: National Grid Carbon

NSIP: Nationally Significant Infrastructure Project

OBN: Ocean Bottom Node

OGA: Oil and Gas Authority

OGTC: Oil and Gas Technology Centre (now known as Net Zero Technology Centre, NZTC)

OREC: Offshore Renewable Energy Catapult

OSV: Offshore Supply (or Support) Vessel

OW: Offshore Wind

OWIC: Offshore Wind Industry Council

POB: Personnel On Board

R&D: Research and development

RW: Relief Well

SAR: Search and Rescue

SIMOPS: Simultaneous Operations

SNS: South North Sea

SRMS: Storage Resource Management System

T&S: Transportation and Storage

TCE: The Crown Estate

TD: Total Depth

TRI: Transportation and Storage Regulated Investment Model

TS: Towed Streamer

TVD: True Vertical Depth

UKCS: United Kingdom Continental Shelf

VFR: Visual Flying Rules

ZDA: Zone Development Area

3D: Three Dimensional

4D: Four Dimensional

1.0 Executive Summary

The Endurance reservoir is the cornerstone of the Northern Endurance Partnership (NEP) project, which will provide transportation and storage of CO_2 for a range of CCUS projects across Teesside and the Humber as part of the East Coast CCUS Cluster (ECC). The ECC was selected in 2021 as a winner of the Government's CCUS Cluster Sequencing Process [1], and is set to become the largest CCUS network in the world. With an estimated storage capacity of 450 million tonnes (MT) and injection rate of 15 million tonnes per annum (MTPA), Endurance will play a major role in delivering the Government's latest ambition of 20-30MTPA by 2030 (in line with the Climate Change Committee's (CCC) 6th Carbon Budget). Industrial decarbonisation through use of CCUS technology will constitute about one sixth of the UK's current emissions reductions (refer to section 5.0).

The Hornsea Project Four wind farm development (Hornsea 4) is an important component of meeting the Government's 40 gigawatts (GW) clean electricity target by 2030. Both developments serve different objectives of key Government policies as Nationally Significant Infrastructure Projects (NSIP) with overlapping use of the United Kingdom Continental Shelf (UKCS) seabed, leased by the Crown Estate (TCE).

The original overlap between the two lease areas is 150 km^2 (Figure 1 – left). Following extensive evaluation and collaboration between NEP and Orsted over a 2-year period (refer to section 3.0), the area of overlap required to develop the Endurance reservoir has been reduced to a minimum requirement of 110 km^2. The reduction is based on the key risks and challenges identified and the associated mitigations forming the Endurance development plan as shown below.

The reduced area of overlap needs to be clear of wind turbine installations during the field life of the Endurance reservoir, until its full developable storage capacity is reached and the licence is transferred to the Government.

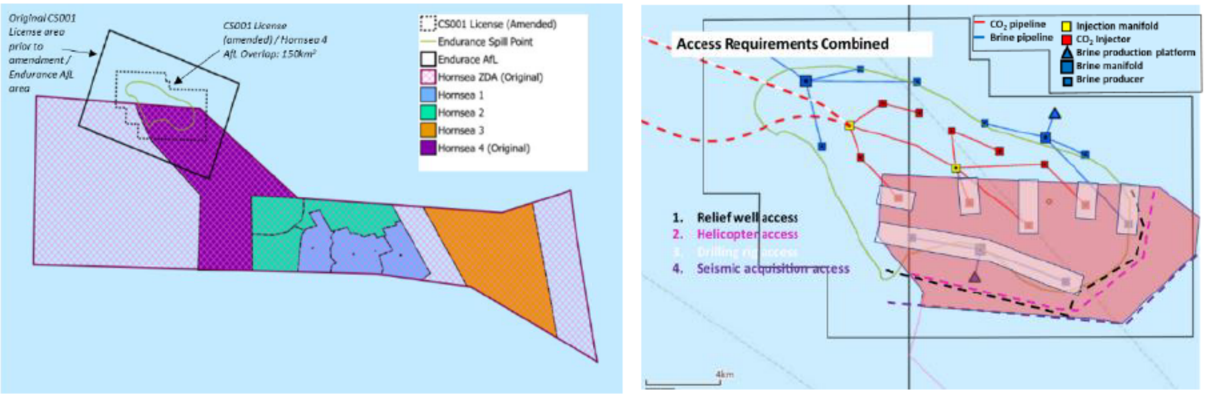


Figure 1: (Left) Endurance licence area mapped onto Hornsea ZDA showing the initial extent of overlap. (Right) Endurance development plan with minimum requirements in the overlap area, referred to as 'Scenario 3', as presented to all parties in May 2021 and finalised in June 2021.

Given that there are no comparable stores that could replace Endurance's role for UK CCUS, it is not straightforward to compare the alternative uses of the overlap area. As a conservative comparison, the Endurance seabed area can store an estimated 12 times the equivalent carbon dioxide (CO_2) reduction per square kilometer (km^2) provided by offshore wind using the planned Hornsea 4 wind array configuration (refer to Appendix C).

The Endurance development plan and the minimum requirements in the overlap area are driven by the unique geological and geographical features of the reservoir itself (refer to section 6.0), as well as the key challenges grouped under the following categories (refer to section 7.0) :

- Wells and Rig Access
- Impact on Infrastructure co-location (and its impact on storage capacity)
- Store Monitorability

Discovered in 1970, Endurance is the best appraised CO_2 store in the Southern North Sea (SNS) containing 2 exploration wells and 1 recent appraisal well from the National Grid-led White Rose Carbon Capture and Storage (CCS) development in 2016. Endurance is a saline aquifer reservoir that is capable of dense phase CO_2 injection at high pressure and at high rates, unlike depleted oil and gas reservoirs. The reservoir stretches over an equivalent seabed area of 140 km^2, and is ideally located geographically to serve both the Teesside and Humber industrial clusters. It lies beneath over 1km of overburden rock up to the seabed, which acts as a natural seal to contain the CO_2 injected for perpetuity. Each injection well is expected to provide 1-1.5 MTPA of CO_2 injection over at least 30 years, with brine producing wells installed in later field life to manage reservoir pressure. The Endurance overburden is relatively shallow when compared to typical offshore hydrocarbon reservoir development analogues which reduces the cost of wells if drilled vertically, but significantly limits the ability to drill deviated wells to no more than a 1.25km horizontal step out (relative to the top of the Bunter reservoir). The shallow overburden also makes it ideal for towed-streamer vessel seismic acquisition to achieve the high quality imaging required to evidence containment of CO_2 within the storage complex and monitor CO_2 plume migration within the reservoir.

Despite prior seismic acquisition and the presence of 3 existing well penetrations with 5-to-7 inch boreholes at the reservoir sand face, the data collected thus far is insufficient to fully extrapolate the properties of the rock quality across a 140 km^2 reservoir. Therefore significant uncertainty remains, which is typically mitigated through an “appraise while develop” approach, similar to a standard hydrocarbon reservoir development process. This approach consists of establishing a baseline seismic acquisition (being planned by NEP in 2022), and repeating it regularly with the exact same technology and with the parameters as similar as possible. The consistency in methodology allows for construction of a reliable, time-lapsed four dimensional (4D) seismic image that will inform where the CO_2 injectors and brine producers will be progressively located based on actual, observed CO_2 plume migration (also known as monitoring for reservoir conformance).

The ability to image and evidence where CO_2 is stored within the Endurance reservoir throughout the injection phase and all the way to closure and transfer to the Government, underpins the ability of bp as the operator to provide confidence to the regulator and the public, in the safety of CCUS operations as a First of a Kind (FOAK) development in the UK. Containment, conformance and confidence constitute the Licence to Operate (LTO) for NEP, regulated by the Oil & Gas Authority (OGA), and requires NEP to utilise best available, proven technologies and techniques to mitigate the risks and challenges of developing the reservoir. This principle is critical given there is no operational experience of CCUS in the UK.

Within the specific context of Endurance, there is a need for flexibility in positioning of wells and associated subsea infrastructure across the reservoir, along with ongoing helicopter and rig access to enable safe operations. This is incompatible with the requirement for certainty in locating wind turbine infrastructure within the Hornsea 4 array to enable the development of a business case and subsequent bid into the Government's Contracts for Difference (CfD) process.

With regards to infrastructure co-location (e.g. adjacency of subsea trees and pipelines to wind turbines and high power cables), compromises can be achieved through collaboration and early planning. NEP and Orsted's efforts in coordinating survey activities, minimising pipeline and cable crossings and ensuring potential electromagnetic interference is minimised are good examples. NEP has independently accepted cost increases for longer pipeline routing to avoid Hornsea 4, given the strategic importance of co-existance. However, long term effects such as seabed disturbance from reservoir pressurisation and unplanned CO_2 venting, whilst very low probability events, cannot be completely excluded during the operation of Endurance. This creates commercial and legal complexities around liabilities which have not been the focus of this technical assessment.

More importantly, given that past experience of CCUS developments globally have repeatedly shown the reservoir behaviour is different from model predictions, any encroachment of fixed wind turbine structures risks preventing NEP from locating CO_2 injector wells and brine producer wells to manage overpressure of the reservoir relative to seal capacity. The immediate consequence is a loss of up to 70% of the Endurance reservoir storage capacity if NEP is solely reliant on the safe pressure limits of the natural seal without brine production.

Towed streamer (TS) seismic acquisition is uniquely suited to the shallow geology and CO_2 plume detection within a saline aquifer, is the most established and well-understood technique, and offers unparalleled quality of data. Towed streamer seismic comes at a cost that is economic and efficient to the UK taxpayer as required by the economic regulator under the Transportation and Storage Regulated Investment (TRI) business model. Given the stated minimum distance between wind turbines and array density in the Hornsea 4 wind farm development consent order (DCO), it is not possible to run conventional towed streamer seismic acquisition within the wind farm. Various alternatives, including use of Ocean Bottom Node (OBN) technology, were explored in collaboration with Orsted and third parties through technical workshops. However, none of the alternatives deliver the quality of data and maturity of technology required for large scale commercial deployment on the largest (and FOAK) CCUS project in the UK, particularly when the requirements for the Government to adopt long term leakage risk and to assure financeability are taken into account (refer to section 4.0).

The specific challenges and risks of co-development in the Endurance-Hornsea 4 overlap area are consistent with the findings of the Crown Estate sponsored CCUS-Offshore Wind overlap study with participation by both industries [7]. NEP welcomes the formation of the co-location forum which was created as recommended by the study. NEP believes that techno-commercial and regulatory solutions can be developed for many of the co-development challenges with time, provided there is operational data and evidence to prove many of the options investigated during the course of this technical assessment. Development of Endurance using currently proven technologies will provide the confidence necessary to advance those options and other opportunities identified for the benefit of both industries (refer to section 8.0).

It is vital to recognise that CCUS is a nascent industry compared to the offshore wind industry, albeit with many potential parallels, including the optimisation of seabed usage, the development of UK supply chains and the importance of leveraging scale to reduce costs. The impact on development of the Endurance reservoir and storage capacity has an outsized impact on the growing UK CCUS industry as a whole and therefore the delivery of the UK's Net Zero ambitions.

2.0 Introduction

This report investigates the limitations and opportunities of co-development between the Hornsea 4 offshore wind (OW) development and the Northern Endurance Partnership CCUS project, located offshore in the Southern North Sea, east of Teesside and the Humber (Figure 2).

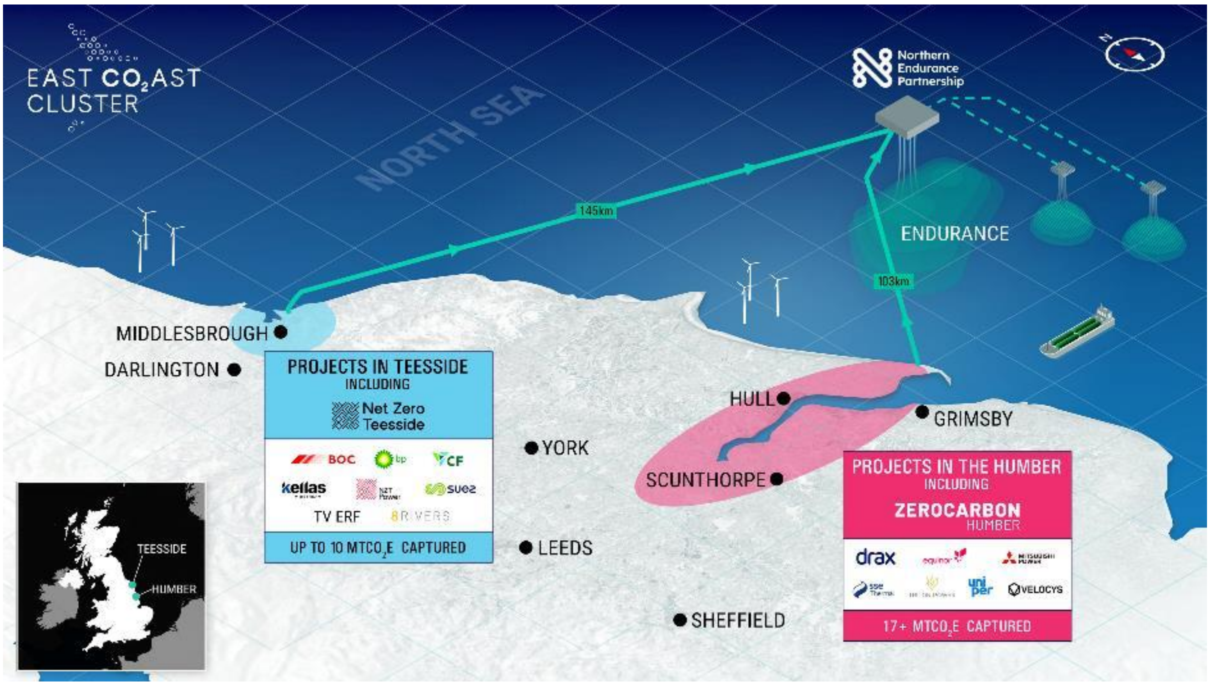


Figure 2: East Coast Cluster Overview

The historical background related to the leasing of both developments is described below, followed by how the layouts of both developments have evolved with time in section 3. Section 4 provides context on the current state of the CCUS industry, followed by further context on the importance of both industries in meeting the UK's net zero targets by 2050 in section 5. Section 6 describes the unique features of the Endurance store which shapes its development plan accordingly. Section 7 goes into detailed description of the technical risks and challenges of co-development within the overlap area, followed by opportunities for future OW and CCUS co-development that can be progressed particularly through the Crown Estate sponsored co-location forum. Finally, section 9 provides a summary of the conclusions and NEP's position on the need for the overlap area to be clear of wind turbine installations during the field life of the Endurance reservoir.

NEP builds on National Grid Carbon's (NGC) 'White Rose' CCUS development during the last DECC-sponsored[1] CCUS competition, which matured the Endurance saline aquifer as a CO_2 store through drilling of an appraisal well and completion of front end engineering design (FEED) studies in 2016. On 6th November 2012, National Grid Carbon (via its affiliate Carbon Sentinel Ltd) was awarded the UK's first carbon storage licence (CS001) and on 6th January

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[1] Department of Energy and Climate Change 'DECC' is now the Department for Business Energy and Industrial Strategy 'BEIS'

2013, a corresponding Agreement for Lease (AfL) was granted by the Crown Estate over the Endurance structure in the Southern North Sea (quadrant 42 and 43) [3]. Operatorship of CS001 and the AfL were transferred to bp, as the duty holder on behalf of the NEP partnership via deeds of amendment. Equinor and National Grid are co-licencees on CS001 whilst bp is sole leasee on the AfL on behalf of NEP. NEP was selected by BEIS as a Track 1 cluster following the CCUS Cluster Sequencing Process in October 2021 to deliver the ECC bid, with a target to commence CO_2 injection from late 2026.

The Hornsea 4 project is operated by Orsted, in conjunction with Hornsea projects 1, 2 and 3, which are located to the southeast of Hornsea 4. In 2010, SMartwind Ltd was awarded a Zone Development Agreement (ZDA) by the Crown Estate which provided the area of seabed large enough to develop all four Hornsea projects. In 2015, DONG Energy acquired SMartwind and in 2017 was renamed to Orsted. In 2016, Orsted and Crown Estate negotiated the subdivision of the Hornsea ZDA into project specific AfLs. Orsted submitted a DCO for Hornsea 4 to the Planning Inspectorate in September 2021 which seeks planning permission to construct up to a maximum of 180 wind turbines. Construction of wind turbines is expected during 2027-28 upon obtaining planning consent [4].

In recognition of the overlapping northwest section of the Hornsea 4 AfL with the southern half of the Endurance AfL (see figure 4), National Grid, SMartwind and Crown Estate entered into an interface agreement on 14th February 2013. Since the inception of the interface agreement, all parties have met multiple times to discuss project progress, with meeting frequency ramping up since 1Q 2020 due to increased activity on both Hornsea 4 and NEP. A summary of the discussions relating to the evolution of each project's development layouts has been included in section 3. This does not include communications between the relevant parties of development layouts prior to 2020 from either the NEP, White Rose or Hornsea 4 projects.

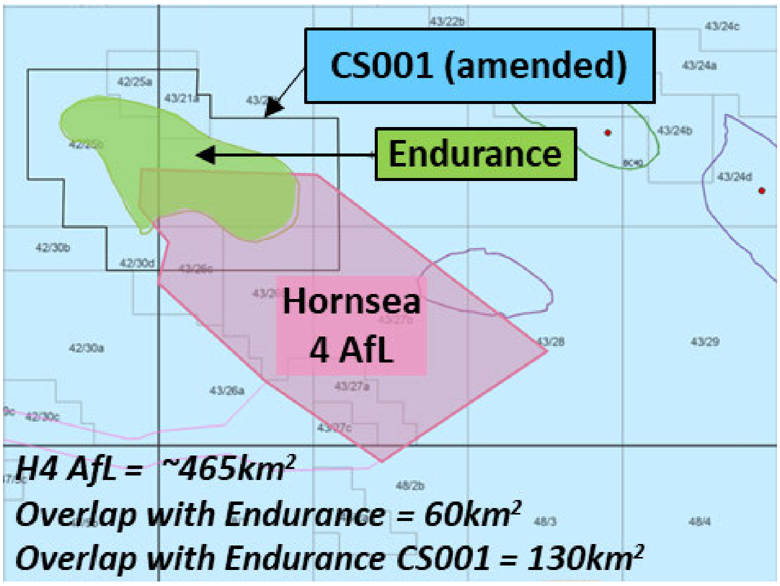


Figure 3: Endurance – Hornsea 4 area of overlap as defined by the Hornsea 4 DCO and the amended CS001 licence boundaries

3.0 Context, History and Layout Evolution

3.1 Timeline of Collaboration

Following the reconfiguration of the Hornsea ZDA between Smartwind and TCE in March 2016 which converted each of the Hornsea offshore wind project phases into individual AfLs, the overlap between the Endurance and Hornsea 4 lease areas became more prominent. BP, on behalf of NEP, and Orsted, committed to seeking technical options that would maximise co-development during the course of over 2 years, through dialogue and technical 'deep dive' workshops involving industry experts and government agencies (Figure 4 - overleaf).

Timeline of collaboration

	1Q'20	2Q'20	3Q'20	4Q'20	1Q'21	2Q'21	3Q'21	4Q'21
NEP – Orsted Layouts information exchange & public notifications	◆ 4 March Endurance White Rose development : • K.42 Storage Risk Assessment, Monitoring and Corrective Measures Report (2016) [4] • K.43 Field Development Report (2016) [6] • Hornsea 4 Red Line Boundary per PEIR available on website	◆ 4 June • Endurance full field development unconstrained • Hornsea 4 Red Line Boundary updated 29 May	◆ 17 Sept • Endurance full field minimum requirements for reservoir monitoring and rig access presented. • Hornsea 4 Red Line Boundary updated 23 Sept following meeting				◆ 2 Jul • Hornsea 4 red line boundary update 2 Jul, reducing area of overlap based on environmental requirements to minimize impact on Auks bird species.	◆ 27 Oct • Hornsea 4 DCO application accepted by Planning Inspectorate (PINS) ◆ 1 Nov • East Coast Cluster (NEP) confirmed as Track 1 cluster by BEIS
Technical deep dive workshops inc NEP partnership expertise (Equinor, Shell) and Orsted external expertise			Helicopter and rig access : • bp described key factors driving width and orientation of access corridors including CAA regulations. • Orsted shared current windfarm operational practices to minimize width of access corridors.	◆ 10 Nov ◆ 12 Nov Seismic monitoring Part 1: • bp described Endurance reservoir-specific monitoring requirements based on operational learnings from the NEP partnership globally • Orsted invited external opinion to suggest the investigation of more experimental techniques e.g. p-cable, sparse OBN.	◆ 12 Feb Seismic monitoring Part 2: • bp shared evaluation of alternative seismic monitoring technologies including pros and cons. 4D towed streamer seismic remained the most suitable method and best available technology for Endurance.			◆ 1 Oct Ocean Bottom Node (OBN) technology: • bp shared current and future constraints of OBN, including direction of future technology development. • Reiterated 4D towed streamer as the most suitable method and best available technology for Endurance, consistent with Scenario 3 shared.
Multilaterals inc the Crown Estate, OGA and other parties		◆ 1 July • Endurance as a hub for Bunter saline aquifer stores presented. • Suggestion of up to 10% lease area flexibility to reduce area of overlap rejected by Orsted, given incompatibility with development timing and duration of environmental surveys for new area that would need to be undertaken.		• Summary meeting to lay out all key issues and collaborate on identifying possible solutions through a range of lenses e.g. technical, commercial, regulatory, legal	◆ 21 Jan ◆ 5 Feb • Independent CCUS-Offshore Wind study led by Net Zero Technology Centre (NZTC) and Offshore Renewable Energy Catapult (OREC), sponsored by the Crown Estate.	5 May ◆ ◆ 14 June • Co-development scenarios presented as follows : ➤ Scenario 1: Endurance unconstrained ➤ Scenario 2: Hornsea 4 unconstrained ➤ Scenario 3: Endurance minimum requirements ➤ Scenario 4: Hornsea 4 reduced turbines in overlap area	◆ 7 Jul • Independent CCUS-Offshore Wind study published. Similar conclusions to the outcome of deep dive workshops between bp and Orsted for Endurance and Hornsea 4. • Co-location forum chaired by the Crown Estate proposed to develop solutions in the future for greater co-development.	

