Pentland floating offshore wind farm

Volume 2: Offshore EIAR

Chapter 3: Site Selection and Alternatives

PENTLAND FLOATING OFFSHORE WIND FARM

OFFSHORE EIAR (VOLUME 2): MAIN REPORT

CHAPTER 3: SITE SELECTION AND ALTERNATIVES

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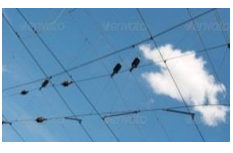

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GLOSSARY OF PROJECT TERMS

Key Terms	Definition
Dounreay Trì Floating Wind Demonstration Project (the 'Dounreay Trì Project')	The 2017 consented project that was previously owned by Dounreay Trì Limited (in administration) and acquired by Highland Wind Limited (HWL) in 2020. The Dounreay Trì Project consent was for two demonstrator floating Wind Turbine Generators (WTGs) with a marine licence that overlaps with the Offshore Development, as defined. The offshore components of the Dounreay Trì Project consent are no longer being implemented.
Highland Wind Limited	The Developer of the Project (defined below) and the Applicant for the associated consents and licences.
Landfall	The point where the Offshore Export Cable(s) from the PFOWF Array Area, as defined, will be brought ashore.
Offshore Export Cable(s)	The cable(s) that transmits electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OECC)	The area within which the Offshore Export Cable(s) will be located.
Offshore Site	The area encompassing the PFOWF Array Area and OECC, as defined.
Onshore Site	The area encompassing the PFOWF Onshore Transmission Infrastructure, as defined.
Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s) (the 'Offshore Development')	All offshore components of the Project (WTGs, inter-array and Offshore Export Cable(s), floating substructures, and all other associated offshore infrastructure) required during operation of the Project, for which HWL are seeking consent. The Offshore Development is the focus of this Environmental Impact Assessment Report.
PFOWF Array	All WTGs, inter-array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the PFOWF Array Area, as defined, excluding the Offshore Export Cable(s).
PFOWF Array Area	The area where the WTGs will be located within the Offshore Site, as defined.
PFOWF Onshore Transmission Infrastructure (the 'Onshore Development')	All onshore components of the Project, including horizontal directional drilling, onshore cables (i.e. those above mean low water springs), transition joint bay, cable joint bays, substation, construction compound, and access (and all other associated infrastructure) across all project phases from development to decommissioning, for which HWL are seeking consent from The Highland Council.
PFOWF Project (the 'Project')	The combined Offshore Development and Onshore Development, as defined.

ACRONYMS AND ABBREVIATIONS

EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
FEPA	Food and Environment Protection Act
HDD	Horizontal Directional Drilling
HWL	Highland Wind Limited
km	kilometres
m	metres
MS	Marine Scotland
NRTE	Naval Reactor Test Establishment
OAA	Option Agreement Area
Offshore EIAR	Offshore Environmental Impact Assessment Report
OECC	Offshore Export Cable Corridor
PFOWF	Pentland Floating Offshore Wind Farm
PAC	Pre-application Consultation
RLG	Regional Locational Guidance
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
SSE	Scottish and Southern Energy
SSEN	Scottish and Southern Electricity Networks
SSSI	Sites of Special Scientific Interest
UK	United Kingdom
WTG	Wind Turbine Generator

3 SITE SELECTION AND ALTERNATIVES

3.1 Introduction

This chapter of the Offshore Environmental Impact Assessment Report (Offshore EIAR) provides an overview of the selection process and alternatives considered for the location and design of the Pentland Floating Offshore Wind (PFOWF) Array and offshore export cable(s), hereafter referred to as the 'Offshore Development'.

The chapter has been drafted in line with relevant legislation, the Scoping Opinion (MS-LOT, 2021), and the Scoping Opinion Addendum (MS-LOT, 2022).

The EIA Regulations (as defined in Chapter 2: Policy and Legislative Context) require that an Environmental Impact Assessment Report (EIAR) include information on alternatives to the relevant project studied by the developer.