Figure 4: Condensed timeline of collaboration pertaining to the evolution of layouts between bp and relevant stakeholders. During 2021, bp and Orsted have had fortnightly bi-lateral meetings to encourage collaboration which are not listed above (Strictly Confidential – Contains Commercially Sensitive Information - FOIA/FOI(S)A Exempt)

3.2 Endurance and the Original Hornsea Zone Development Area

Figure 6 below outlines the issue of the overlap zone between Hornsea 4 and the Endurance store through the perspective of the entire Hornsea ZDA, issued in 2010. The ZDA includes the Hornsea 1, 2, 3 and 4 projects, including some area that has since been relinquished under the agreement with Crown Estate or through environmental and competing industry pressure.

The original Endurance AfL and CS001 licence overlap was ~7% versus the original Hornsea ZDA. The CS001 licence area was later amended and the overlap of the developable Endurance area versus the original Hornsea ZDA reduced to ~3%. However, as an immovable geological store, the Endurance reservoir as outlined by its spill point still has ~50% of its required seabed for development overlapping with the Hornsea ZDA, despite the licence area reduction.

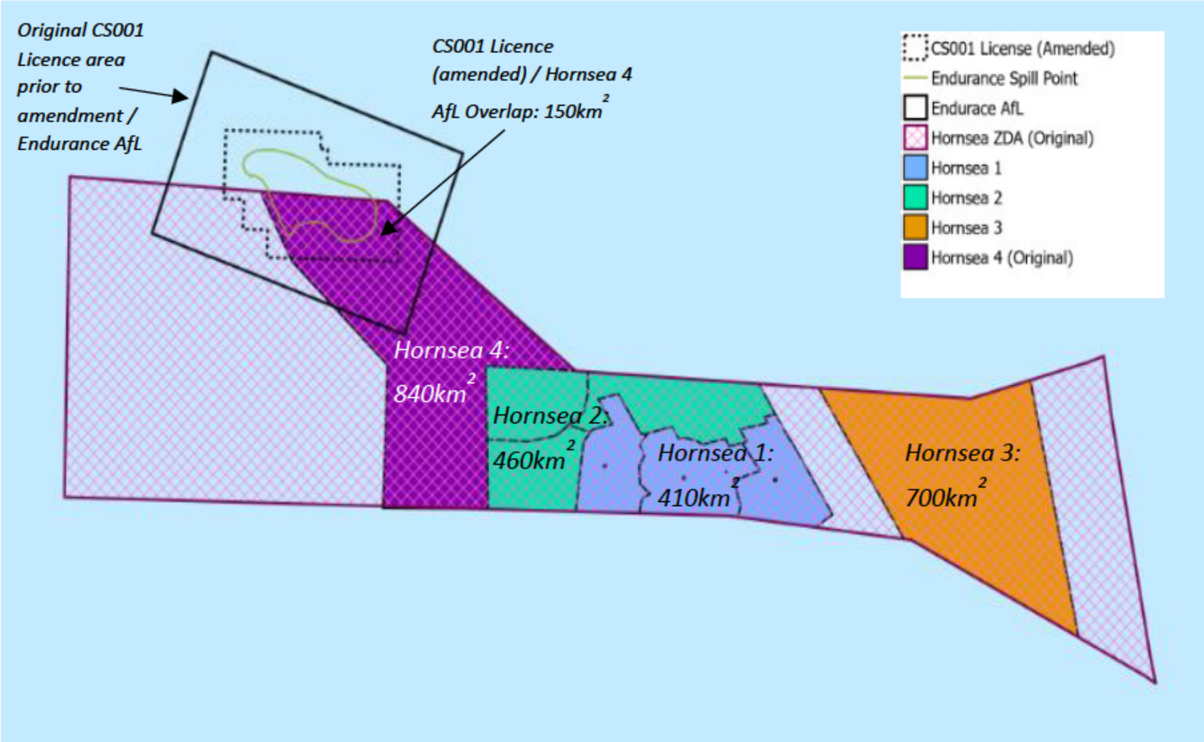


Figure 5: Size of area (orange) needed to develop Endurance overlain on Hornsea 1-4 outlines. This represents 6% of the total Hornsea area (using updated Hornsea 4 order limits).

With Hornsea projects 1, 2 and 3 under either consenting, development or operation, the focus turned to developing Hornsea 4, which had an initial AfL area of ~840km². Figure 7 displays how the Hornsea 4 AfL area (established in 2015) has been amended over time with Crown Estate. The southern block was relinquished first (~250km²), followed by a further relinquishment to the remaining southern section (~100km²).

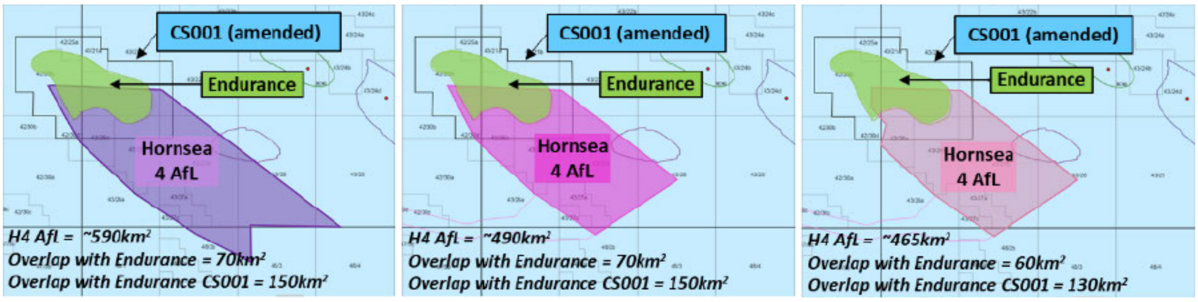


Figure 6: The three iterations of the Hornsea 4 outline (pink) and the overlap with Endurance (green). Left: Original layout, Middle: Revised layout 1, Right: Revised layout 2

The latest change to the Hornsea 4 AfL area was due to a red line boundary (RLB) change communicated in July 2021 as an amendment to the Hornsea 4 DCO application. The AfL area reduced from ~490km^2 to ~465km^2. The overlap of AfL areas was 150km^2 prior to the change in RLB by Hornsea 4, and it is now reduced to 130km^2 due to environmental pressure from stakeholder consultations. The overlap with the Endurance reservoir started at 70km^2 and reduced to 60km^2 with the final change to the Hornsea 4 AfL area. The overlap zone as a proportion of the Hornsea 4 AfL area and CS001 licence area has increased from ~18% to~32% as non-overlapping areas have been removed from the latest boundary, increasing the pressure on NEP's development plan (Figure 6).

NEP and the Endurance reservoir require development flexibility in managing subsurface uncertainty as a FOAK CCUS development. In order to safely develop Endurance, it is critical to monitor the migration of CO_2 within it. This is best achieved through using a towed streamer seismic technology (see section 6) on an orientation that is perpendicular to the structure. With this design, the overlap required for safe monitoring operations was 220km^2. Through technical collaboration with Orsted and pushing vessel turning circles and safety exclusion zones to the minimum permissible, NEP has been able to amend its towed streamer seismic monitoring design and reduce the overlap area to be within the amended CS001 boundary and down to ~110km^2 (see Figure 7) from the initial 150km^2 overlap (see Figure 6). This is a 40km^2 reduction of the overlap with the Hornsea 4's AfL area.

Figure 7: Comparing the change in overlap for planned seismic acquisition: (Left) original Seismic acquisition plan using traditional three dimensional (3D) towed streamer; (Centre) new plan using 3D high resolution seismic with shorter streamers, prior to RLB change in Hornsea 4's DCO application; (Right) new plan using 3D high resolution (HR) with shorter streamers, after the RLB change in Hornsea 4's DCO application.

4.0 State of the CCUS Industry

4.1 Background

CCUS has been identified as one of the key components of decarbonisation in the UK and will underpin the UK's Clean Growth Strategy (October 2017), as well as more recent strategic aims set out in the 'Ten Point Plan for a Green Industrial Revolution' (Nov 2020) and the 'Energy White Paper' (December 2020). Both of these more recent strategies outline the commitment to capture and store 10 MTPA by 2030 through the development of four industrial clusters which could potentially save up to 50,000 jobs. In December 2020, the CCC released its recommendation for a 'Sixth Carbon Budget' where the requirement for CCUS capacity in the UK needs to reach 22 MTPA by 2030 to meet the UK's net zero commitments. In October 2021, BEIS announced that the ECC, (based on the Endurance saline aquifer store) and the Hynet cluster (based on depleted gas fields) will be the first commercial projects and are expected to be operational by the mid 2020s [1]. At the same time, Government ambition for CCUS has increased from 10 MTPA to 20-30 MTPA by 2030 which is in line with the 6th Carbon Budget. It also notes that the UK will need at least 50 MTPA by the mid 2030s.

There are three key areas of CO_2 emission reduction that CCUS addresses:

1. Gas and biomass power generation with CCUS will provide reliable decarbonized electricity to complement intermittent wind and solar electricity generation;
2. Blue hydrogen requires CCUS to provide decarbonised hydrogen for heat and transport;
3. Many industries such as cement, steel and fertilisers produce CO_2 as part of their industrial processes. The capture and storage of these emissions enables decarbonisation of these industries and reduces imports of higher-emission products from overseas.

CCUS is still in early stages globally [11], with relatively small amounts of CO_2 being sequestered annually. The offshore UK has high potential for CCUS but despite some very high quoted numbers of storage capacity (78 gigatonnes of theoretical resources,[12]), very few stores have been progressed through any subsurface exploration and appraisal analysis, producing high uncertainty i.e. possibly 1.6 GT of practical resources, mainly in the Bunter formation in the South North Sea (SNS) and the Captain formation in the Central North Sea (CNS) [12].

The SNS is viewed as a high priority for CCUS due to its proximity to the large industrial areas along the east coast of England and relatively short distance for transportation to CO_2 stores. Of the saline aquifer stores identified by numerous reports, the Endurance structure is the largest store of this type in the SNS [13] with an estimated capacity of 450MT CO_2.

In contrast to the Offshore Wind industry, there are no operational CCUS projects in the UK. Endurance, the primary CO_2 store for the ECC, represents two thirds of the funded CCUS capacity in the UK today [8]) and is well documented as the largest and best appraised saline aquifer store in the Southern North Sea [9] [10]. Endurance will be the FOAK saline aquifer store project in the UK and be significantly larger than other projects in the Norwegian sector of the North Sea such as Northern Lights, Snohvit, or Sleipner. Most CCUS projects have demonstrated that reservoirs are more complex under CO_2 injection than under hydrocarbon production and that achieving and maintaining high injection rates requires high-quality data and flexibility regarding infrastructure locations.

4.2 Economic and Regulatory Framework

Key to establishing a successful CCUS industry in the UK is ensuring a safe, cost efficient and timely development process and central to achieving this is a clear and balanced business model. In the UK there are no existing business models and even globally there are very few. Recognising this, Government established an industry wide CCUS working group forum in 2018. This was subsequently divided into key subject matters to develop specific aspects of CCUS business models. The first draft transportation and storage business model was released in 2019 and after multiple updates, the latest revision is expected in 4Q 2021.

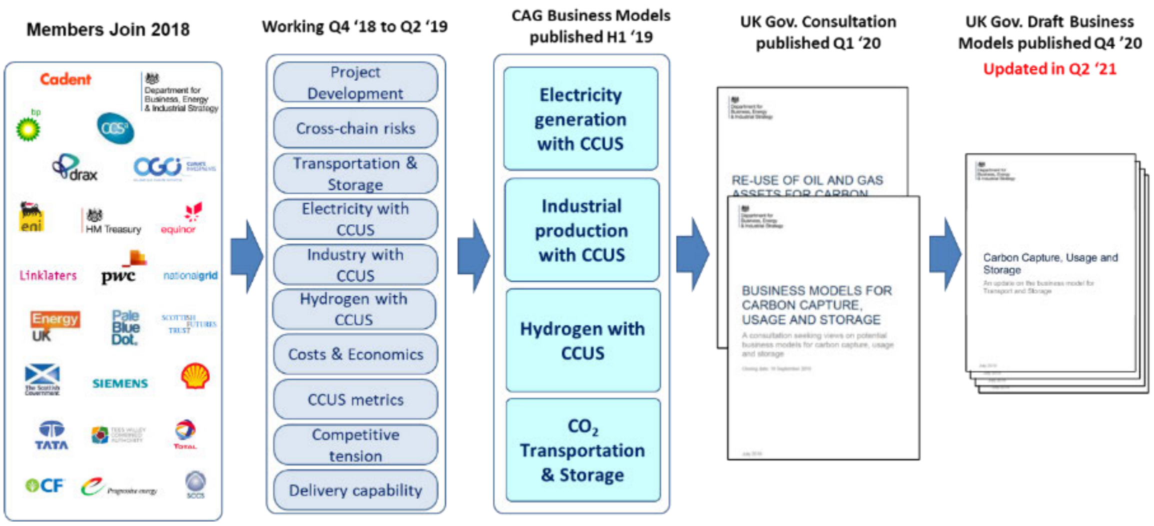


Figure 8: Economic and Regulatory Framework for CCUS in the UK

A summary of the key highlights arising from the first versions of the 'Transportation and Storage Regulated Investment (TRI)' model includes:

- Industry will be regulated by an economic regulator, with costs judged as economic and efficient allowed for cost recovery by the Transport and Storage (T&S) company;
- The business model will ultimately become a 'user pays' model with Government support tapering off as the CCUS industry matures and costs reduce;
- CCUS developments must be debt financeable by 3rd party sources (e.g. banks);
- Government will take on long-term leakage risk, provided that a technical regulator recommends that a project has been operated safely under its storage licence.

Some key implications for the nascent CCUS sector include:

- T&S companies must employ the most economic and cost efficient practices to ensure regulatory compliance and best use of taxpayer and billpayer support for CCUS;
- HSE and technical risks associated with development and operation of CCUS assets require careful management to meet the standards required by operators, investors and regulators.
- T&S companies are obliged to utilise the best available technology for monitoring plans to ensure proven and safe practices [35]. This allows operators to provide assurance that CO_2 is stored safely and permanently, enabling transfer of long term storage liability to Government.

These considerations are central to enabling the creation of a new UK CCUS industry and underpin the development of the commercial structures for the NEP project.

4.3. Public Perception of CCUS

On 8th July 2021, BEIS published a report called 'Carbon Capture Usage and Storage: Public Dialogue' [32]. The report was commissioned to engage with the UK public on their perceptions of CCUS as a tool for reaching the UK's net zero ambitions. The majority of participants were supportive of CCUS in reducing CO_2 emissions, however their support was conditional on two main factors:

1. "CCUS must be safe"
2. "CCUS needs to be an effective strategy in reducing CO_2 emissions"

The primary concern was safety, focussed on the principle of CO_2 storage under the seabed. The participants indicated that CO_2 leakage from the store was the primary concern, followed by leakage from transportation. The concern was centred on harm to marine life and the participants wanted the entire CCUS process (including decommissioning) to be safe.

The second major factor for the participants was the concern on cost control and the need for oversight or regulation over costs. This was coupled with the need for CCUS to make a timely and significant contribution to reaching net zero by 2050. CCUS developments needed to be efficient and effective in order to justify high start up costs.

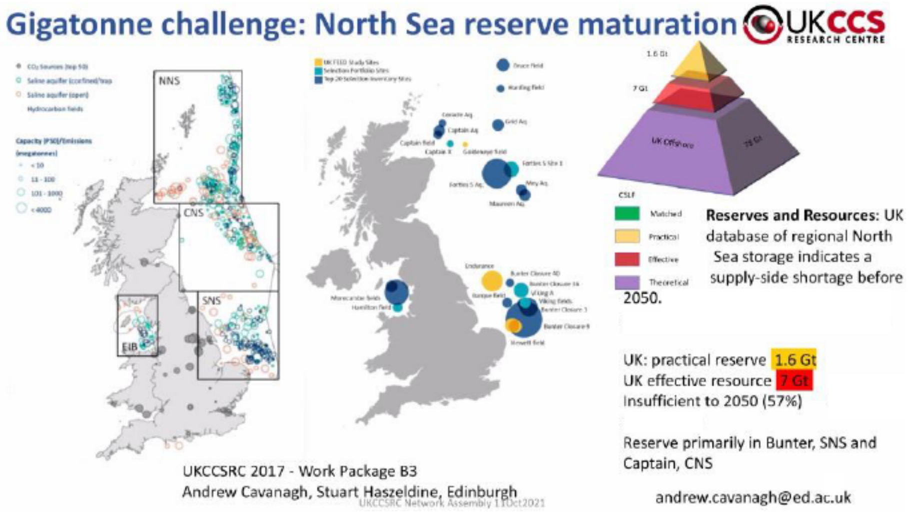
5.0 Importance of CCUS and Offshore Wind In UK Net Zero by 2050

Per the initial findings of the Energy Integration Project, a collaboration between the OGA, the Crown Estate, Crown Estate Scotland, BEIS and Ofgem, it is estimated that the UKCS could support up to 60% of the UK's decarbonisation requirements. CCUS and OW are both crucial components relying on the same UKCS to meet the UK's net zero by 2050 target. Collaboration, planning and technology development are hence important to maximise the potential for co-development between CCUS and Offshore Wind.

In a detailed listing of the UK policy support for CCUS and OW by Orsted, it is stated that: "Government policy is clear insofar as CCUS and offshore wind are not considered as 'either/or' technologies, either nationally or locally, but both have essential benefits both for local communities and for the UK as a whole in achieving Net Zero, building a secure and affordable energy system and providing jobs and supporting a green recovery."

As a cursory comparison, the seabed areal extent of the Endurance reservoir is estimated to be capable of storing the equivalent of 3.21 million tonnes of CO_2/km^2 versus reducing the equivalent emissions of 0.26 million tonnes of CO_2/km^2 in the national electricity grid for the Hornsea 4 windfarm, assuming a 30-year design life for both – an estimated 12x difference in carbon abatement potential (refer to Appendix C). However, CCUS and OW accomplish very different objectives, with the former critical for decarbonising industry representing one sixth of the UK's total emissions whilst the latter providing renewable electricity as stated by the UK's ambition to have 40GW by 2030. HM Government therefore needs to make strategic choices – as illustrated by the interactive energy map for the UKCS by OGA, the Crown Estate and Crown Estate Scotland which identifies areas in the UKCS where such choices need to be taken.

The UK CCUS industry is in a very early stage of development, with zero operational injection in the UK today and significant uncertainty in the maturation of North Sea storage reserves as shown in figure 10 below (taken from a recent UKCCS Research Centre presentation in October 2021). Progression of the Endurance store represents a significant part of the UKCS's commercially investable storage reserve per the Storage Resource Management System (SRMS) classification, without which the UK would be lagging even further behind the pace required to meet the UK's net zero ambition (refer to Appendix B).



Gigatonne challenge: North Sea reserve maturation

Reserves and Resources: UK database of regional North Sea storage indicates a supply-side shortage before 2050.

UK: practical reserve 1.6 Gt
UK effective resource 7 Gt
Insufficient to 2050 (57%)

Reserve primarily in Bunter, SNS and Captain, CNS

UKCCSRC 2017 - Work Package B3
Andrew Cavanagh, Stuart Haszeldine, Edinburgh
UKCCSRC Network Assembly 11Oct2021

andrew.cavanagh@ed.ac.uk

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Figure 9: The Gigatonne challenge, Cavanagh et al, 2017

Given the nascent state of the CCUS industry versus the rapidly expanding market of the largest offshore wind market in the world, in the UK, there is a need to balance First of a Kind (FOAK) risk and inherent subsurface uncertainty whilst investing in the right technological and regulatory solutions as the CCUS industry scales up, evidenced by operational experience. Sections 6.0 and 7.0 articulate that in further detail, through options evaluated for each co-development challenge and the compromise proposed.

6.0 Endurance CO_2 Store

6.1. Endurance Description

The Endurance reservoir is located ~1,000m below the seabed and under a water depth of ~60m. The reservoir is found in the extensive Bunter sandstone as depicted in Figure 11. First discovered in 1970, its north-western part of Endurance is well appraised and its containment of brine at pressure means it is able to support dense phase CO_2 injection at high rates compared to depleted reservoirs – crucial to enable CCS in the UK to scale at pace to meet net zero ambitions. The Endurance structure is approximately 25km by 8km with an estimated storage capacity of 450 MT. It is located directly east of Flamborough Head in the Southern North Sea (SNS). The store is capped by the Rot series of clay and halite, which prevents upward migration of CO_2 and is the seal for the store. There are three existing well penetrations in the structure, an exploration well (1970): 43/21-1, a second exploration well in 1990: 42/25-1 and a CCUS appraisal well drilled by National Grid in 2013: 42/25d-3. A large portion of the structure is not drilled, and along with the limited dynamic data [10], there are remaining geological uncertainties that will need to be monitored, interpreted and potentially mitigated against during development. Injected CO2 and brine are held in the reservoir under a rot clay and halite seal which is impermeable (primary seal). Between this and the seabed, other forms of halite and shales can be found, which provide additional sealing lithology. The Bunter sandstone at Endurance is a saline aquifer where the pore spaces within the rock are filled with brine. Upon drilling a CO2 injector well to the target depth in the sandstone, CO2 will rise to the top of the sandstone and displace the brine downwards, creating increased pressure under the rot halite seal. Brine producing wells will be drilled over time and where required to reduce pressure in the reservoir.

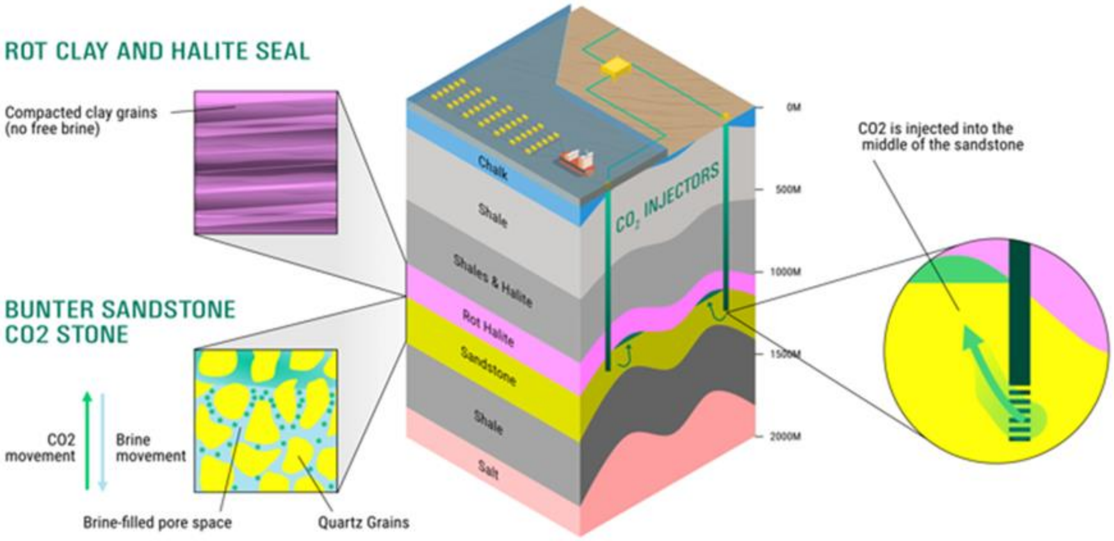


Figure 10: Illustration of the injection of CO_2 into the Bunter sandstone

6.2. Storage Complex and Monitoring Area

There are three defined terms for CO_2 storage (listed in increasing size): Storage site, storage complex and monitoring area (see figure 12).

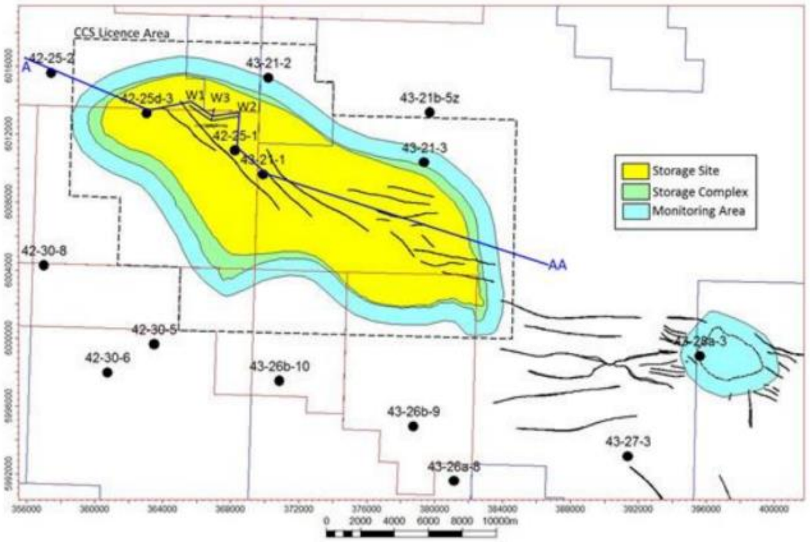


Figure 11: Extract from National Grid's Key Knowledge Document K.43 [6]. This diagram outlines the three areas of Endurance relating to CO_2 storage.

The *storage site* is the Bunter sandstone formation within the Endurance structure. This is a defined volume within a geological formation used for CO_2 storage and associated injection wells and pumps [6].

The *storage complex* encompasses the storage site as well as secondary containment formations that could affect overall storage integrity and security [6]. This is defined vertically from the base of the Bunter sandstone formation, includes the seal facies (Rot Clay and Rot Halite) and the shallower sealing facies up to the shallowest seal up to the top of the Liassic. The areal dimensions for the storage complex are defined by the structural closing contour on the top of the Bunter sandstone at circa 1450 m TVDSS (known as the spill point).

The *monitoring area* includes the lateral and areal extent of the storage site and storage complex, but additionally includes further lateral and vertical extent to ensure no migration outside of the storage complex has occurred. As such the monitoring area extends beyond the spill point of the structure, especially in the south and east where the spill point is shallow, to ensure no lateral migration of CO_2 in these areas, and vertically it includes shallower stratigraphy up to the top of the Quaternary (seabed).

6.3. Subsurface uncertainty

The Bunter sandstone is an extensive sandstone unit with extensive well penetrations across the basin. It is well known to be a high net to gross sandstone of around 250m thickness in the area with good well coverage. The key uncertainties are the degree of compartmentalisation in the reservoir (vertical barriers that stop fluid flow), vertical stratification (the ratio of vertical to horizontal permeability Kh/Kv) which inhibits upward migration of CO_2, and the long-distance connectivity of the structure into the Greater Bunter Aquifer. These factors influence how the CO_2 will move within the reservoir and the degree to which the CO_2 forms a central plume versus moves in unexpected ways which could lead to unexpected pressurization of the reservoir (Figure 12).

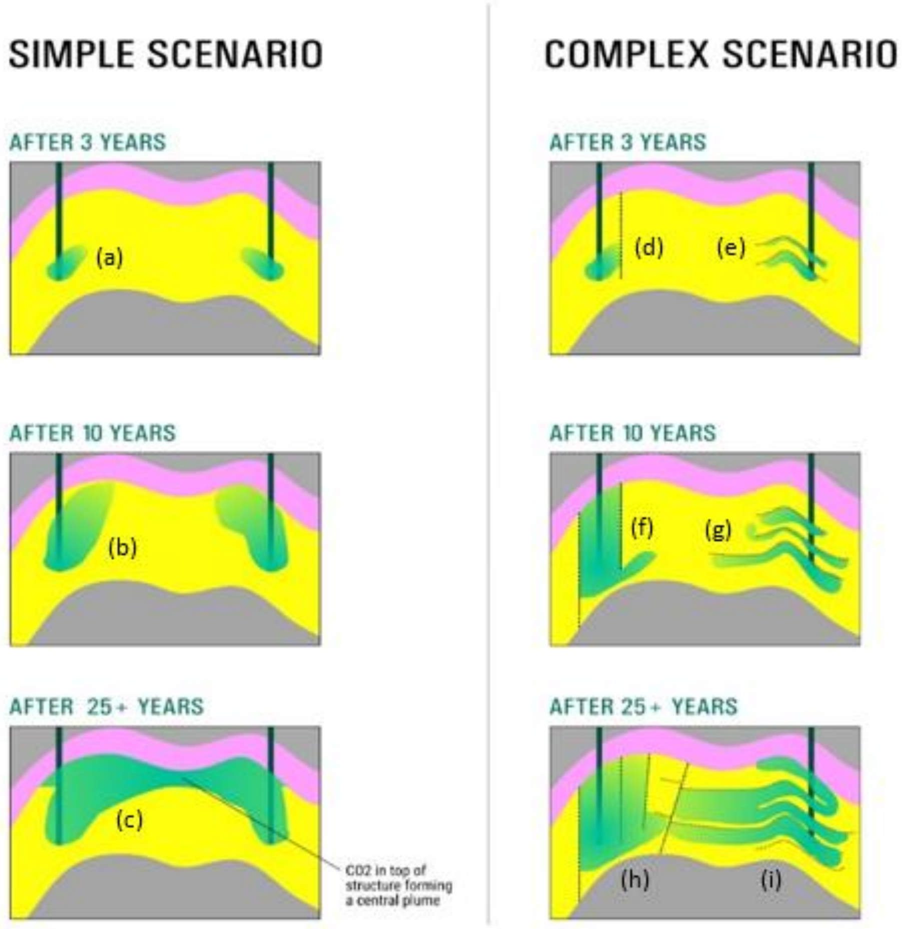


Figure 12: Cartoons to demonstrate the key subsurface uncertainties: In the simple scenario the CO_2 rises inside the reservoir and forms a crestal plume. In the complex scenario compartmentalisation (left) and vertical stratification (right) inhibit cretal plume formation and the location of the CO_2 in the reservoir is much more complex.

(a) CO_2 injection into the centre of the Bunter Sandstone reservoir
(b) Without barriers to the flow of CO_2, it rises within the reservoir towards the crest of the structure
(c) A plume of CO_2 forms in the crest of the structure
(d) Injection of CO_2 into the middle Bunter sandstone, flow of CO_2 is inhibited by a vertical barrier
(e) Injection into the middle Bunter sandstone, CO_2 encounters lateral barriers which trap the CO_2
(f) More vertical barriers are encountered, pressure rises significantly in this compartment. Injection may have to be stopped in this well to ensure seal integrity
(g) Lateral barriers continue to control the flow of CO_2 along stratigraphic layers, CO_2 is not rising to the crest of the structure
(h) Additional faults prevent the flow of CO_2 in the structure. Again, injection may have to be stopped if pressure is too high
(i) Lateral barriers continue to control the movement of CO_2, these may push the CO_2 out of the structure laterally.

The consequences of these reservoir complexities could ultimately lead to stopping or curtailing the CO_2 injection. For instance, in the case where the reservoir pressure around an injector is locally rising (high compartmentalisation), a full subsurface 4D image would be needed to be able plan a new CO_2 injector at an alternative location (or a brine producer to reduce pressure in the specific compartment). Where one observes strong lateral migration with CO_2 trapped beneath impermeable layers there is a risk that continued injection would push CO_2 beyond the spill point of the structure. This would be a direct impact on the store licence and ability to continue the project. It would also initiate the need for monitoring off structure wells for CO_2 for a potentially very long period of time, which lengthens the long-term liability and may prevent official store closure whilst preventing the further sequestration of CO_2.

High resolution seismic data is the best available technology to monitor the reservoir and its uncertainties to understand whether any of these scenarios are likely to occur. It will in time prevent premature cessation of injection and reduce long term liability.

6.4. Development Plans for Endurance

Endurance has an estimated injection rate of 15 MTPA (with 15 CO_2 injectors and up to 14 brine extractors) when fully developed, and is the core storage asset underpinning the East Coast Cluster (ECC) plan selected by BEIS into Track 1 of the Cluster Sequencing Process. With Endurance as the hub, ECC will enable up to 20 MTPA CO_2 injection by 2030, rising to 23 MTPA by 2035 (27 MTPA , peak) and has the potential for more beyond that to decarbonise Teesside and Humber industries (see Appendix B).

NEP is compelled by the regulator to maximise the economic storage capacity of Endurance and ensure that the reservoir reaches its full potential to meet the UK's net zero objectives and the needs of the industrial customers at Teesside and Humber. This will be achieved through an "appraise while developing" approach, which incorporates periods of seismic monitoring to track CO_2 migration and confirm injector and brine producer well placements. The need for seismic is driven by subsurface uncertainty and any potential barriers to the flow of CO_2 through the reservoir. Subsurface imaging is a constantly evolving picture from repeated surveys that informs a CCUS operator where to drill wells for maximum impact.

The development plans for Endurance hence follows 3 discrete decision triggers.

The first relies on the natural rock strength of the overburden in the best appraised northwest section of the reservoir, as confirmed by the appraisal well drilled in 2013 and various studies and modelling carried out since. This allows for five CO_2 injection subsea wells in the northwest section and a monitoring well to deliver an initial rate of 4 MTPA by year end 2026. A subsea distributed concept has been selected to enable flexibility in well placement, and maximise mitigation against local heterogeneities, or compartmentalization. Dynamic appraisal during the first 3 years through operational feedback will enable the understanding of well injectivity and storage capacity of the site to be refined e.g. long-distance connectivity into the Greater Endurance Aquifer.

The second decision trigger relies on the operational feedback from the dynamic appraisal in the prior stage to locate the brine producers and manage reservoir pressure (safely below the seal fracture pressure) via a controlled pore voidage replacement process. Brine producers will naturally need to be located at the edge of the spill point, ensuring a sufficient standoff distance with the injectors located close to the crest of the reservoir structure. This ensures a buffer between injectors and producers to prevent CO_2 breakthrough and controlled plume migration. This second trigger unlocks the injection rate of Endurance up to 10 MTPA with ten CO_2 injection wells. Depending on the reservoir compartmentalization, there is a theoretical potential for the ten wells to each deliver a peak injection rate of 1.5 MTPA, resulting in the 15 MTPA full field development to be achieved. The decades of cumulative experience within NEP's partnership in global reservoir development however, shows that this scenario has a very low probability of being realised given the complex nature of geology. Therefore, a third decision trigger for an 5 additional CO_2 injector wells and associated brine producers would be expected to be required as the final optimisation. These additional wells would be placed close to the locations of the installed wells depending on where the localised reservoir compartmentalization and irregularities are encountered during the course of CO_2 injection operations over time (see Figure 13 below).

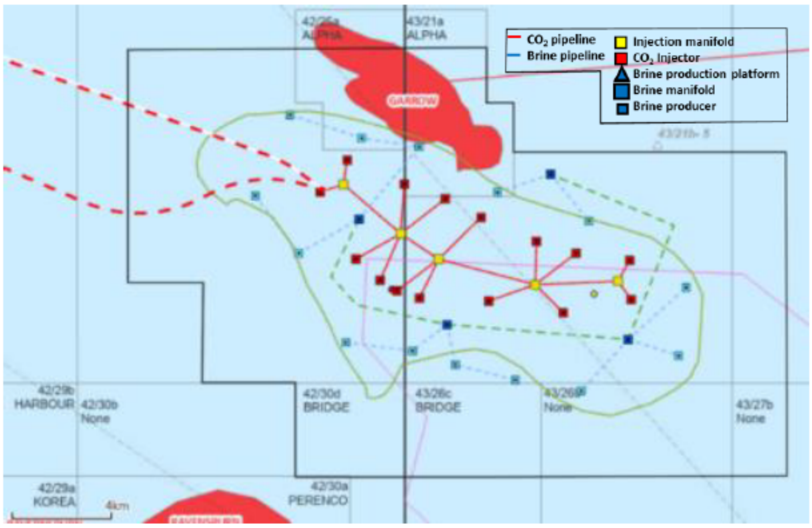


Figure 13: Notional full field development of Endurance at 15 MTPA injection rate

Given the full field Endurance development footprint to reach its 15 MTPA injection rate potential is quite similar to the 10 MTPA footprint, NEP has selected to base this assessment on the latter, reflecting less conservative requirements particularly in the area of overlap.

7.0 Overlap with Hornsea 4 wind farm: technical risks and challenges

Co-development of Endurance and Hornsea 4 in the area of overlap creates a series of technical risks and challenges which have been described under the following categories, and summarised in Table 2, along with the mitigations that have been incorporated within the Endurance development plan as a result.

- 7.1 Wells and Rig Access
- 7.2 Impact on Infrastructure co-location (and its impact on storage capacity)
- 7.3 Store Monitorability

This is consistent with the generic identification of risks across the full CCUS development lifecycle as identified in the CCUS & OW Overlap Study Report [2] (refer to Appendix A). Co-development within close proximity naturally also brings commercial and legal risks such as liability during Simultaneous Operations (SIMOPS) and force majeure events such as damage from the collapse of a wind turbine. These are not fully explored within this report as the focus is on technical risks and challenges.

Table 1: Summary risk assessment on windfarm overlap

Category	Concern	Risk Impact	Mitigations incorporated within Endurance development plan
Wells and Rig Access	Well construction: Limited deviated drilling possible due to shallow overburden	Loss of significant storage capacity if access to well location is limited Loss of containment	Drill and complete vertical wells, limit well total depth step outs to no further than 1.25km (at Top Bunter)
	Life of field rig access: - Drilling of new wells - Well workovers and maintenance - Well abandonment: Rig cannot access any area within the wind farm overlap area. Inability to fully develop Endurance due to large areas of the structure in the overlap being	Loss of significant storage capacity from onset Storage capacity is significantly reduced and brine producers cannot be placed in optimum areas for pressure management resulting in further decreases to storage capacity; Reduced ability to respond to updates in sub-surface understanding with further optimization of well targets and	Rig access corridors to injector and brine producer locations Deviated drilling is an option, however this limits well locations (sub optimal) and increases costs and risk; Note however, most critical risk concern of zonal Isolation increases as well deviation increases

	occupied by wind turbines	surface locations as store is developed Loss of storage capacity from impaired wells Timely abandonment could be jeopardised leading to future risk of CO_2 leakage	
	Relief well (RW) access: In the case of a well control incident or major integrity intervention requirement, rig access is required to drill a relief well	Loss of Brine or CO_2 containment Hindered or inefficient response to major incident or emergency situation, increasing severity of incident	Rig access corridors to subsea wells, clear space and access to relief well locations Optimized RW placement with respect to prevailing Metocean currents is SW quadrant relative to impacted well
	Marine support vessel access: Increased limitations to marine access for support vessels and increased response times with having to negotiate overlapping infrastructure and additional marine traffic	Marine access efficiency reduced; Typical spill response and Search and Rescue (SAR) box grid operations impacted and SAR SIMOPs risk introduced	Marine access corridor or no overlapping infrastructure impeding SAR operations
	Aviation access: Helicopter access windows limited to a greater dependence on VFR (Visual Flying Rules) over IFR (Instrument Flying Rules); Typical SAR operations impacted and SAR SIMOPS risk introduced	Helicopter access windows to rig for crew change during drilling or intervention or for SAR operations restricted; Efficiency and risk profile of SAR operations reduced and increased respectively, increasing risk of facility	Helicopter access corridors or no overlapping infrastructure impeding SAR operations
Infrastructure co-location	Electromagnetic Interference (EMI):	Electromagnetic induced deterioration of	Minimize infrastructure cross over turbine HVDC

	Close proximity electromagnetic impacts between subsea infrastructure and offshore power cables	wells subsea infrastructure	cables and wells subsea hardware; Limit to a minimum separation (exclusion zone)
	SIMOPS and CO_2 Venting: Inefficiencies from SIMOPS planning Inadvertent CO_2 exposure through planned or unplanned venting	Increased stakeholder coordination resulting in increased costs and/or schedule delays CO_2 induced asphyxiation of any personnel supporting operations in adjacent wind turbine assets	Limit to a minimum separation (exclusion zone)
	Seabed Disturbance: During life of field injection into the store there is a modelled uplift of injection reservoir cap with an impact all the way to seabed	Resultant ground disturbance could lead to incremental destabilization of overlying wind turbine foundation infrastructure (seabed uplift and uneven tilt [14])	Limit to a minimum separation (exclusion zone)
Store Monitorability	4D seismic monitoring: Towed streamer 3D seismic surveys are not possible in the windfarm	4D seismic data must be acquired by OBN within the windfarm which has not been proven to provide high quality results in this scenario and increases the risk of an inability to continue injection if containment cannot be proven from the results of the surveys.	Very dense OBN at over 10x cost than the towed streamer seismic option and the residual risk is still higher for OBN. There are also acquisition challenges due to strong, variable currents and vessel safety concerns as a result of months of operations within the wind turbines.
	Store closure: Insufficient 4D data to prove long term CO_2 containment and conformance after injection has ceased	Unable to hand over the long-term leakage liability of the CO_2 store to the Government, resulting in increased monitoring cost and risk.	Very dense OBN at over 10x cost than the towed streamer seismic option and the residual risk is still higher for OBN.

	Public acceptance of CCUS safety: Without 4D seismic data we are unable to prove safe storage of CO_2	Public perception may jeopardise the ability to continue operating the project [32]	Open Access Forums, Public Consultations (EIA, DCO)

7.1 Wells and Rig Access

If the wind farm limits the amount of seabed access, it will directly and disproportionately reduce the developable CO_2 storage capacity.

Dynamic appraisal (monitoring of CO_2 injection activity) of the structure is required to progressively evolve the full field development plan, and this cannot be pre-planned. Rig and well access is required for base case drilling activity but also any intervention or emergency response requirements which may require heavy work over activity or drilling of a relief well (RW), throughout life of field operations until post closure and handover to the Government.

7.1.1 Well Construction

Challenge and recommendation

The storage site is relatively shallow and deviated drilling introduces containment risk. Consequently, all wells to be drilled will have limited horizontal deviation. This requires rig access above all existing, planned and potential relief well sites throughout the entire lifecycle of the Endurance store.

Options and Analysis – Deviated Wells

There are some options to drill deviated wells, but these will increase both cost and well integrity challenges (due to increased well length and relative increased complexity in cement placement with increased well inclination). As well inclination increases, the challenge of achieving uniformly circumferential placement and displacement of cement in the annulus around the casing strings increases. This is influenced by:

I. the increasing impact of the longer well measured depth (MD) (required to achieve the same true vertical depth (TVD)) on the associated wellbore cumulative frictional impact to fluid flow,
II. the increased impact of gravity effects along the deviated wellbore during fluid circulation. This is experienced as the associated impact of gravity on fluid flow, and in particular fluid weighted with particulates, during dynamic placement and displacement of fluids, together with the additional complexity of varying rheology (due to fluids viscosity & weight differences), and,
III. the impact of gravity segregation under static conditions along the length of the deviated wellbore.

The above phenomena increase the risk of poor integrity and lack of continuity in cement to casing and / or cement to formation isolation, particularly on the upper or “high side” of the aforementioned interfaces. Even with deviated wells, due to the relatively shallow depth of the Bunter structure, directional drilling into the reservoir beneath the windfarm is limited.

A review of well trajectories in the Southern North Sea (SNS) to assess the analogous well step-out which has been historically achieved to similar true vertical depths (TVDs), indicated that:

- Maximum inclination is of the order of 68 deg but typically 55 to 60 deg (Figure 14)
- Maximum step-out, assuming 60 deg in overburden and reservoir, to:
    - Top Bunter (~1200 mTVD) is of the order of 1250m
    - Well TD (~1500 mTVD) is of the order of 1800m

Attempts to increase step-out by increasing inclinations beyond these limits will be challenged by shallow drilling directional capability and will also further increase the risk to well construction such as wellbore instability. Beyond 60 deg inclination, well trajectories also start to impact intervention capability e.g. tractors may be required for slickline and e-line conveyance. This will increase the risk profile to the future intervention MMV requirements that are reliant upon wireline conveyance.