In Schedule 4 of the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017, the requirement is:

> *"a description of the reasonable alternatives (for example in terms of project design, technology, location, size and scale) studied by the developer, which are relevant to the proposed project and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects".*

In Schedule 3 of the Marine Works (Environmental Impact Assessment) Regulations 2017 (as amended), the requirement is:

> *"a description of the reasonable alternatives (for example in terms of project design, technology, location, size and scale) studied by the applicant, which are relevant to the proposed project, the regulated activity and their specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects."*

The Scoping Opinion (MS-LOT, 2021) and Scoping Opinion Addendum (MS-LOT, 2022) provide the advice set forth in Table 3.1:

Table 3.1 Scoping Opinion comments of relevance to the site selection and alternatives process

Scoping Opinion Comment	Response
Scoping Opinion	
The Scottish Ministers advise that these considerations must include how decommissioning has been taken into account within the design options. The Scottish Ministers advise that decommissioning considerations must be based on the presumption of as close to full removal of all infrastructure and assets as possible and should consider the methods and processes of doing so.	Considerations have been made for decommissioning as part of the Design Envelope approach and will continue to form part of the design risk assessment and technology selection process for the Offshore Development. In line with Section 105 of the Energy Act, Highland Wind Limited (HWL) will prepare a Decommissioning Programme for the Offshore Development for approval by the Scottish Ministers. This programme will consider comparative assessments of decommissioning options and, in line with the Scottish Government's guidance, the starting position will be a requirement for all offshore components (above and below seabed) to be removed. Throughout the Offshore Development's operational life-cycle, the Decommissioning Programme will be reviewed and updated every five years and decommissioning best practices and legislation will be applied at the time of the Offshore Development's decommissioning.

Scoping Opinion Comment	Response
The Scottish Ministers acknowledge section 3 of the Developer's Scoping Report which sets out a brief consideration on site selection for the Proposed Development however, advise that further consideration on other aspects, not just regarding site selection must be included in the EIA Report. The Scottish Ministers recognise that at this stage the exact siting and final design of the Proposed Development has yet to be decided by the Developer.	This chapter of the Offshore EIAR sets out the site selection process and alternatives considered by HWL in the development of the Offshore Development. This includes consideration of the wind farm site and PFOWF Array layout, export cable routeing and parameters, and design of the floating substructures and mooring and anchoring systems. Due to the novel technology proposed, some flexibility in the final design of the Offshore Development will be necessary to ensure HWL can utilise the most technologically advantageous solution, which will ultimately provide the best cost of energy to the consumer. Therefore, the final design of the Offshore Development is not yet able to be confirmed and the Offshore Development will be assessed using a Design Envelope Approach as set out in Chapter 6: EIA Methodology.
For the avoidance of doubt, the Scottish Ministers advise that the EIA Report must include an up to date consideration of the reasonable alternatives studied as the parameters of the Proposed Development have been refined. This includes but is not limited to the identification of the potential wind turbine layouts within the array area, the parameters of the export cables, the floating substructure designs, mooring and anchoring systems, the cable corridor options, the landfall location and decommissioning considerations. The Scottish Ministers expect this to comprise a discrete section in the EIA Report that provides details of the reasonable alternatives studied across all aspects of the Proposed Development and the reasoning for the selection of the chosen option(s), including a comparison of the environmental effects	This chapter of the Offshore EIAR sets out the site selection process and alternatives considered by HWL in developing the Offshore Development. This includes consideration of the wind farm site. Section 3.3.4 discusses the PFOWF Array layout, export cable routeing and parameters, and design of the floating substructures and mooring and anchoring systems.
Scoping Opinion Addendum	
The EIA Regulations require that the EIA Report include 'a description of the reasonable alternatives (for example in terms of project design, technology, location, size and scale) studied by the Developer, which are relevant to the proposed works and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects'. The Scottish Ministers advise that these considerations must include how decommissioning has been taken into account within the design options. The Scottish Ministers advise that this must be based on the presumption of as close to full removal as possible of all infrastructure and assets and should consider the methods and processes of doing so.	See responses above.
For the avoidance of doubt, the Scottish Ministers advise that the EIA Report must include an up to date consideration of the reasonable alternatives studied as the parameters of the Proposed Development have been refined. This includes but is not limited to the identification of the potential wind turbine layouts within the array area, the parameters of the export cables, the cable corridor options and the landfall location or locations. The Scottish Ministers expect this to comprise a discrete section in the	See responses above.