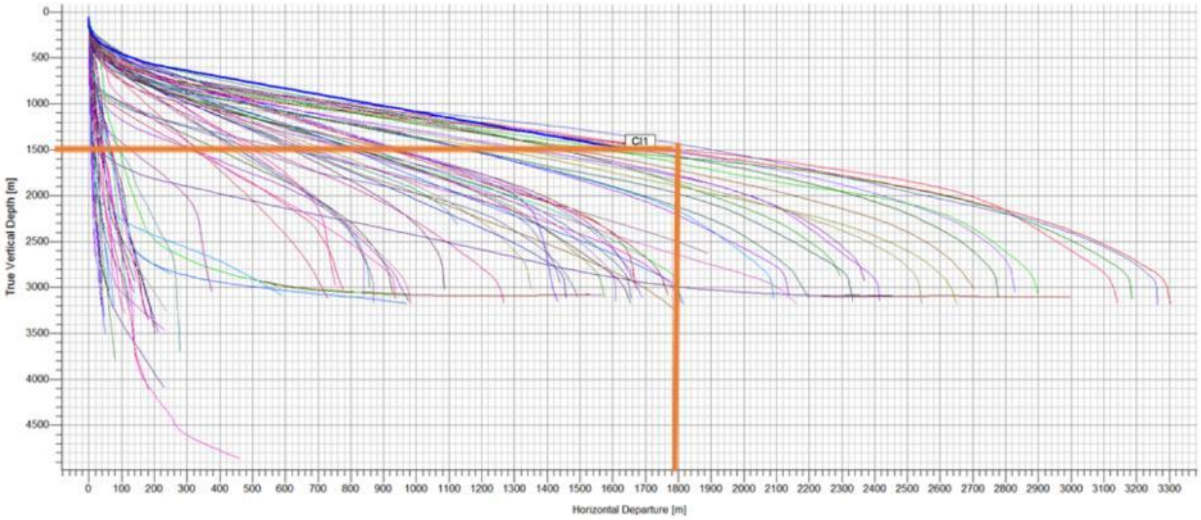


Figure 14: Well inclination for analogous wells drilled in the South North Sea (SNS)

Also, the DST (Drill Stem Test) and VIT (Vertical Interference Test) at well 42/25d-3 would indicate the likely presence of extensive horizontal baffles (strong partial penetration effect observed for the PBU (Pressure Build Up) interpretation) which would result in a small Kv/Kh ratio at the macro-scale across the full Bunter reservoir. In addition to the lower risk associated with vertical well construction, the project bias is to drill vertical wells and perforate up to 80 meters of sands to maximise completed pay intervals to mitigate against low Kv/Kh ratio. A similar strategy is being envisaged for brine extractors downdip. Whilst horizontal wells would enhance productivity, it is also perceived as risky at present as per the given reservoir architecture challenge and the requirements to mitigate the risk of low Kv/Kh ratio. To mitigate this risk with horizontal wells would require S well type construction, with the well TD'ing close to vertical. This type of well construction will further exacerbate the well trajectory challenges articulated above.

Deviated drilling cannot replace having full access to the seabed for future development drilling to accommodate expansion to 15 MTPA. Future well locations are at this stage notional and will have to be refined with the learnings from initial injection operations. Access may be required for relief wells and plugging and abandonment operations in future.

7.1.2 Marine and Aviation Access

Rigs and associated OSVs (Offshore Supply (or Support) Vessels) will be required during operations for expansion well drilling, well maintenance or emergency response (relief wells). Helicopter movements are required (e.g. for crew change / emergency response) to any rig / vessel operating above the storage site. Turbine installation above the storage site, even at 3km spacing, will limit both rig and helicopter access to only the most favourable weather conditions and introduce significant additional risk.

BP Marine, BP Aviation, Bristows, Maersk and Valaris have all been engaged and consulted [16,17]. Two of the highest risks, passing vessel collision and aviation accident are today safely managed by regulator or industry best practice for rig /vessel and supporting helicopter crew change operations within the UKCS. These procedures have been developed and established over a long period of operating time with added experience of investigation recommendations from near miss, incident and accident reports. The introduction of drilling rig operations adjacent to or within new wind farm developed areas brings new additional uncharted risks for rig, vessel and helicopter operations – rig move, crew change, emergency response. The prevailing metocean conditions for Endurance would dictate that rig positioning and approach for any potential relief well is south-west of any impacted well.

Additionally, as any reservoir uncertainties are updated with the relevant data acquisition from each successive well drilled, the reservoir targets and associated well surface locations will be optimized as the storage unit is developed. Similarly, as well surface locations move so will any required rig and helicopter access corridors. This flexibility to optimize reservoir development will be challenged within the rigid pattern of a fixed wind turbine matrix.

De-conflicting marine and aviation operations of any surrounding wind farm infrastructure is seen as the safest and recommended option at this time. Though it is viewed as possible to bring a jack-up into the windfarm where clearance between wind turbines is less than 3km, down to 1km, the expectation is that there will be significant weather window impacts. That is, the allowable annual weather window/s for a safe rig move could be significantly reduced within the matrix of a windfarm. Helicopter access will require dedicated 2 – 3 km access corridors and emergency and search & rescue (SAR) operations will be significantly impacted within the windfarm matrix.

[References 16 to 24]

7.1.2.1 Rig and Vessel Marine Access

Challenge and recommendation

It is necessary to tow a rig above wells on the Endurance site and position its associated OSVs in close proximity, for e.g. for expansion, well maintenance or emergency response. Manoeuvring rigs and vessels between the turbines increases risk and requires good weather

Additionally, more vessels on location increases the risk of collision (e.g. between the rig and a turbine, or marine traffic) arising from supporting overlapping operations (SIMOPS).

The safest and lowest risk approach is to avoid any turbines above the storage site.

Options and analysis – Rig Positioning

BP Marine and Rig Contractors Maersk and Valaris have been consulted on rig move operational considerations within the proposed overlap. Although the expected turbine spacing is 1 – 1.2 km, different turbine spacing scenarios were initially considered (Figure 15) with spacing ranging from 3km to 0.5km (it was recognised that 0.5km is tight, but there was a desire to test the limits when engaging with the marine specialists).

The required understanding is which scenarios are operationally plausible and statistically how feasible is it to be able to manoeuvre a jack-up rig through the wind farm under those scenarios, for e.g.

- Is scenario 1: possible 270 days out of 365 (P50)
- Is scenario 3: possible 180 days out of 365 (P50)

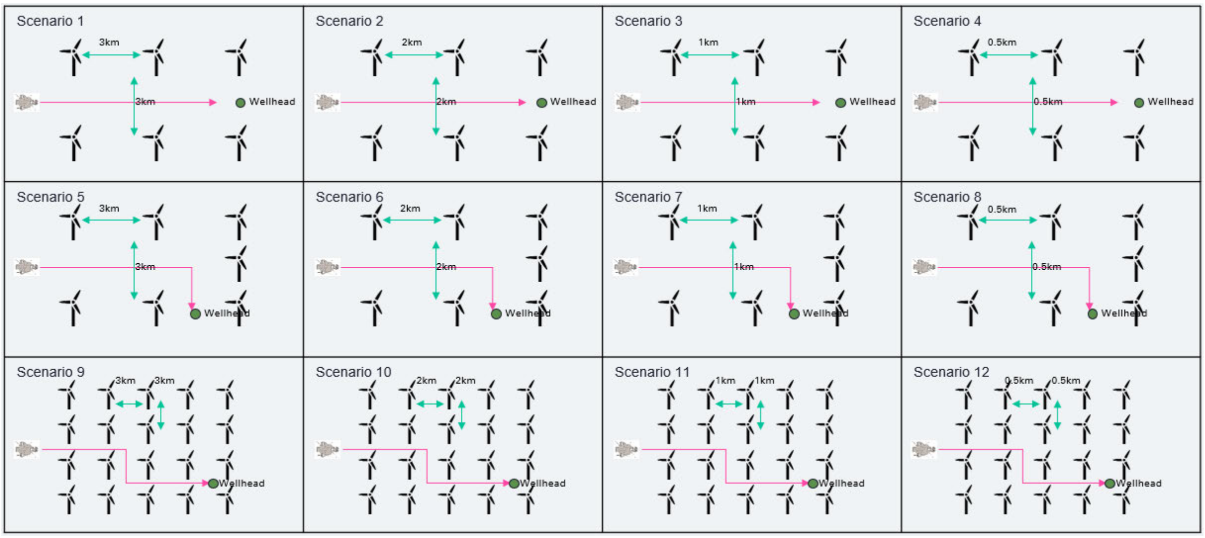


Figure 15: Rig move scenarios

Approach and departure to the location with a jack up rig and its associated tow spread creates specific challenges for the tow operation.

A 1km spacing is not manageable even in perfect conditions (based on a typical 500m tow length which gives 1200m spread diameter). However, a 2km to 3km turbine spacing is expected to be more manageable but carry the risk of significant operational weather inefficiency impacts.

There is significant risk for the turbines in the event of a tow failure impacting the ability to manoeuvre the unit within such a confined area. Similarly, any subsea power cables and possible turbine mooring lines would be particularly vulnerable during the approach if there is a need to have jack up (JU) rig legs engaging on bottom for greater control as the rig approaches both the stand-off and final alongside positions.

For final rig positioning, moving onto an open water location allows considerably more flexibility for positioning and course of approach with relative flexibility in how movements are managed and executed. However, once subsea infrastructure is installed, approach zones and course of approach will be more restricted to align the final heading and position of the unit, so any adjacent structures will create specific challenges for the initial and final positioning.

Positioning a self-elevating unit on an open water location may or may not be completed with a mooring spread and anchors deployed. There may be a requirement to deploy JU Legs to seabed and also possibly deploy anchors to facilitate controlled final positioning, particularly for a rig returning to existing infrastructure, e.g. for a heavy work over requirement. There may also be the requirement for possible JU / seabed stability operations such as "stomping – JU legs", working the legs on the seabed, to achieve a stable base prior to jacking up, e.g. if returning a JU rig to old spud can impressions. For such operations an anchor mooring spread would typically be required. Anchor mooring spreads can range from 500m to 1500m from each corner of the drilling rig depending on the unit and its equipment, the water depth, the weather conditions and the subsea infrastructure in situ. Similarly, the rig's position would need to be aligned to the subsea infrastructure orientation. Hence, to maintain an asymmetrical anchor spread for final positioning requires relatively tight tolerance on anchor locations. With adjacent structures and subsea infrastructure (Wind Turbines moored cables, electrical cables, etc.) the additional in place infrastructure associated with the turbines may significantly restrict the ability to place the unit in the required position and brings additional risk to subsea infrastructure and any subsea crossings that would need to be managed.

For rig towing operations the consequences of a tow spread failure, (e.g. failure of a tug), would be unacceptable within the constraints of surrounding wind turbine infrastructure. The tow spread requires a minimum of 3 tugs, all to have redundant power. Ideally the operation would limit tugs to providing 50% of max pull (to ensure sufficient reserve in the event of failure). Weather is the key issue or challenge, positioning in tighter patterns requires good weather windows and close tug control. The safe allowable weather window to bring a jack-up rig into the Hornsea-4 windfarm/Endurance overlap area for well activities could be reduced due to the presence of the wind turbines which could lead to higher well activity durations, costs and also delayed emergency response if a rig move is required for relief well drilling.

Further work would be required to understand location specific weather sensitivity associated with manoeuvring a rig within a windfarm. This would require further weather analysis to determine minimum turbine spacing with metocean conditions at location and / or impact of given turbine spacing on waiting on weather (WOW) timeframes to allow for safe rig moves. For example, it's not currently clear if the average weather window allowing safe rig moves for the year would be reduced from say 75% of the time with unimpeded access to 50% of the time between the turbines. Initial feedback from rig contractors is that 2-3km turbine spacing appears to be more feasible.

Options and analysis – Relief Wells

As indicated above, for the Endurance site the prevailing metocean conditions (NW/SE currents/winds [24]) dictate that the optimized sector for a rig positioning and approach for any potential relief well is from the southwest and within the southwest quadrant relative to any impacted well/s. This indicates a further extension of the overlap SIMOPs interface beyond the base case wells (planned injectors and extractors) in case of any emergency response which may require the drilling of a relief well (RW) to address a concern at any of the planned wells and also the legacy wells.

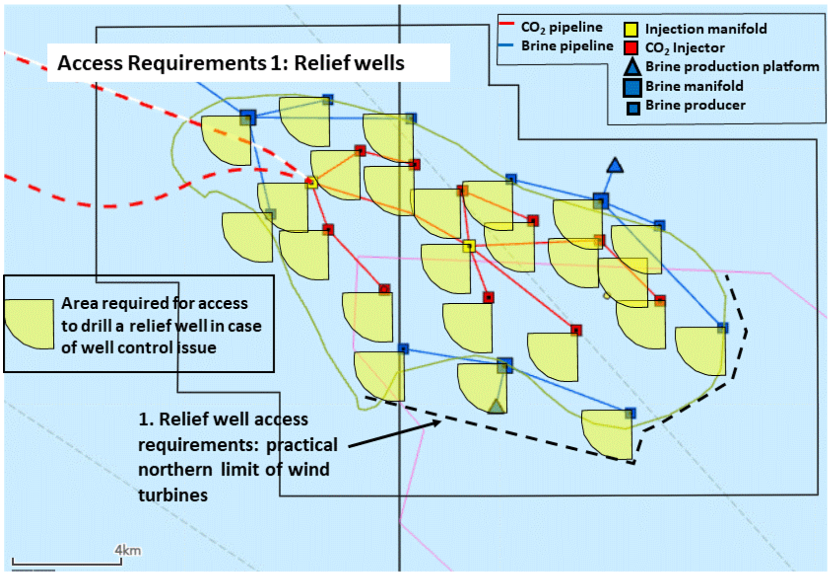


Figure 16: Relief Well Access requirement for Endurance development (10 MTPA)

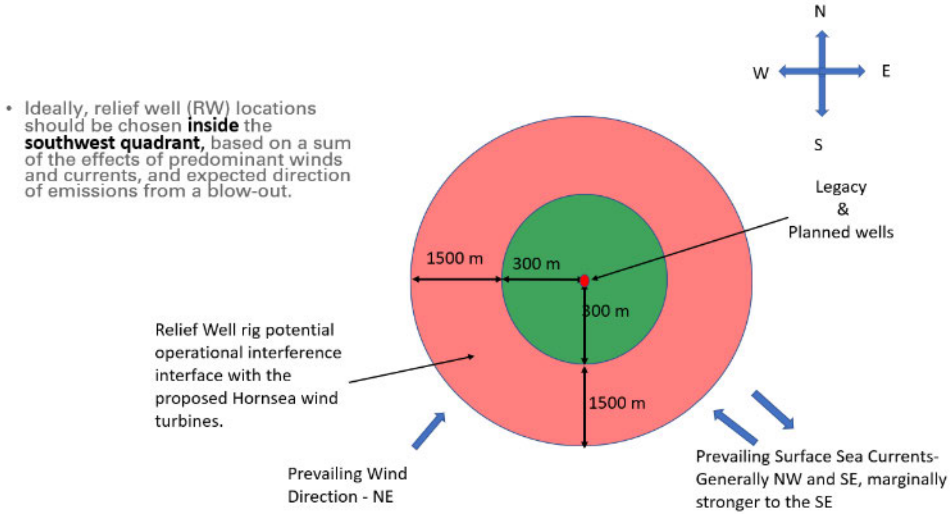
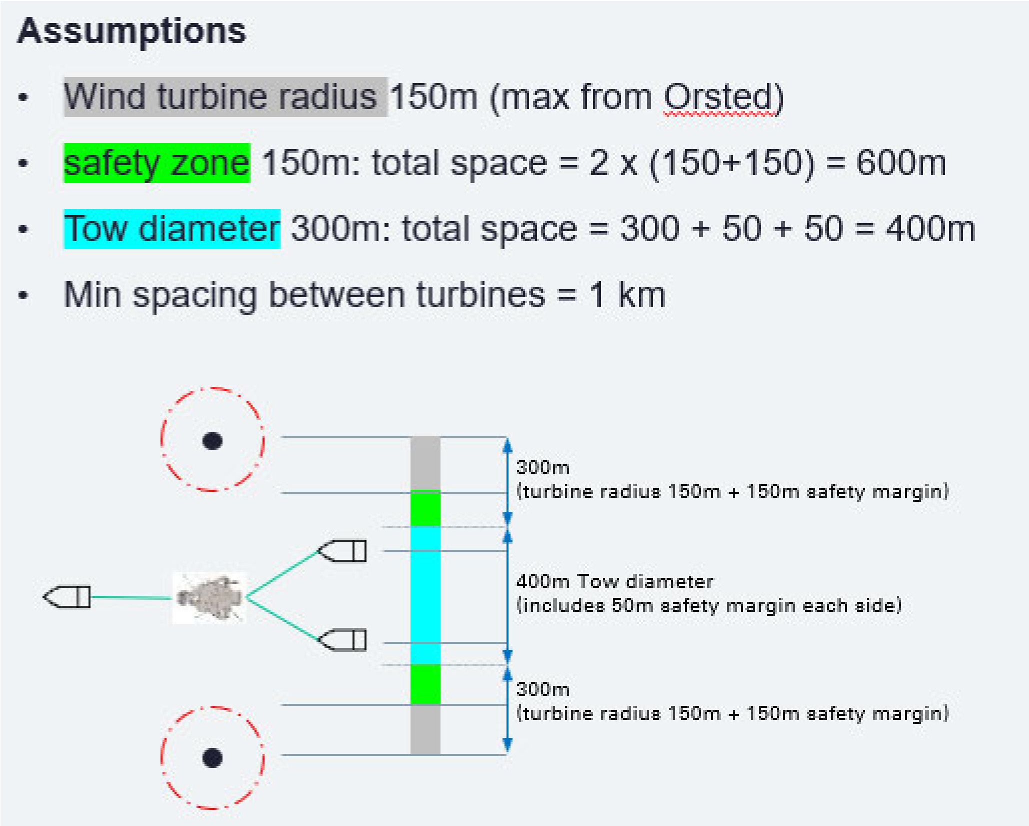


Figure 17: Relief well access

RW rig mobilization and rig logistics support (Boats & Helicopters) considerations within the overlap of a windfarm would be the same as that for the planned wells currently within the proposed Hornsea windfarm overlap, but with a further operational overlap into the windfarm interface. As with the more conventional rig operations, the same challenges will apply for relief well operations with respect to rig access, helicopter support and also any alternative options with service operations vessels (SOV) as outlined below. However, the additional implication with relief well operations above the already identified schedule, cost and risk impact to rig operational execution is a potential risk of longer duration of uncontrolled brine or CO_2 release prior to being able to commence a required relief well intervention.

Options and analysis – Reduced Tow Spread

Rig contractors Maersk and Valaris were further engaged as to future considerations for rig mobilization within and adjacent to a windfarm. It may be possible to bring a jack-up rig into the Hornsea-4 windfarm/Endurance overlap area for well activities with a 1 km turbine spacing, with the full cooperation of wind farm operator (Orsted), based on a Super-Gorilla rig (e.g. Gorilla V, VII), with the utilization of shorter tow cable / tow spread. A smaller class rig would also further reduce the tug size requirements. As above, the consequence of tug failure is unacceptable but would be further exacerbated in an even more constrained spacing. Also, this consideration is based upon desktop assessment to date without any operational experience and track record of execution within the matrix of a windfarm. The anticipation is that this level of constraint will ultimately result in significant WOW impacts.



Assumptions

- Wind turbine radius 150m (max from Orsted)
- safety zone 150m: total space = 2 x (150+150) = 600m
- Tow diameter 300m: total space = 300 + 50 + 50 = 400m
- Min spacing between turbines = 1 km

Figure 18: Possible future rig access consideration

Options and analysis –Search and Rescue (SAR)

In the event of any major incident on the rig, a field congested with wind turbines will ultimately increase response times and may make it particularly challenging for search and rescue operations. Vessels will also be limited with operations to effectively:

- conduct required towed skimmer activity in the event of some sort of loss of primary containment and an associated spill occurrence,

- manage evacuation from a possible CO_2 plume dispersion pathway, or
- conduct standard box grid search patterns for SAR operations

Overall response times will also be increased due to OSV positioning, as considered to be normally outside of the windfarm.

Additional risk and emergency response time will be ever present with a co-located solution. Increased size of on-site workforce for simultaneous operations (~140 to 150 workers on rig at any given time, 4 to 5 flights per week) is greater than the number of workers required to operate the windfarm exclusively, thereby increasing the probability of occurrence of a serious incident involving personnel who would be operating within an overlap. We are required to have emergency response and rescue vessels on location to provide support to the rig operation. Multiple adjacent assets will create blind sectors for radar coverage to detect passing vessel collision threats and will require vessels to remain clear of the overlapping field area unless close standby duties are required. A heightened state of awareness and navigation is required when operating in such a congested area. This, coupled with the supporting vessel location outside of the area of operational overlap, will ultimately increase the response times and ability to respond quickly to an event on the rig. BP marine and aviation have indicated that even a 3km turbine spacing would not significantly improve search and rescue (SAR) operations. It is unclear what the SIMOPS interface for a SAR operation would look like with the surrounding assets, inclusive of how a seamless coordination of primacy and command / control would be managed. With all the considerations currently assessed, the likely outcome of a person overboard situation would be a longer timeframe to rescue the person/s who may become adrift from the rig operations or a ditched helicopter flight.

Options and analysis – Crew Change

Utilizing service operations vessels (SOVs) for rig access within or adjacent to the Hornsea 4 wind farm has been investigated as a possible alternative to direct helicopter access for rig crew-change. This may be possible for well construction and subsequent well intervention activities. This could involve helicopter crew changes to a vessel (stationed outside the windfarm), with personnel then being shuttled to the rig location and transferred to the rig via a motion compensated gangway, which allows a walkway to and from the rig.