Scoping Opinion Comment	Response
EIA Report that provides details of the reasonable alternatives studied across all aspects of the Proposed Development and the reasoning for the selection of the chosen option(s), including a comparison of the environmental effects.	
The Scottish Ministers advise that the Developer must make every attempt to narrow the range of options. Where flexibility in the design envelope is required, this must be defined within the EIA Report and the reasons for requiring such flexibility clearly stated. At the time of application, the parameters of the Proposed Development should not be so wide-ranging as to represent effectively different projects. To address any uncertainty, the EIA Report must consider the potential impacts associated with each of the different scenarios. The criteria for selecting the worst case and the most likely scenario, together with the potential impacts arising from these, must also be described. The parameters of the Proposed Development must be clearly and consistently defined in the application for the s.36 consent and marine licences and the accompanying EIA Report.	Chapter 5: Project Description sets out the project design parameters being applied for, and any flexibility sought within this application is clearly described. Within each chapter of this Offshore EIAR, the potential impacts associated with each of the different design scenarios are considered, and the worst case design parameters for assessment are identified and clearly presented. Throughout the project development process, a number of refinements to the design parameters have been made; the design evolution process is described in this chapter.

3.2 Background

This chapter sets out how the Offshore Site (the area within which the Offshore Development will be located) location has been determined and how the Design Envelope has been refined since Scoping, in line with the evolution of the Offshore Development.

This chapter also includes an overview of the site selection and alternatives considered for the Dounreay Trì Floating Wind Demonstration Project (the 'Dounreay Trì Project'), to provide a holistic overview of the final Offshore Site location and technical design alternatives explored for the Offshore Development consent application. The general process undertaken is shown in Figure 3.1 below and is further explained throughout this chapter.

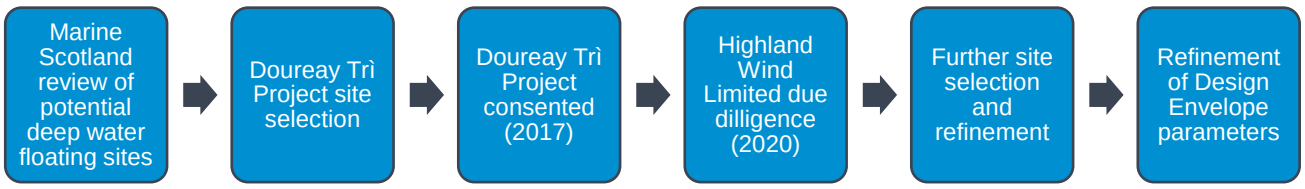

Figure 3.1 General site selection and Design Envelope refinement process

This chapter focuses on the location of the Offshore Site, the options considered for the landfall location and Offshore Export Cable Corridor (OECC) to connect the Offshore Development to the grid, and grid connection options; it also provides an overview of the technical alternatives considered for the Offshore Development.

3.2.1 Potential Scottish Test Sites for Deep Water Floating Offshore Wind Technologies – Regional Locational Guidance

In 2014, Marine Scotland (MS) carried out a review of potential sites for floating offshore wind technologies, with capacities of up to 100MW, and therefore applicable to this application. From this review, sites were identified as being suitable and subsequently, three of these sites were identified as meeting the Regional Locational Guidance (RLG) criteria. These were:

- Southern Moray Firth;
- North East Aberdeen; and
- North Coast (Dounreay).

These three sites were examined by the Dounreay Trì Project in greater detail using publicly available information.

Following further refinement the Southern Moray Firth Site was considered unsuitable for development. For example, a deep trench landward of this site would make it difficult to install marine cables. Further, the Southern Moray Firth Site is also intensively fished and is within an area designated for the protection of marine mammals.

The North East Aberdeen Site is located approximately 23 kilometres (km) from shore. Use of this site would significantly increase offshore export cable length and cost along with the potential environmental impacts associated with cable installation. Further, the site and associated OECC lay within an area that is fished by a range of gear types, including scallop dredgers. Scallop dredging has the potential to damage subsea cables and constitutes a significant risk to the Offshore Development, which is reliant on offshore export cable(s) to transport energy generated to shore.

From the three sites identified as meeting the RLG criteria, the Dounreay site was originally selected for the following reasons:

- The site has suitable water depths and is located close to shore, thus reducing offshore export cable length and potential environmental impacts and costs as compared to other sites;
- The average wind speed is good and has been calibrated with data from other wind farms in the region. Power generation will therefore be reliable and efficient and obviates the need to install an offshore anemometer mast;
- Based on discussions with Scottish Fishermen's Federation in 2014, the Dounreay site appeared to lie outwith intensively fished areas thereby reducing potential environmental effects on commercial fisheries;
- MS completed a detailed geophysical survey, including drop down video and grab samples, during Summer 2014, which provided a clear, up-to-date understanding of the water depths and seabed conditions; and
- The site is located in close proximity to grid connection locations at Dounreay.

3.2.2 Consented Development

The Offshore Development is being developed in the same location as the consented Dounreay Trì Project; however, the application has a smaller footprint than the original consented project due to project design refinement, as shown in Figure 3.2 below. The landfall location for the Offshore Development is at Dounreay, adjacent to the Vulcan Naval Reactor Test Establishment (NRTE) site, approximately 14 km west of Thurso in Caithness.

Whilst the Offshore Development is a larger-scale floating offshore wind farm, the fundamentals of this location and the site's suitability for a floating offshore wind farm were demonstrated through the consent granted in 2017.

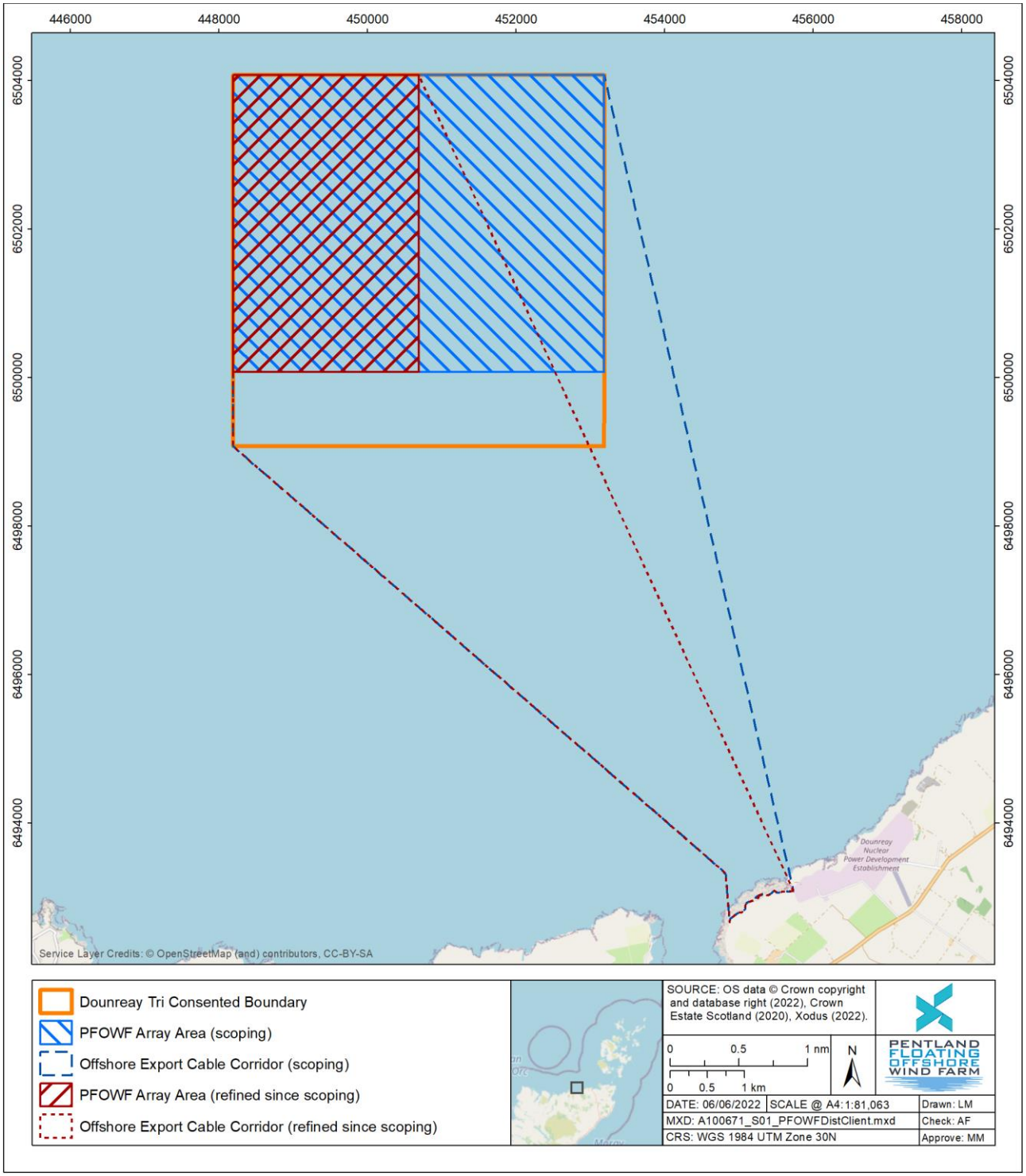

Figure 3.2 The PFOWF Array Area and OECC in relation to the Dounreay Trì Project consented boundary and the boundary presented at Scoping