The options are for an SOV to be used for crew changes from shore or for the SOV to sail to the periphery of the windfarm with helicopter crew transfer at the periphery. This SOV alternative is subject to identifying a suitable vessel which is capable of crew transfers to the jack-up rig according to the required air-gap elevation (which is dependent on weather conditions, 100 year – storm, surge and tidal impacts). Indications are that the expected rig air gap requirements are at or beyond current vessel capabilities for year-round operation and further work and investment would be required for this to become a reality.

The current limitations imposed by weather in this area and by available vessels capability, indicates that a motion compensated gangway might only be feasible for circa 4 months of the year within the calmer summer period. This has not been done with a jack up in this location and the maximum gangway elevations of currently available vessels are circa 20 – 25 m. This situation may require a circa 30 + m elevation and so may require new builds or modification to existing SOV's. This alternative would also be subject to weather window impacts for safe approach and transfer of personnel to and from the rig which could also lead to inefficiencies, higher well activity durations, costs and delays for possible emergency transfers.

Introducing this type of unfamiliar operations (BP's current standard operation is to use helicopters for crew transfers) would result in:

- significant logistics cost increases, increased commuting time and crew welfare impacts (and the potential knock-on mental considerations for ongoing safety critical job tasks)
- increased marine traffic within the confines of a windfarm (increasing risk of collision),
- increased marine vessel approaches to the rig, with increased risk of collisions.
- increased personnel risk associated with use of a motion compensated walkway to the rig and other possible / riskier transfer methods in emergency situations where gangway deployment is not possible.

Significant additional work would be required to define further requirements to enhance the feasibility of SOV type operation.

7.1.1.4 Aviation Access

Challenge and Recommendation

Helicopter access is required during rig operations for crew change, Medevac requirements and SAR operations. This is already a significant risk, made more hazardous if there is a requirement to fly close to wind turbines.

Having considered the challenges of close turbine spacing and its impact on weather tolerance, the risk of turbine-induced turbulence, the current lack of regulatory certainty associated with flying within a windfarm and the frequency of flights required to support rig activity, the use of helicopters within a windfarm to support rig activity is seen as significantly challenging and high risk with respect to crew change, Medevac, and emergency response.

[References 26 to 31]

Options and Analysis – Turbine Spacing and Weather Requirements

Aviation Access Wind Turbines considerations are as follows:

- Max blade diameter 305m
- Blade tip height 35m - 370m above lowest astronomical tide (LAT)
- Nacelle (adjacent to rotor hub) will be able to rotate to face wind direction
- Expected wind turbine spacing 1 – 1.2 km

This is also coupled with an increased frequency of flights into windfarm - Additional 4 – 5 flights per week (to support rig (POB ~ 150) crew change) above typical wind farm helicopter support for maintenance activity.

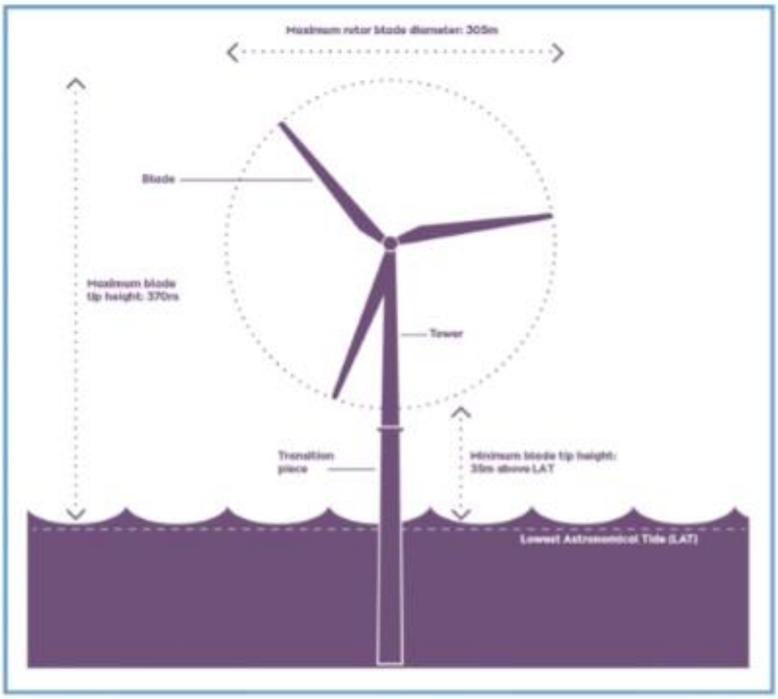


Figure 19: Overview of a typical wind turbine generator (indicative only)

Although the expected turbine spacing is 1 – 1.2 km, as with the rig moving considerations, different turbine spacing scenarios were considered with spacing ranging from 3km to 0.5km.

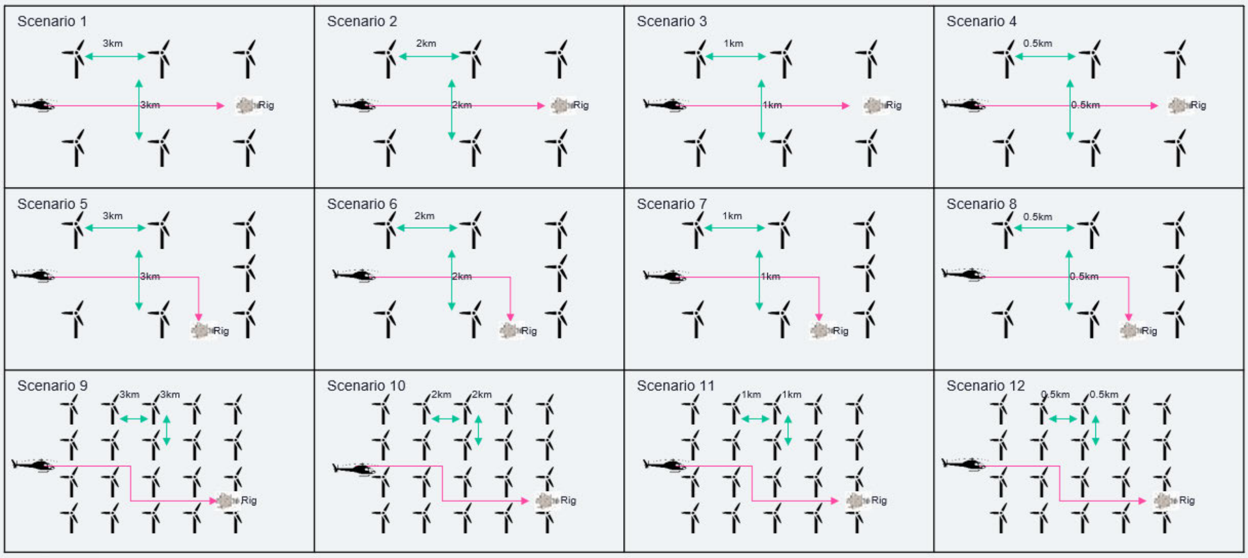


Figure 20: Helicopter access scenarios

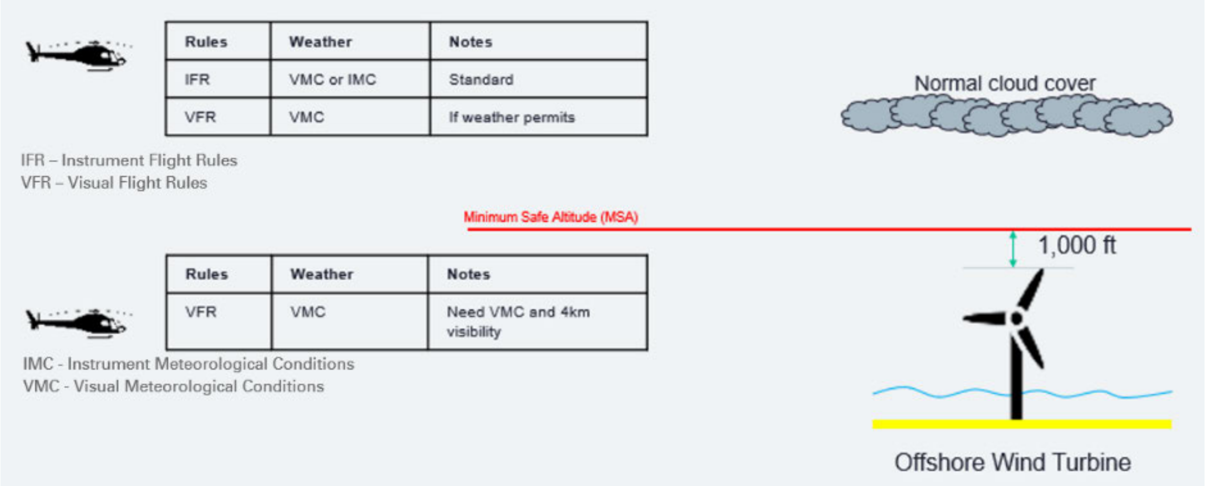
Similar to the rig access, the understanding that is required, given the flight risk considerations, is which scenarios are plausible and statistically how feasible is it to be able to access a jack up rig via helicopter transportation through the wind farm for the plausible scenarios, e.g.

- Is scenario 1: possible 300 days out of 365 (P50)
- Is scenario 2: possible 250 days out of 365 (P50), and
- Are there any other restrictions for the given scenarios (e.g. the requirement to stop turbine rotation during close proximity aviation operations)

Helicopters fly under either IFR (Instrument Flight Rules) or VFR (Visual Flight Rules):

- IFR indicates flying with sole reference to instruments (without, or with limited forward visibility). Safe height is deemed to be 1,000ft above the nearest obstacle (offshore this is Miller/ETAP which are ~500ft tall).
- VFR indicates flying in clear weather / visibility based on what can be seen – this depends on airspace and aircraft type and day or night.

Boundaries between IFR and VFR depend on speed, aircraft type, airspace and the task. A typical North Sea (NS) flight will take off on IFR, follow air traffic control (ATC) instructions enroute to destination (still on IFR), descend through cloud, and then land under VFR. NS helicopters must also obey Commercial Air Transport (CAT) rules which are intended to ensure passenger safety at all times. There are currently no special regulations for flying within windfarms and thus such operations fall under existing Civil Aviation Authority (CAA) rules, or those developed for offshore platform operations. The CAA is looking into establishing applicable rules which are still pending. Currently, the closest considered analogue is flying between multiple platforms (e.g. Forties / Ekofisk). This requires flying on VFR at altitude 500 ft with 4km visibility.



Rules	Weather	Notes
IFR	VMC or IMC	Standard
VFR	VMC	If weather permits

IFR – Instrument Flight Rules
VFR – Visual Flight Rules

Rules	Weather	Notes
VFR	VMC	Need VMC and 4km visibility

IMC - Instrument Meteorological Conditions
VMC - Visual Meteorological Conditions

Figure 21: Helicopter navigation considerations

Bristow Group is a leader in global vertical flight solutions, offering historical helicopter services for offshore oil and gas (O&G) transportation as well as search and rescue (SAR) services, not only to the O&G industry but also to civil and government organizations. Bristow's current views on flying within a windfarm are in summary:

- Weather conditions need to be suitable to enable VFR within confines of windfarm
    - Estimated visual conditions needed: 600ft altitude with 4km visibility

    - Flights would be limited to daylight time only.
    - bp/Bristow estimate that these conditions are presently met by 75-80% of daylight hours each year
- Safe altitude for IFR (see above) will need to be raised to ~2,200 ft for turbines which are 370m (1,200 ft) tall. That is, at least 1000 ft above the nearest obstacle.
- Accounting for reduced speed on approach, the turn radius is expected to be ~1km with a further 1.5km needed (into the wind) for landing
- In absence of specific regulations, Bristow currently consider 2km spacing (giving worst case 850m clearance to blades) is the minimum possible with 3km spacing being more reasonable
- Helicopters land into the wind (or as close as possible). It is envisaged that there will be several entry/exit "gates" to the windfarm, with visual navigation being required at 400-500 ft.
- Considerations of the impact of turbulence from wind turbines:
    - The impact of turbulence from wind turbines on passing helicopters requires further study as to impacts on SIMOPS with helicopter flight operations. The impact of this extends to the following operations and associated frequency:
        - Crew Change - Estimated number of crew change flights while the rig is in the field: circa 4 flights per week (150 POB, 19 seats on helicopter, 2on / 2off rotation)
        - Search and Rescue - SAR teams have also been looking into this with respect to the considerations and risks for any required emergency operations.

Weather restrictions considerations for Visual Meteorological Conditions (VMC) are currently:

- By day – 3 km visibility and 600 ft cloud base
- By night – 5 km visibility and 1200 ft cloud base (cloud base 100 ft higher than highest obstacle - turbine blade tip at 12'oclock position in the case of a windfarm)

Weather restrictions considerations for flight operations within and / or adjacent to a windfarm will ultimately be dictated by the CAA's guidance - currently under consideration but not yet published.

Note, in poor weather conditions (e.g. fog) without a windfarm in place, helicopter approaches are typically guided with airborne radar. Rig/Vessel positioning permits helicopter low visibility, airborne radar approach operations to the helideck to maximise helicopter operating weather windows without CAA special restrictions for CAT. Additional work is needed to determine and define a weather window for windfarm restricted versus unrestricted operations and to consider other possible mitigations such as installation of navigation lighting on all turbine towers within the wind farm.

Options and Analysis – Regulatory Aspects

The extent of the impact of windfarm turbines on Air Traffic Control (ATC) services would require further investigation. Wind Farm structures/turbines are expected to have some impact on ATC surveillance radar returns for helicopter flight tracking adjacent to / within the wind farm, to helideck height. CAA approval would be required for ADS-B (Radar Tracking) use for ATC surveillance in wind farm areas and the Endurance location would also need to be approved or confirmed as an approved location for ADS-B use.

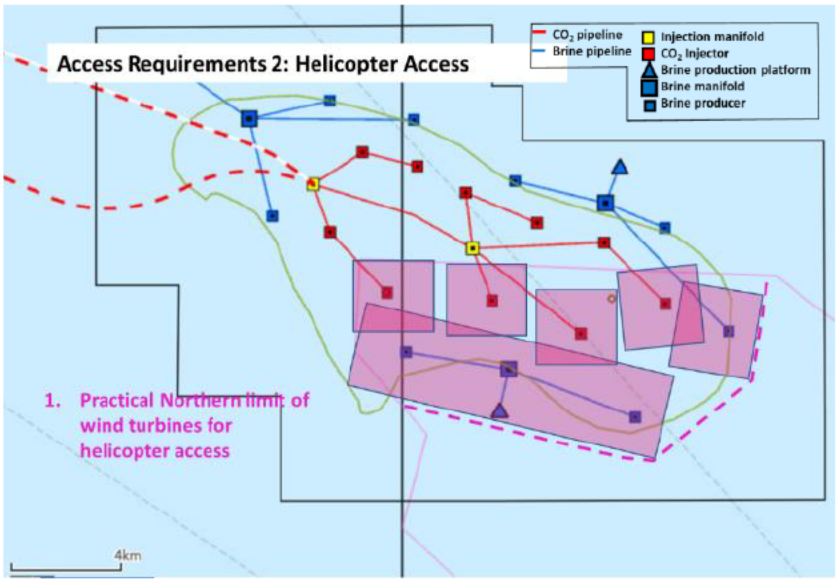


Figure 22: Helicopter Access Corridors

CAA and helicopter operators will be required to develop and approve new helicopter operating procedures for CAT flights adjacent to /within wind farms. This should include, for e.g., guidance and procedures to cover missed approaches and go-around for standard crew change operations. These will be among some of the considerations that will be under current CAA deliberations.

Options and Analysis – Turbine Induced Turbulence and SIMOPS

Turbulence and SIMOPS with Wind Farm Operator Aerial Works:

- As mentioned above, helicopter operations adjacent and within wind farms will be subject to turbulence from turbines. The impact of turbulence from wind turbines on passing helicopters requires further study as to any additional impacts on minimum required turbine spacing.
- Further work will be required to determine if wind farm turbines within close proximity will need to be shutdown/ stationary for the period of nearby helicopter operations within wind farm.
- Wind Farm operators aerial winch work will require co-ordination to de-conflict aerial work with crew change flights adjacent to /within the wind farm. Wind farm aerial work may need to cease during crew change flight operations. The risk of hazards during SIMOPS will be increased. The only way to reduce or de-risk these hazards is to avoid the conducting of such SIMOPS.

Options and Analysis – Medevac and SAR (Search and Rescue)

Medevac and SAR (Search and Rescue) Helicopter operations:

- The ability for medevac operations will be impacted by the VFR and IFR. This will result in additional time and risk to carry out medevac to and from rig/vessel located adjacent/within wind farm due to weather flying restrictions. As indicated previously, the risk profile is significantly changed with a standard rig POB (Personnel on board) of 140 persons compared to say <10 for windfarm operations. The surrounding turbine infrastructure will also further complicate any required helicopter SAR operations for recovery of any rig overboard personnel or personnel who may become adrift form a ditched helicopter, enroute to/from the rig.
- The indication from the bp marine and aviation team is that no significant SAR advantage would be gained even with a 3 km wind turbine spacing given the potential prevailing metocean conditions. Further work as well as guidelines from the CAA will be required to better define how SAR SIMOPS would be coordinated within overlap of rig operation / windfarm.

Options and Analysis – Human Factors

It must also be noted that there will be significant human factors considerations with respect to managing the special conditions which will be associated with helicopter operations within / adjacent to a windfarm. This introduces the risk of human error for pilots who may be servicing different operations, that is, interchanging between normal crew change flights to operations and crew change flights within a wind farm. One possible consideration to help to reduce this risk would be for operations within / adjacent to a wind farm to have an assigned dedicated flight crew for their crew change roster period.

7.2 Infrastructure Co-location : Impact on NEP Subsea Infrastructure

Challenge and recommendation

The intermeshing of seabed infrastructure e.g. flowlines, umbilicals and cabling is not recommended due to additional risks to SIMOPS and access for future maintenance and interventions. These considerations result in increased safety risk and additional costs. There will also be operational liability if any low probability risk materialises on either party (rig or wind farm operations), with the attendant legal complications as a responsible duty holder.

The shortest distance CO_2 pipeline corridor from Humber to Endurance would create additional constraints on the currently proposed Hornsea 4 layout, similar to the shipping corridor to the south of Hornsea 4 that Orsted created for DFDS Seaways. The CO_2 export pipeline from Humber was therefore rerouted to avoid the windfarm completely resulting in additional 15km length (ca. 20% longer), to minimize complexity. This reduces the number of crossings to just 1 with the Hornsea 4 export power cable to shore.

7.2.1 Power Cable / Pipeline Interaction - Electromagnetic Interference (EMI)

Electromagnetic interference from overlaying flowlines with high power array cables between wind turbine generators could result in accelerated corrosion issues and interference with subsea electrics for CO_2 injection. It is recommended that outside of crossings, pipelines should have a minimum of 2km separation from power cables to avoid interference and mitigate the impact of the HVDC (High Voltage Direct Current) cable on the mechanical and material design of the pipeline. There is also potential for interaction between the daisy chain flowlines to the wells and the turbines/cables. In addition to the electromagnetic impact to the flowlines there will also be a need to ensure the flowlines do not damage the windfarm cables.

Subsea wellheads, umbilicals and flowlines are dictated by optimum well locations for reservoir management and safe monitoring. Overlap design considerations will be for the offshore pipeline to be installed first with the wind farm power cable crossing over the top. Infield this will be the opposite. Greater pipeline protection at the windfarm interface would have to be considered due to electromagnetic fields and also the potential for collision/damage through windfarm SIMOPS - construction/operational/maintenance activities. SIMOPS risks during construction, operations and future intervention will continue to be a challenge with increased costs should intermeshing be required. This will require further study and careful coordination, including appropriate liability frameworks to be put in place to ensure co-existence is feasible over the life of the facility. If the wind farm cables move overtime this could also further impact the flowlines.

7.2.2 SIMOPS and CO_2 Venting

SIMOPS will remain a challenge from construction through to operation. Considered challenges may include:

- Risk of CO_2 plumes within the windfarm during manned activity
- overlapping dropped objects management
- work prioritisation
- vessel and/or turbine collision
- drill rig approach
- drill rig interaction with the construction/operation of the wind farm such as impact of drilling activity on turbine piled structures and conversely piling activity near wells and subsea architecture

A SIMOPS plan would need to identify who has primacy in differing scenarios, likely resulting in inefficiencies for both parties such as :

- Poor design interfacing/scheduling between NEP and the windfarm contractors as a result of the cumulative impact of two major infrastructure projects gaining DCO approval and progressing EPCI (Engineering, Procurement, Construction & Installation) over similar timeframes.
- Engagement with inshore fisheries may be more sensitive given increased activity in the area.
- The cumulative impact of simultaneous noise inducing operations within close proximity, such as turbine foundations and subsea manifolds installation.

- The impacts to operation efficiency due to increased collision risk / primacy with increased vessel traffic and associated narrower corridors.
- Subsequent operations for water washing of wells and ROVs operating in the vicinity of wind turbine foundations
- Commissioning and Maintenance CO_2 venting - Venting of carbon dioxide during commissioning/start-up and maintenance poses an HSE risk to windfarm personnel. CO_2 is an asphyxiant and a relatively heavy gas, thus any required or inadvertent venting would pose a risk to personnel attending to surrounding assets.

7.2.3 Seabed Disturbance

Over the life of CO_2 operations, there is an expectation of uplift of the injection reservoir cap with impacts all the way to the seabed per geomechanical modelling of the Endurance reservoir. Given the large seabed area over which the uplift forces may act upon, the scale of vertical displacement is expected to be small. Further engineering assessment will be required to determine the possible impact of this phenomena on wind turbine foundations.

7.3 Store Monitoring (4D Seismic)

Challenge and recommendation

As stated in the overlap report [2], towed streamer seismic is considered the best technical solution for 4D seismic store monitoring. The conditions at Endurance, with a shallow seabed (60m) and shallow reservoir (1000m) mean that towed streamer seismic will achieve the required high resolution reservoir to seabed imaging.

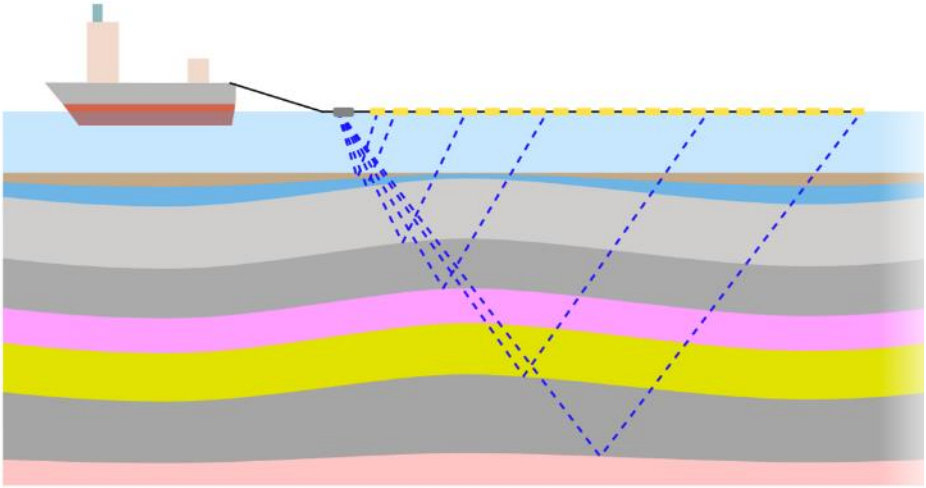
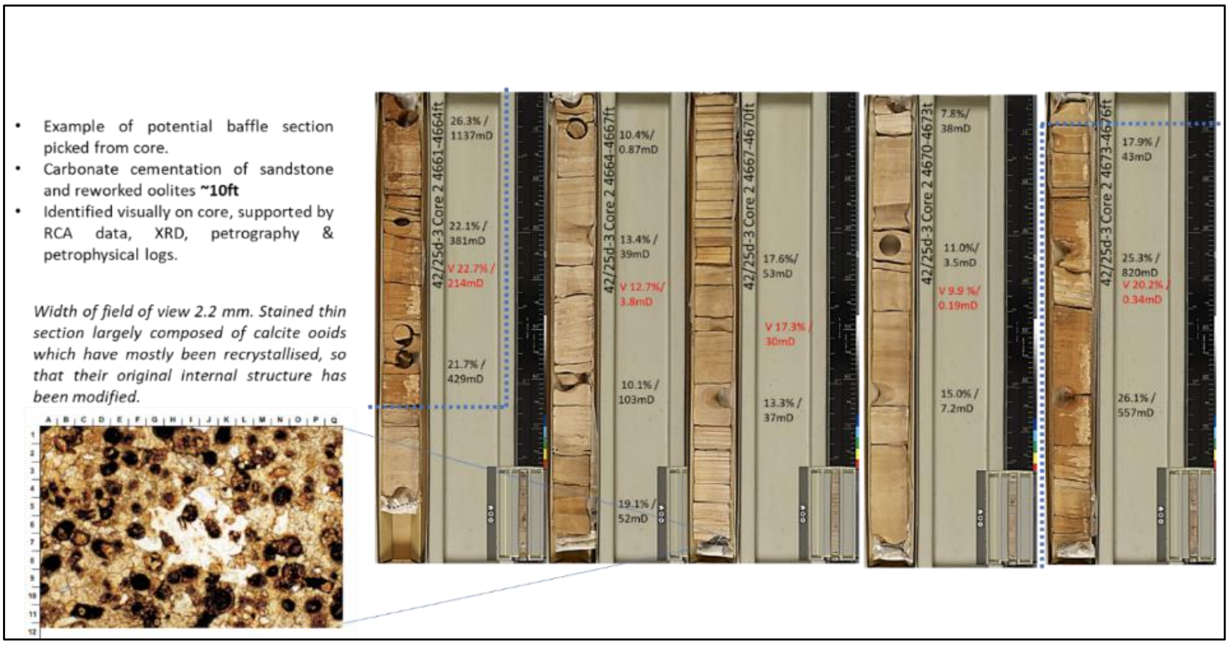


Figure 23: Illustration of seismic acquisition with towed streamer

7.3.1 Requirements for 4D Seismic Data

The resolution of the seismic data required is dependent on the geology of the reservoir. Core taken in well 42/25d-3 of the Bunter Sandstone shows that it is a clean reservoir with thin layers (1-3m) of shale and calcite cemented layers (Figure 24). These thin layers both have low porosity and permeability and will act as restrictions to fluid flow, impacting the migration of CO_2 in the store. At core scale we see the permeability within the main sandstone is highly stratified, and the combination of stratified permeability and lateral barriers to flow is likely to create a complex distribution of CO_2 within the store. Therefore imaging at high resolution to see where the CO_2 is and where it could move to is an essential part of the monitoring plan. To simulate CO_2 in high porosity/permeability in thin beds a fluid substitution was carried out with a porosity cut off at 28% (Figure 25). This shows that whilst any standard resolution seismic will detect thicker layers of CO_2, the thinner layers only show a 4D response (4D Nears and 4D Fars on the figure) at high resolution. Additionally, the lack of resolution places the base (blue peak) of the CO_2 filled layer in the wrong place, giving an incorrect view on the position of CO_2 within the reservoir.



- Example of potential baffle section picked from core.
- Carbonate cementation of sandstone and reworked oolites **~10ft**
- Identified visually on core, supported by RCA data, XRD, petrography & petrophysical logs.

Width of field of view 2.2 mm. Stained thin section largely composed of calcite ooids which have mostly been recrystallised, so that their original internal structure has been modified.

Figure 24: Scale of potential baffles/barriers in the Bunter Sandstone at Endurnace - example from core at 42/25d-3

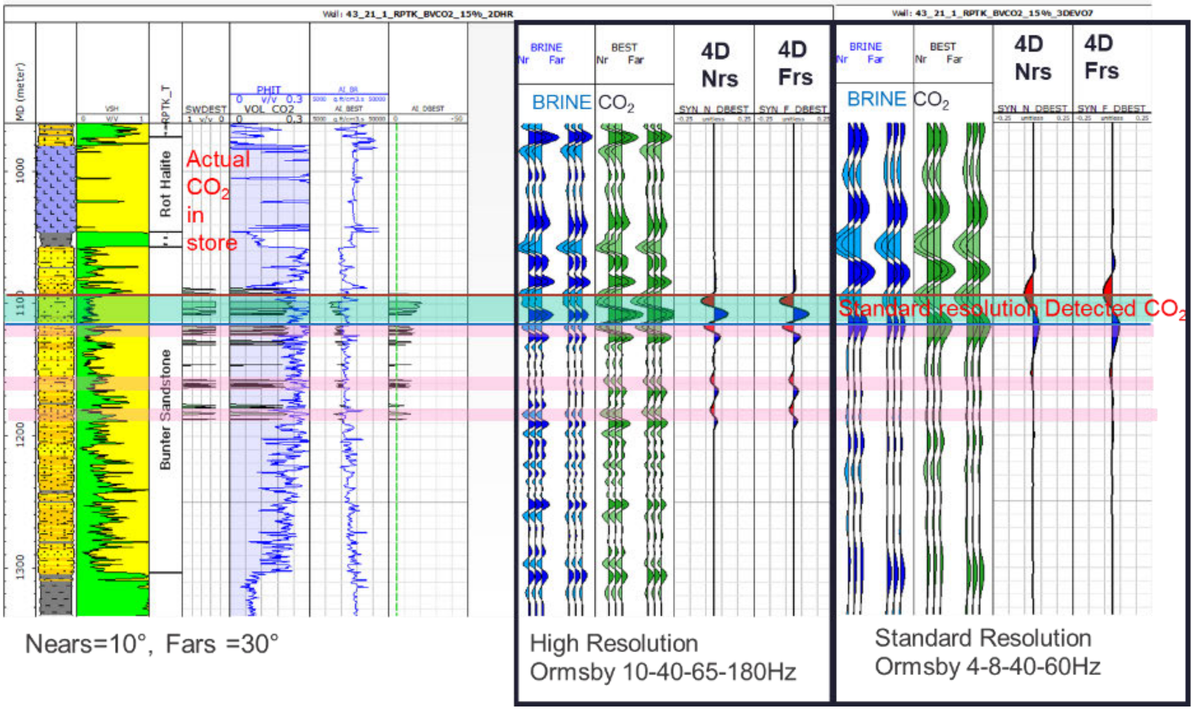


Figure 25: Detectability of CO_2 in thin beds.The seismic response is shown in tracks '4D Nrs and 4D Frs' (Nears = 10^0 and Fars =30^0). Standard resolution only detects part highlighted in green and misses the additional CO_2 shown in pink, which is detected at high resolution.

The examples below show the difference between the high-resolution towed streamer data and the legacy sparse OBC (ocean bottom cable) data. The High Resolution (HR) Towed Streamer (TS) data (Figure 26) provides imaging over the entire monitoring area from store to seabed at high resolution.

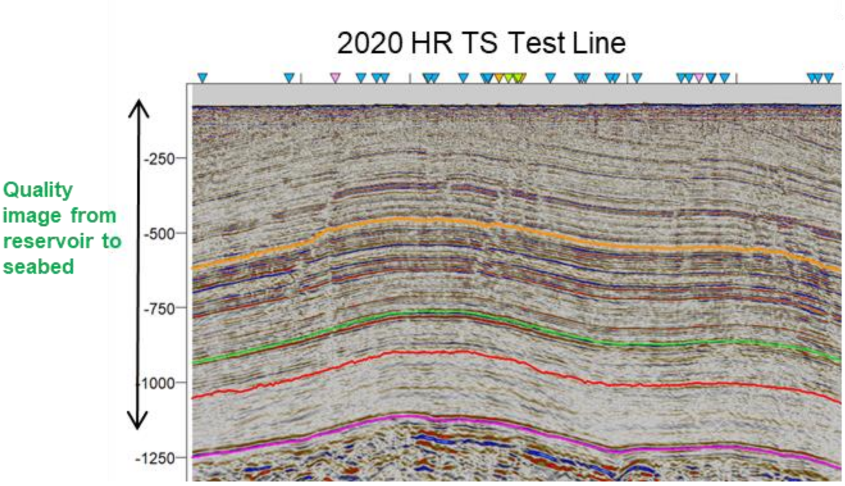


Figure 26: Example of high resolution towed streamer data over Endurance

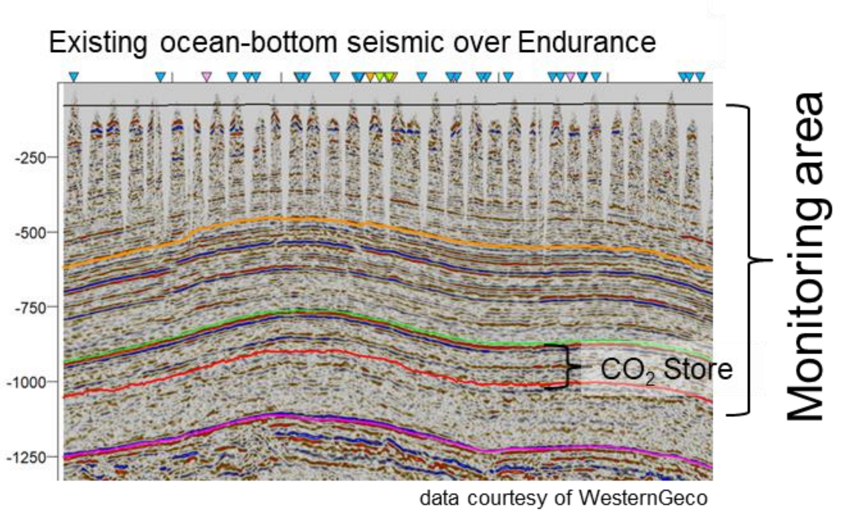


Figure 27: Matching line to Figure above for the legacy OBC data

7.3.2 4D Seismic Studies: options considered

Given the knowledge of the overlap with Hornsea 4, the project has undertaken test seismic acquisition along with many other studies to fully investigate the options for acquiring reliable 4D seismic. The original seismic acquisition plan was to use a typical industry seismic vessel towing multiple 4-6km long streamers. This would have required an area of around 220km^2 to be removed from the windfarm and was clearly not an acceptable solution for this situation. The following options were considered as alternatives:

1. High Resolution 3D with shorter streamers
2. 2D/4D seismic
3. P-cable (very short streamer seismic)
4. Sparse OBN
5. Dense OBN

In 2020 four high resolution 2D (2DHR) seismic lines were acquired to test the imaging of the reservoir with a shorter streamer/ high resolution set up, repeatability of the 2D data, and the impact of acquisition direction.

High Resolution (HR) Seismic

It was proven that the shorter streamer HR data provided excellent imaging of the reservoir (Figure 26) at much higher resolution than traditional data, and that acquisition direction was not a particular concern on imaging quality, which would allow a survey to be optimised with the windfarm in mind. It allowed for a reduction of the seismic survey overlap by 90km^2 (and with the new Hornsea 4 outline this is reduced to a total 110km^2 overlap from an initial 220km^2), by shifting to short streamers and changing acquisition orientation.

2D/4D Repeatability

2D/4D (time lapse 2D seismic lines) was trialled as the only option to acquire towed streamer seismic data in the windfarm, it was envisaged as being a ‘quick check’ survey that could reduce the need for full 3D seismic repeated surveys. However, the repeatability of the 2D lines was particularly poor, with even the near offsets at the seabed providing a different image on the repeat lines (shot on consecutive days in the same direction). The currents in the area of interest are strongly tidal and change direction completely every 12 hours (Figure 28), making matching source-receiver pairs (to image the same piece of the subsurface) with 2D data a challenge. Along with the lack of any map view (which is only provided by 3D seismic) to provide additional quality checks, and the difficulty in repeating 2D lines, a 2D/4D plan was decided to be unfeasible. There would also be operational concerns, with an escape path needed out of the windfarm to avoid the seismic vessel sailing all the way to the southern end of Hornsea 4 to turn.

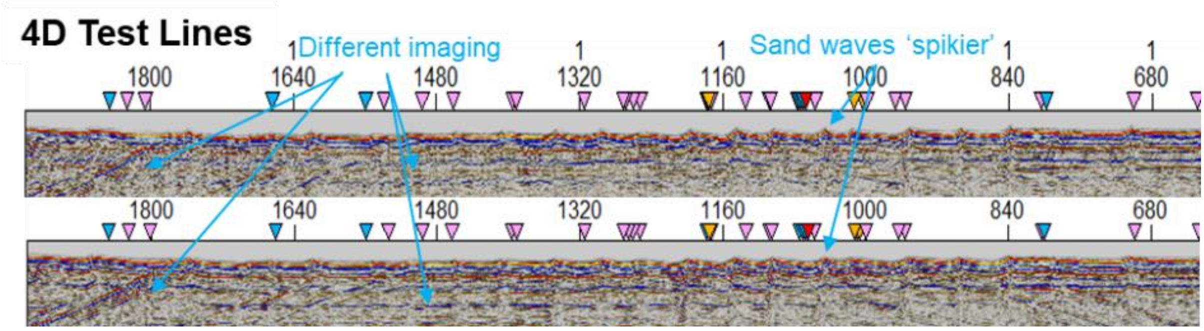


Figure 28: Comparison of the 2 repeat 2D/4D test lines. The sail line was identical but the currents caused different subsurface imaging even at the shallowest depths/nearest offsets.

P-Cable

P-cable is a system used for shallow hazards imaging that acquires 3D seismic data with very short cables. The short cables would allow for swaths of 3D to be acquired in the windfarm but would still leave significant gaps in coverage. To test this, the 2DHR lines were reprocessed with only 200m streamer length to test the feasibility of P cable imaging of the reservoir. It was found that the top of the Bunter sandstone was not imaged on this data, which made it unsuitable. Even with a 200m long streamer, the safety margins around the turbines would create significant holes in the survey, which would not be filled due to the lack of offsets. Additionally, P cable has not been proven for use in 4D and works best in deep water where multiples become less of an issue.

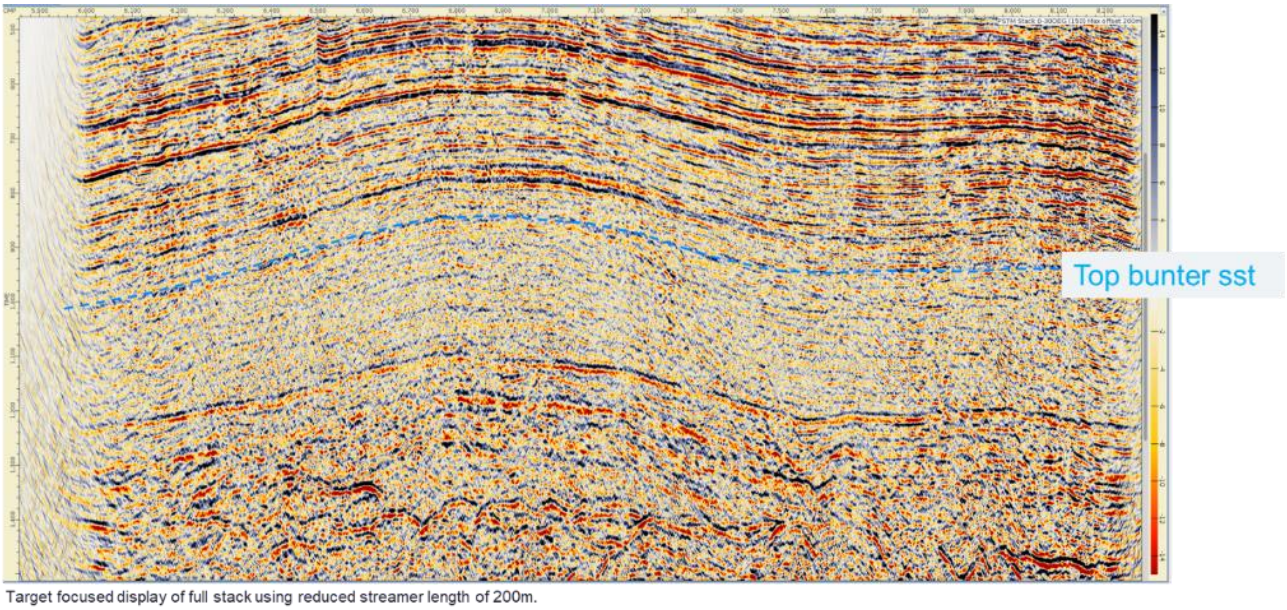
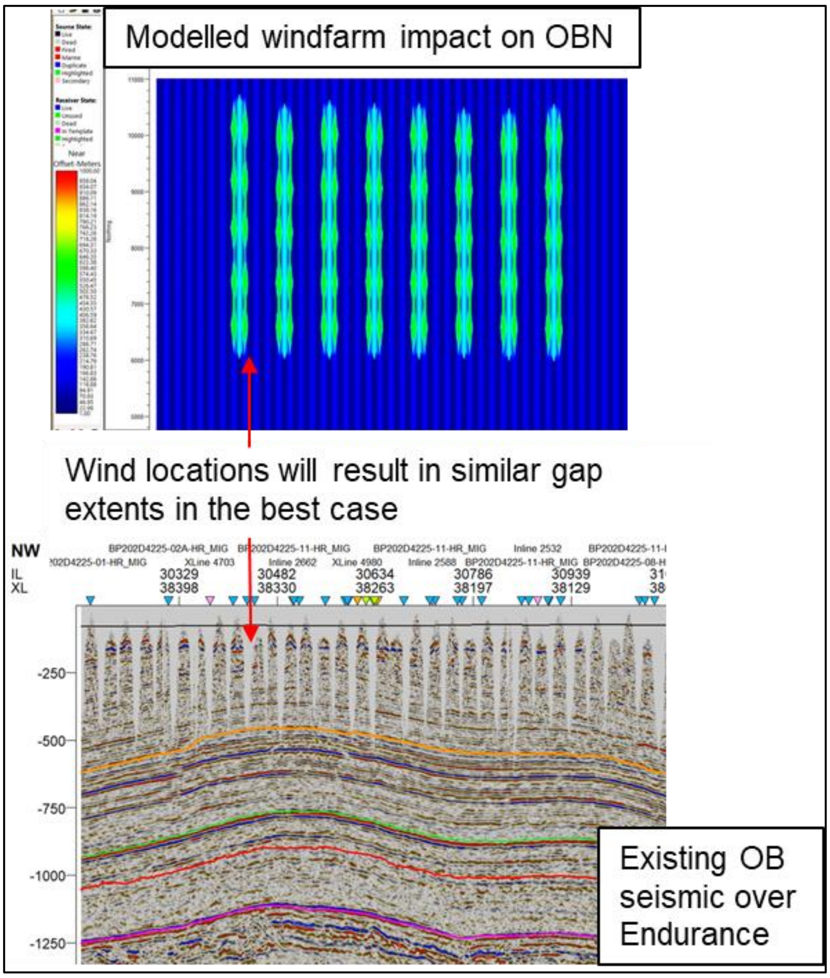


Figure 29: Cropping the offset range to 200m to simulate a typical P-cable offset range. top Bunter (blue dashed line) is barely imaged. The quality at reservoir level is not sufficient for reservoir monitoring.

Sparse Ocean Bottom Node (OBN)

A sparse ocean bottom survey already exists over Endurance (1997 WG Ravenspurn survey) and there are very clear limitations with this technique. Above the Triassic there is no consistent imaging (Figure 30), and this means that the route to seabed is not monitorable. It was suggested to use the sparse OBN for full waveform inversion (FWI), but a velocity cube does not have the resolution required and 4D FWI velocities are not proven to work. The 4D response is the result of changes in both velocity and density with about equal weighting, so only half the response would be seen on a velocity cube versus amplitude. Sparse OBN is therefore not going to provide the necessary 4D monitoring required for the store.


Modelled windfarm impact on OBN

Wind locations will result in similar gap extents in the best case

Existing OB seismic over Endurance

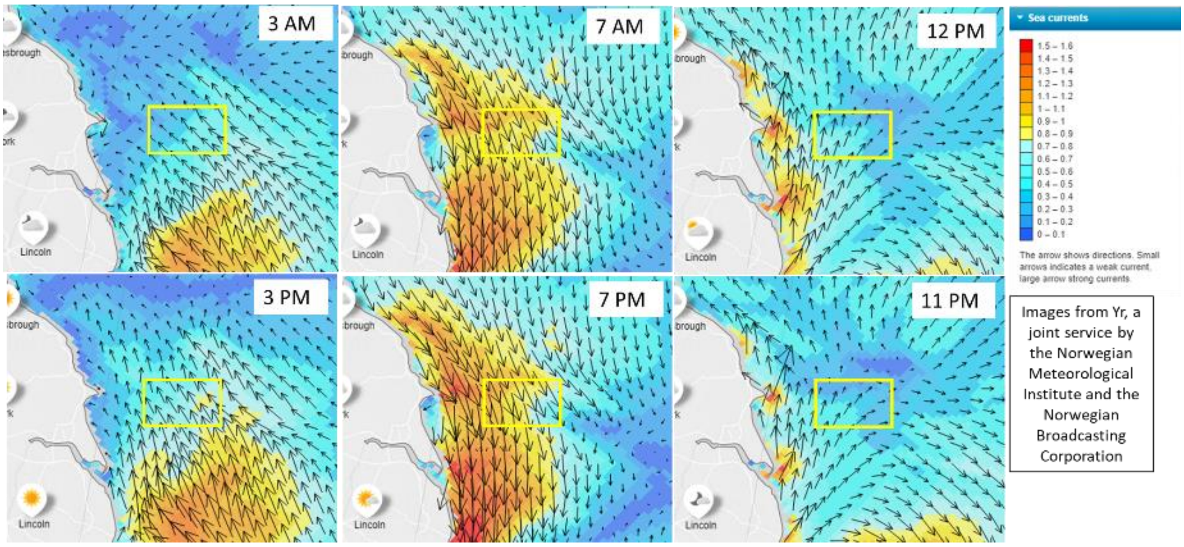
Figure 30: Modelled near offsets with wind turbine exclusion zones

Dense OBN

Dense OBN may be feasible but it is not yet proven. No-one has conducted an OBN survey in a windfarm, and there are definitely no 4D examples. A dense OBN survey will still have significant gaps in offset coverage, and sailing of a source vessel through the wind farm will be difficult and not without risk. With the strong currents (Figure 34) it may be challenging to fully replicate source-receiver pairs. Weather conditions will be very important and could lengthen the survey, increasing the risk of timely data acquisition. The 10-15X cost increase of a dense OBN survey over a 3DHR towed steamer survey cannot be ignored.

7.3.3 Acquisition Challenges

Acquisition in the area around Endurance is complicated by the strong tidal currents. The maps below illustrate the change of direction of the dominant current every 12 hours. This will make sailing the seismic source boat along specific lines inside the windfarm difficult. We anticipate that at least 25% extra time will be required for weather restrictions and difficulty in achieving matched source-receiver pairs for accurate 4D differencing. There is also extra operational risk to spending months sailing within the windfarm to acquire the data.



Images from Yr, a joint service by the Norwegian Meteorological Institute and the Norwegian Broadcasting Corporation

Figure 34: Example of variation in current direction and strength in the area (yellow box) over a 24-hour period (22/09/21)

7.3.4 Benchmarking from other CCS MMV experience: example of Sleipner

There are few long standing offshore CO_2 injection sites with similar complexity as Endurance. However, Sleipner CCS project (offshore Norway) can be used as a benchmark for Endurance as it has been in operation for the last 25 years and has become one of the most recognised examples of safe and reliable CO_2 injection.

Sleipner experience [34] demonstrates that towed streamer seismic monitoring is the most efficient and effective means of acquiring the high resolution data needed to verify containment and conformance of the CO_2 plume within the storage site. Its effectiveness lies in its flexibility to cover large survey areas, and the ability to detect small changes in CO_2 saturations over time. The quality of the data showed that actual plume migration was markedly different from original model predictions, as a result of the reservoir complexities encountered during injection operations. Frequent towed streamer surveys became instrumental in accurate plume migration detection and mapping, thus revealing the complex nature of the Sleipner reservoir system.

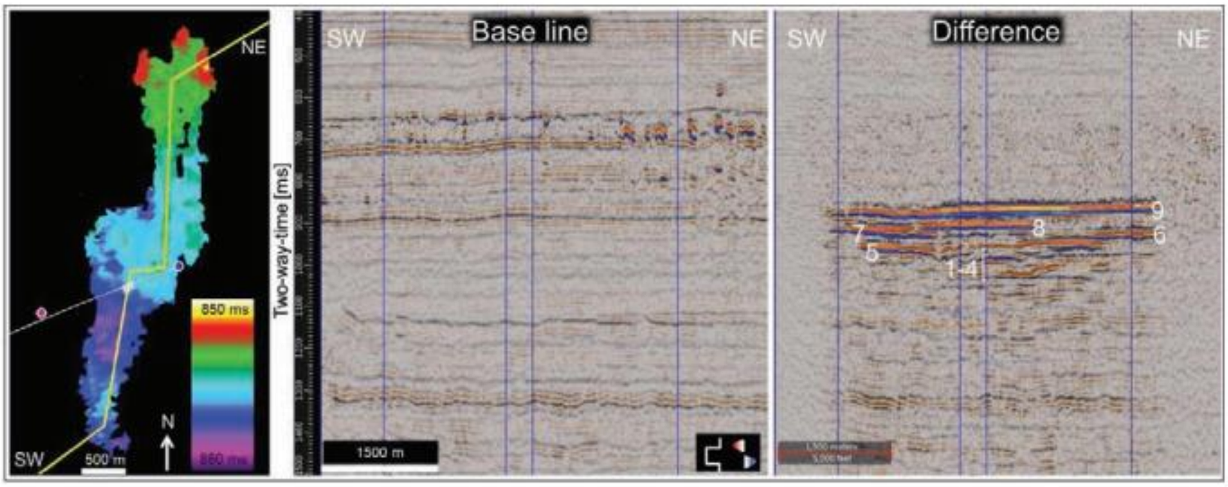


Figure 35: Example - Sleipner CO_2 detection results using streamer surveys [34]

7.3.5 Monitorability: Conclusions

Monitoring of injection at Endurance is essential to demonstrate the safe storage of CO_2 and allow for economic phased development. This is the first project to use the Bunter sandstone for CO_2 storage so there are many remaining uncertainties in the subsurface, in particular the way the CO_2 will move through the sandstone and what barriers it may encounter along the way that will alter its course. These uncertainties require data and time to understand and mitigate against.

Containment of CO_2 within the store needs to be demonstrated throughout the project and at the end of injection for store liability to transfer safely to the state. The planning of new injectors and implementation of pressure management requires a full 3D view of the migration of CO_2 in the reservoir. The risks if reliable monitoring data is not available are very high – either expansion beyond phase 1 is not possible, severely limiting the amount of CO_2 stored, or injection has to completely stop in some or all of the wells if subsurface behaviour cannot be understood. A project on the scale of Endurance cannot be safely managed without it. The only option, apart from towed streamer, would be dense OBN, however it has not been demonstrated in industry that an OBN survey within a dense windfarm would provide reliable 4D results. With the significant additional cost that this also adds, which will ultimately limit the amount of monitoring possible, it is a high risk.

8.0 Opportunities

In July 2021, the Crown Estate established a co-location forum for the Offshore Wind and CCUS industries to identify the key challenges and opportunities associated with co-location of infrastructure, building on the recommendations of the OGTC-OREC co-location report [2]. This forum brings together the two industries through active involvement of organisations such as the Oil & Gas Authority (OGA), the Carbon Capture and Storage Association (CCSA), Offshore Wind Industry Council (OWIC) and RenewableUK, as well as Government and Crown Estate Scotland. A primary purpose of the forum is to provide strategic coordination of co-location research and activity and help maximise the potential of the UKCS seabed for these two critical industries.

From the outset in 2020, NEP has sought to maximise opportunities for collaboration, particularly in establishing areas of common ground. This has resulted in the adoption of the same approach to communicating and managing impact on fisheries during survey activities as shared by Orsted. NEP and Orsted also investigated sharing of survey vessels to minimise environmental footprint, safety exposure and cost. Whilst the benefits were limited given the type of data acquisition for different developments, it nevertheless initiated a valuable conversation on supply chain collaboration, particularly in offshore services. Given the extent of infrastructure development in the Southern North Sea basin, the collaboration between NEP and Orsted also resulted in minimising crossings and electromagnetic interference between high power transmission and cathodic protection of carbon steel pipelines. This increased NEP costs slightly but reduced overall risks to both projects. As an extension of the concepts being developed by the OGA-led Energy Integration Project, NEP also explored the purchase of power from the Hornsea windfarm development for CO_2 injection. Whilst there is additional capital cost for voltage conversion equipment that could be offset by shorter power cables to the Endurance subsea development, there remained power supply intermittency challenges which could eventually be addressed through technological solutions such as underwater batteries but which are currently incompatible with the timing needs for both developments.

In addition to the shorter term opportunities above, bp are also investigating medium to longer term opportunities. bp has invested as a major shareholder in ‘Blue Ocean Seismic Services (BOSS)’, which aims to commercially develop autonomous ocean bottom nodes (AUV OBNs) which can be deployed within a windfarm without need for larger vessel access. Currently at R&D stage, maturation of this technology will improve safety and timing difficulties with seismic acquisition but can only be deployed when proven data is available at scale to satisfy regulatory requirements. Similarly, there have been theoretical ideas to utilise the natural frequency of wind turbines as acoustic sources which would complement AUV OBN technology. The use of offshore wind energy to power CCUS offshore developments can also be technically developed further, building on the many offshore facility electrification initiatives being studied and deployed successfully in the North Sea. Acceleration of these technologies would depend on a combination of successful technical trials, aggregated demand and regulatory acceptance to enable cost effective deployment at scale. These options could be advanced through the Crown Estate sponsored co-location forum which NEP are keen to support, given they create win-win solutions for both CCUS and offshore wind in future reservoir developments from Endurance as the hub. However, it needs to be stressed that unproven technologies are not suitable for a FOAK development due to the risks outlined above from technical, regulatory and public acceptance criteria.

By its nature, CO_2 injection into saline aquifers necessarily requires an "appraise while developing" approach. As the CO_2 plume migration is observed over time through high quality 4D seismic imaging, reservoir uncertainty is reduced. Once all injectors and brine producers are in-situ and full field development is complete, the rig access corridors and the frequency of 4D towed streamer seismic acquisition may be reduced, provided the wells and reservoir perform as predicted. However, the regulator will still expect the operator to complete final post closure seismic acquisition for verification when the store is at capacity, prior to handover back to the Government. If this requirement is replaced with alternatives acceptable to the operator and regulator, e.g. desktop modelling of final reservoir state supported by past high quality 4D towed streamer data, then there is opportunity to enable phased co-development with a wind farm before the end of the Endurance field life. Similarly, floating offshore wind concepts that can be easily repositioned also enable greater phased co-development to maximise the UKCS potential for both industries. The UK has set a target of 1GW of floating offshore wind by 2030 and the Equinor Hywind development has demonstrated capacity factors that are significantly higher than fixed offshore wind to offset the increased costs [33]. These opportunities cannot be realised at this stage however, as they are decisions that can only be made with sufficient evidence of actual Endurance operational data and the availability of commercially competitive floating wind technology. NEP recognises the importance of keeping a watching brief on these opportunities, given the strategic significance of both industries as highlighted in section 5.0.

9.0 Conclusions and recommendations: NEP Position on Endurance and Hornsea 4 Overlap

The UK has set ambitious targets along its journey to reach net zero by 2050, and CCUS has a major role to play, with Government announcing a requirement for up to 20-30 MTPA of CCUS capacity by 2030. However, compared to offshore wind that has delivered 10 out of the 40GW clean electricity target by 2030, CCUS is not a mature industry and is in the early stages of technical, commercial and regulatory development. It is therefore critical to the industry's growth and Government commitments that new CCUS developments are supported.

ECC is the largest and one of the first two industrial CCUS clusters to be selected for development by BEIS with an ambition to develop up to 20 MTPA of CCUS capacity by 2030 and 27 MTPA (peak) by 2035. At the core of the transportation and storage network (NEP) is the Endurance saline aquifer, the largest and best appraised reservoir in the Southern North Sea with an estimated capacity of 450 MT and injection rate of 15 MTPA. NEP is the only CCUS project that can meet the Government's ambitions as a standalone project and co-development with the Hornsea 4 wind farm risks up to 10-11 MTPA (~70%) of its CO_2 injection rate and capacity. The Hornsea 4 wind farm development is an important component of meeting HMG's 40GW by 2030 clean electricity target, but with no geological constraints compared to Endurance and greater flexibility in wind turbine placement, subject to consent. Both developments serve different objectives of key HMG policies as Nationally Significant Infrastructure Projects (NSIP) with overlapping use of the UKCS seabed. With at least 12x difference in carbon abatement potential between the projects, strategic choices must be made to ensure optimal use of UK resources.

Given requirements of Government, regulators, banks/financiers and the public on the critical matters of safety and cost efficiency, NEP's position is to develop Endurance to its maximum storage potential and while effectively managing the CO_2 storage risks. To deliver this NEP requires a reasonable and practicable degree of separation from Hornsea 4 based on a number of key considerations (see Figure 36):

1. Relief well access: safety exclusion zones required to provide for the need to drill relief well(s) in case of well control issues
2. Helicopter access: corridors required to allow crew changes on drilling vessels and for search and rescue operations.
3. Rig Access: corridors required to allow rigs to navigate between the wind turbines and drill CO_2 injector and brine producer wells.
4. Towed streamer seismic access: minimum area required to conduct towed streamer seismic surveys to obtain the best data to prove the containment, conformance and confidence of the CO_2 stored.

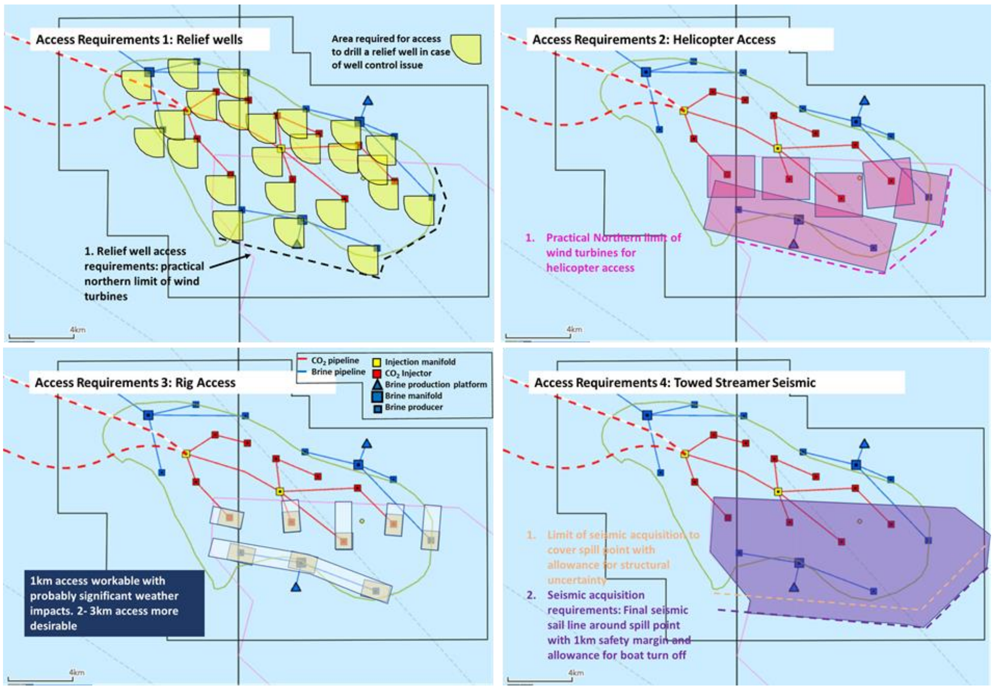


Figure 36 - Summary of requirements for a reasonable and practicable degree of separation from Hornsea 4 based on a number of key considerations

The above safety and access requirements overlap each other and figure 37 shows the combined area that covers the northwestern corner of the Hornsea 4 project area.

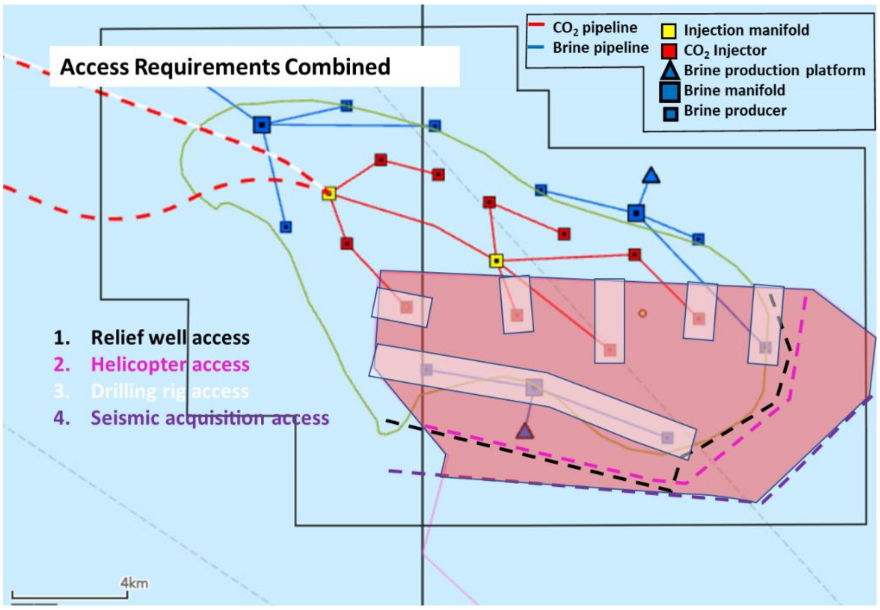


Figure 37: Minimum degree of separation required for Endurance full development

NEP and Orsted have collaborated on technical solutions for 2 years and the area required for towed streamer seismic has been heavily reduced to its minimum requirements in order to allow for maximum wind turbine installation in the remaining Hornsea 4 project area. The minimum requirements for the development of the Endurance reservoir necessitate that no wind turbines can be installed within the reduced 130 km^2 of overlap area.

NEP and Orsted have investigated and implemented a number of short term opportunities through collaboration. For medium to longer term opportunities as described in section 8.0, NEP recommends and supports the Crown Estate’s co-location forum (established in July 2021) that brings together representative industry bodies and regulators to mature solutions that will enable greater co-development of future CCUS and Offshore Wind projects in the UKCS. Technology development and pilot testing before full scale deployment will play a vital role in building confidence across all parties to enable greater co-development. Accelerating the development of these solutions through NEP and Orsted’s experience on Endurance and Hornsea 4, along with other CCUS and Offshore Wind developments, will be critical as competition for seabed use intensifies on the pathway to net zero.

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[17] MAERSK engagement - Global offshore drilling contractor. Owns a fleet of about 24 rigs including about 16 offshore jackup rigs, 4 semi-submersibles and 4 drillships

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[21] Offshore rig manoeuvring guidelines for approach (bp proprietary information)

[22] Offshore rig manoeuvring guidelines for positioning (bp proprietary information)

[23] OGUK Emergency Response and Rescue Vessel Management Guidelines – Issue 6 May 2018

[24] Project metocean criteria (bp proprietary information)

[25] Windfarm-Endurance Infrastructure Overlap Study (bp proprietary information)

[26] BRISTOWS Helicopters Ltd. engagement - British civil helicopter operator established in 1955, corporate headquarters in Houston, Texas, US., Fleet size about 490

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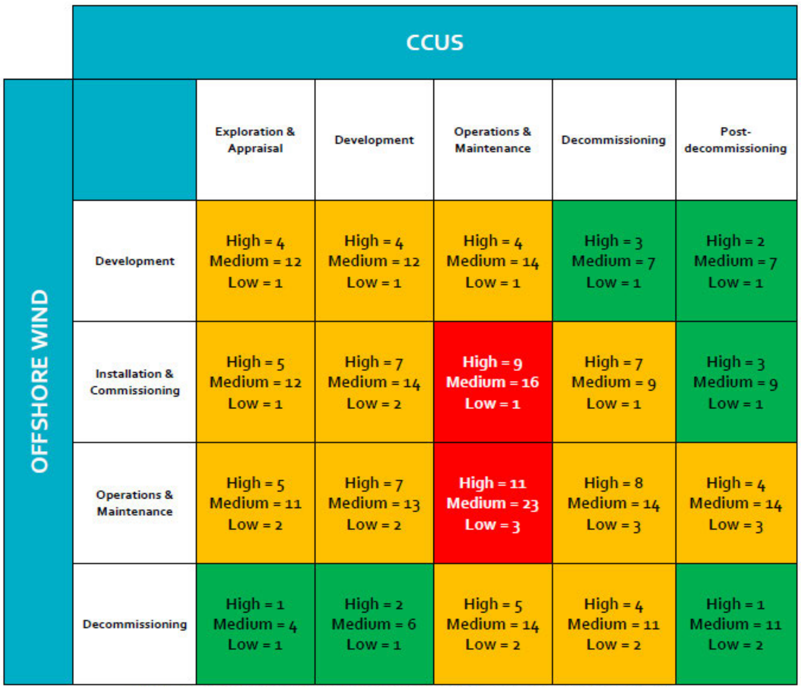
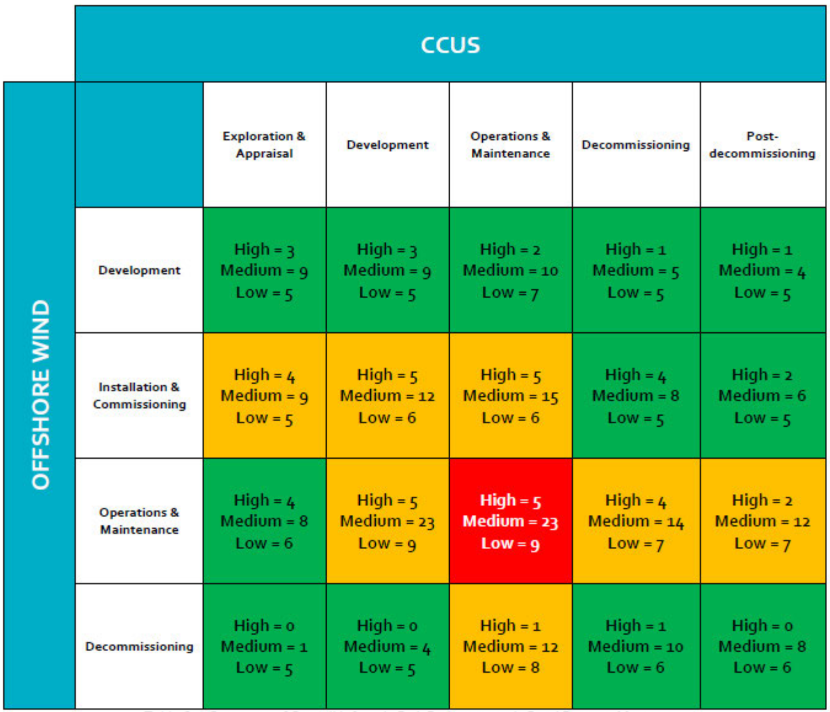
Appendix A - Summary of Identified Risks for Offshore Wind and CCUS Over Project Life Cycle

(Extracted from CCUS & Offshore Wind Overlap Study Report, p46 and p48)



		CCUS				
		Exploration & Appraisal	Development	Operations & Maintenance	Decommissioning	Post-decommissioning
OFFSHORE WIND	Development	High = 4 Medium = 12 Low = 1	High = 4 Medium = 12 Low = 1	High = 4 Medium = 14 Low = 1	High = 3 Medium = 7 Low = 1	High = 2 Medium = 7 Low = 1
	Installation & Commissioning	High = 5 Medium = 12 Low = 1	High = 7 Medium = 14 Low = 2	High = 9 Medium = 16 Low = 1	High = 7 Medium = 9 Low = 1	High = 3 Medium = 9 Low = 1
	Operations & Maintenance	High = 5 Medium = 11 Low = 2	High = 7 Medium = 13 Low = 2	High = 11 Medium = 23 Low = 3	High = 8 Medium = 14 Low = 3	High = 4 Medium = 14 Low = 3
	Decommissioning	High = 1 Medium = 4 Low = 1	High = 2 Medium = 6 Low = 1	High = 5 Medium = 14 Low = 2	High = 4 Medium = 11 Low = 2	High = 1 Medium = 11 Low = 2

Table 5.1: Summary of Identified Risks for Offshore Wind and CCUS Over Project Lifecycle
Note: Table shows risk impact levels and number of risks per project overlap stage.

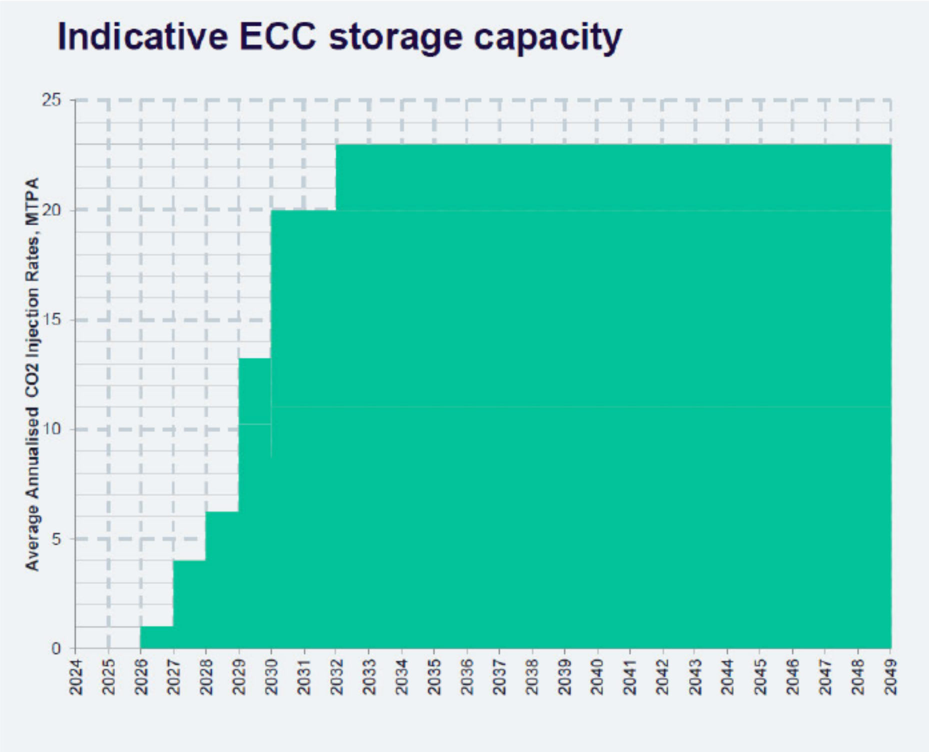


		CCUS				
		Exploration & Appraisal	Development	Operations & Maintenance	Decommissioning	Post-decommissioning
OFFSHORE WIND	Development	High = 3 Medium = 9 Low = 5	High = 3 Medium = 9 Low = 5	High = 2 Medium = 10 Low = 7	High = 1 Medium = 5 Low = 5	High = 1 Medium = 4 Low = 5
	Installation & Commissioning	High = 4 Medium = 9 Low = 5	High = 5 Medium = 12 Low = 6	High = 5 Medium = 15 Low = 6	High = 4 Medium = 8 Low = 5	High = 2 Medium = 6 Low = 5
	Operations & Maintenance	High = 4 Medium = 8 Low = 6	High = 5 Medium = 23 Low = 9	High = 5 Medium = 23 Low = 9	High = 4 Medium = 14 Low = 7	High = 2 Medium = 12 Low = 7
	Decommissioning	High = 0 Medium = 1 Low = 5	High = 0 Medium = 4 Low = 5	High = 1 Medium = 12 Low = 8	High = 1 Medium = 10 Low = 6	High = 0 Medium = 8 Low = 6

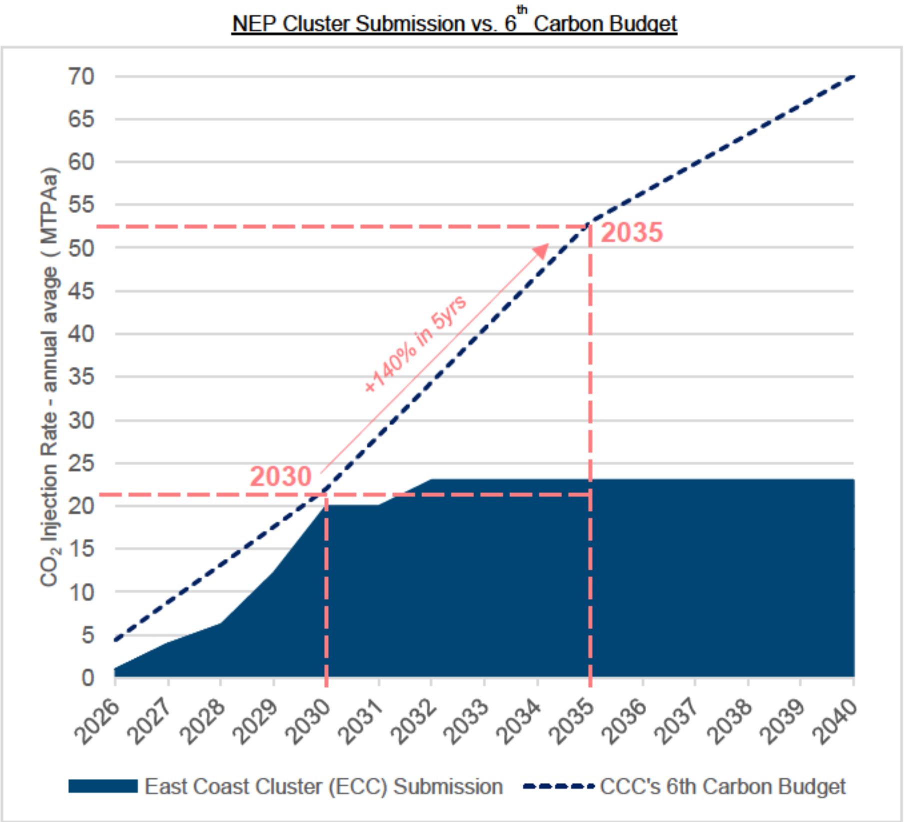
Table 6.1: Summary of Overall Lifecycle Risk Reduction with Good Practice Mitigations

Appendix B – East Coast Cluster Engagement Forum, 2021

(i) indicative annual average CO_2 injection rate as per East Coast Cluster Submission (July 2021)



(ii) Comparison of ECC submission to CCUS capacity requirements as stated in CCC's 6th Carbon Budget



Appendix C – CO$_2$ Reduction / Storage Per km^2 seabed area

Each project is assumed to have a 30 year design life for the purpose of these calculations. This calculation informs us of how much CO$_2$, in millions of tonnes, is displaced or stored over 30 years and converts it into an equivalent per square kilometer seabed area usage for a cursory comparison between Endurance and Hornsea 4 projects.

(i) Hornsea 4 wind farm calculations

General Assumptions	**Value**	**Units**
Hours per Annum	8,760	h/yr
Carbon Intensity of Offshore (2020)[2]	440	TCO$_2$/GWh
Load Factor[2]	39.94%	%
Hornsea 4 Assumptions	**Value**	**Units**
Hornsea 4 Total Capacity[3]	2.6	GW
Hornsea 4 Wind Farm Area[3]	466	km^2
Carbon Reduction Calculation		
Annual Power Production * Load Factor	9,097	GWh
30yr Power Production	272,902	GWh
CO$_2$ Emissions Reduction (total)	120	MT
CO$_2$ Emissions Reduction (per unit area)	**0.26**	**MT/km^2**

ii) Endurance reservoir calculations

Endurance Estimates	**Value**	**Units**
Endurance CO$_2$ Storage Capacity	450	MT
Endurance Storage Area	140	km^2
CO$_2$ Emissions Abatement through Storage (per unit area)	**3.21**	**MT/km^2**

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[2] Renewable UK : [redacted]

[3] Planning Inspectorate: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010098/EN010098-000700-A1.4%20ES%20Volume%20A1%20Chapter%204%20Project%20Description.pdf

Annex 2

bp Protective Provisions and Protective Provisions Plan

SCHEDULE [ ], PART [ ]
Protection for Carbon Dioxide Appraisal and Storage Licensee(s)

Application:

1. For the Protection of the Licensee(s) from time to time of United Kingdom Carbon Dioxide Appraisal and Storage Licence CS001, unless otherwise agreed in writing between the Undertaker and the Licensee the provisions of this part of this Schedule shall have effect.

Interpretation:

2. In this Part of this Schedule—

"Activity" or "Activities" means either (i) the activity or those activities (as appropriate) that the Licensee plans to undertake within the Exclusion Area or (ii) the Undertaker's Works and/or any other activity or activities (as appropriate) which the undertaker is proposing that may have an impact on the Licensee's activities within the Exclusion Area;

“Applicable Laws” means applicable laws, rules, orders, guidelines and regulations, including without limitation, those relating to health, safety and the environment and logistics activities such as helicopter and vessel operations;

"Authority" means an authority whether statutory, public, local, European, government department, agency or otherwise;

“BP Exploration Operating Company Limited” means BP Exploration Operating Company Limited, with Company Registration Number 00305943, whose registered office is at Chertsey Road, Sunbury On Thames, Middlesex TW16 7BP;

“Carbon Sentinel Limited” means Carbon Sentinel Limited, with Company Registration Number 08116471, whose registered office is at 1-3 Strand, London WC2N 5EH;

"Consultation Process" means the consultation processes undertaken by or on behalf of an Entity in respect of its project as required by an Applicable Law and/or regulation but excluding any bilateral consultations between the Entity and a particular individual or organisation;

"Entity" means the undertaker or the Licensee as appropriate and "Entities" means both of them;

"Exclusion Area" means any area within the area coloured yellow on the Protective Provisions Plan and as delineated in the Table of Co-Ordinates;

“Good Offshore Wind Farm Construction Practice” means the application of those methods and practices customarily used in construction of wind farms in the United Kingdom Continental Shelf with that degree of diligence and prudence reasonably and ordinarily exercised by experienced operators and contractors engaged in the United Kingdom Continental Shelf in a similar activity under similar circumstances and conditions;

“Interface Agreement” means the agreement dated 14 February 2013 between (1) The Crown Estate Commissioners (2) Carbon Sentinel Limited and (3) Smart Wind Limited, as varied and adhered to by an agreement dated 12 September 2016 between (1) The Crown Estate Commissioners (2) Smart Wind Limited (3) Carbon Sentinel Limited and (4) the Undertaker and a Deed of Covenant and Adherence dated 10 February 2021 between (1) The Crown Estate Commissioners (2) the Undertaker (3) Smart

Wind Limited (4) Carbon Sentinel Limited and (5) BP Exploration Operating Company Limited, or such other agreement as may be entered into by the parties in substitution for those agreements;

“Licence” means the United Kingdom Carbon Dioxide Appraisal and Storage Licence CS001;

“Licensee” means the licensee from time to time of the Licence (or any one of them);

"Necessary Consent" means all consents, licenses, permission, orders, exemptions and approvals required from any Authority in relation to the Activities and shall include, for the avoidance of doubt, all assessments that may be required to be undertaken before the issue of any of the foregoing;

"Notification Area" means any area within the area coloured turquoise on the Protective Provisions Plan and as detailed in the Table of Co-Ordinates;

“Plan of the Undertaker’s Works” means a construction programme, method and details of the proposed location of the Undertaker’s Works and minimum requirements known at that time such as safety in accordance with Good Offshore Wind Farm Construction Practice and Applicable Laws to enable the Undertaker to construct and operate the Undertaker’s Works;

“Smart Wind Limited” means Smart Wind Limited, with Company Registration Number 07107382, whose registered office is at 5 Howick Place, London, England SW1P 1WG;

“The Crown Estate Commissioners” means The Crown Estate Commissioners on behalf of Her Majesty the Queen, acting in exercise of the powers of the Crown Estate Act 1961;

"the Protective Provisions Plan” means the plan entitled Protective Provisions Plan and certified as the Protective Provisions Plan for the purposes of this Part of this Schedule;

"the Table of Co-Ordinates" means the following table:

Exclusion Area	
54°12'39.8773"N	0°58'36.8579"E
54°12'20.2291"N	1°12'20.3103"E
54°10'50.2641"N	1°15'39.1847"E
54°08'17.9732"N	1°11'7.0954"E
54°08'54.7372"N	1°00'38.3340"E
54°09'17.9239"N	1°00'46.6079"E
54°10'51.6355"N	0°58'27.9060"E
Notification Area	
54°09'53.6616"N	1°13'59.4422"E
54°08'1.0435"N	1°14'0.4599"E
54°07'59.9095"N	1°00'14.9388"E
54°08'54.7372"N	1°00'38.3340"E
54°08'17.9732"N	1°11'7.0954"E

"Undertaker's Works" means the indicative works permitted by this Order.

The Undertaker's Works

3. The undertaker must not construct any of the authorised project within the Exclusion Area.

4. The undertaker must not commence construction of any of the authorised project within the Notification Area unless the undertaker has submitted to the Licensee, not less than 56 days' prior, a Plan of the Undertaker's Works within that area and must have regard to any written representation received from the Licensee on the same.

5. Nothing in this paragraph precludes the undertaker from submitting at any time or from time to time, but in no case less than 56 days before commencing construction, a new plan, instead of the plan previously submitted in accordance with paragraph 4 above, and having done so the provisions of this Schedule will apply to and in respect of the new plan.

Interface Agreement

6. From the date of this Order, the Interface Agreement shall no longer have effect, and no claim for any damages may be made as a result of any alleged antecedent breach of the Interface Agreement prior to the date of this Order.

Collaboration

7. Each Entity shall consult early and fully with the other as part of any Consultation Process it is conducting for the purpose of applying for and procuring any Necessary Consent required in connection with their Activities (as relevant).

8. The Entities shall set up an interface management group comprising the project managers for each Entity's proposed Activities, and such other technical person as each determines necessary, who shall meet at six monthly intervals or at such frequency as the Entities reasonably determine necessary to discuss and understand the respective Entities' Activities and their impact on each other's Activities.

9. In or pursuant to such six monthly meetings held in accordance with paragraph 8 above, each Entity shall act reasonably in providing to the other Entity information (other than third party proprietary information) on its Activities, and such information shall be at a sufficient level of detail to allow the other Entity to understand the impact on their proposed Activities.

10. The Entities shall act in good faith in seeking to negotiate any crossing agreement required to facilitate each Entity's projects. The form of crossing agreement will be based on the Oil and Gas UK Industry Model Form: Pipeline Crossing Agreement (2015) or such other form published by Oil and Gas UK as may be current from time to time amended as necessary to reflect crossing of a pipeline by an electricity cable or cables, or vice versa.

Notices

11. Any notice or other written communication required shall be sufficient if made or give to the other Party by personal delivery or by first class post, postage prepaid, to the address set out below:

if to the undertaker, at:

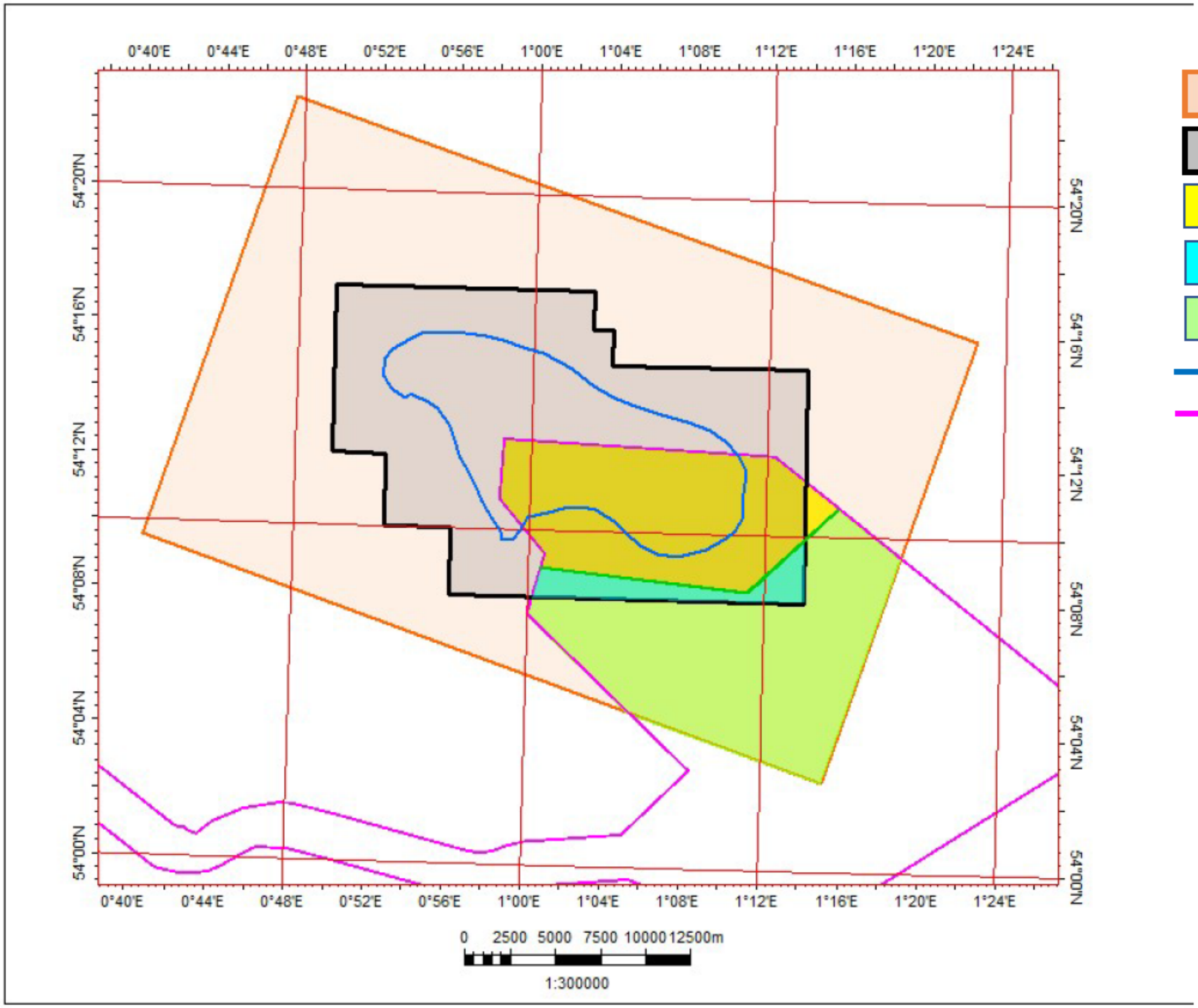
[ ]

if to the Licensee at:

Andy Lane, VP CCUS Solutions and MD Net Zero Teesside
Email: [redacted]
[redacted]

By way of copy to Clare Haley
Email: [redacted]
[redacted]

12. Notices or written communications made or given by personal delivery shall be deemed to have been sufficiently made or given when sent (receipt acknowledged), or if posted, 5 business days after being placed in the post, postage prepaid, or upon receipt, whichever is sooner.



Exclusion Area	
54°12'39.8773"N	0°58'36.8579"E
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