3.2.3 Highland Wind Limited Site Review and Due Diligence

Prior to acquiring the Dounreay Trì Project, Highland Wind Limited (HWL) undertook extensive due diligence work in 2020 and 2021 to support the decision to acquire the consented project. The site selection process and description of alternative sites for the Dounreay Trì Project were considered in line with HWL's project needs for the Offshore Development and considered in conjunction with the reasonings presented within the Dounreay Trì Project Environmental Statement (Dounreay Trì Ltd, 2016).

A review of the RGL and the Dounreay Trì Project Environmental Statement (and subsequent consent) confirmed the suitability of the location for the Offshore Development (as set out in Chapter 5: Project Description).

The sections below outline the site selection and alternatives process considered for the Offshore Development and demonstrate why the Offshore Site and the associated landfall location have been selected as the optimal solution.

3.3 Offshore Site Selection

To ensure the principles of the RGL were suitable for the delivery of the Offshore Development's technology, the following principal criteria were used to assess the Offshore Site location options:

- Environmental considerations, informed by previous survey work;
- Technical considerations of the metocean, wind, and seabed characteristics;
- Distance to shore;
- Shipping and navigational features;
- Commercial fisheries activity;
- Programme of works and contract dates;
- Proximity of electrical and grid infrastructure;
- National Electricity Transmission System capability, constraints and requirements for wider improvement works;
- Economic efficiency for the United Kingdom (UK) electricity consumer; and
- Optimal nationwide electrical solutions.

To ascertain the Offshore Site's viability as a suitable location, the following reviews were undertaken by HWL, in line with the principal criteria set out above:

- Review of environmental criteria, including:
  - Previous survey work (including, but not limited to, benthic, ornithology, marine mammals, terrestrial ecology, shipping, and navigation) undertaken in 2015 to support the Dounreay Trì Project; and
  - Seascape, landscape, and visual considerations.
- Review of technical criteria, including:
  - Wind resource potential;
  - Grid connection availability and options;
  - Availability of ports and harbours;
  - Metocean, geophysical, and geotechnical seabed conditions; and
  - Offshore export cable installation and protection.

- Review of other criteria, including:
  - Public perception and stakeholder feedback;
  - Contracts for Difference and project timelines;
  - Supply chain potential; and
  - Post-consent requirements (e.g. monitoring).

A review of this material highlighted that the Dounreay Trì Project's offshore site boundary, off the coast of Dounreay, was a favourable location for the Offshore Development. The site would allow floating offshore wind technologies to be tested and demonstrated in a suitable environment in terms of resource, power generation, and viable connection to the grid.

The following considerations were key drivers for HWL's decision to site the Offshore Development at this location:

- Suitable water depths (60 metres [m] to 102 m) and wind resource within this area to support a floating offshore wind project;
- Avoidance of shipping lanes which will reduce interaction with existing vessel traffic;
- Well-established ports and harbours to aid the construction, operation and maintenance, and decommissioning works required for the Offshore Development;
- No overlap of the PFOWF Array Area with designated sites protected for seabed features which could be impacted through the deployment of the substructures required for the Offshore Development;
- Likely viability of horizontal directional drilling (HDD), at a suitable landfall location, to bring cables ashore, to ensure impacts are minimised to birds associated with the North Caithness Cliffs Special Protected Area (SPA) and other identified constraints at the landfall location; and
- Close proximity to the identified landfall location, leading to offshore export cable efficiencies and reduced impacts on marine life and habitats.

3.3.1 PFOWF Array Area Design Evolution Process

In reviewing the stakeholder consultation responses associated with the original Dounreay Trì Project, a decision was taken early in the design evolution of the Offshore Development to set back the PFOWF Array Area (the area where the Wind Turbine Generators [WTGs] will be located) from the mainland coast by 1 km. The primary purpose of this setback was to reduce potential visual impacts by increasing the distance between the north coast and the closest WTG.

Following the Pre-application Consultation (PAC) event held in May 2022 (see the PAC Report accompanying the application), the PFOWF Array Area was further refined. This refinement reduced the PFOWF Array Area by 50% with the primary aim of decreasing the horizontal spread associated with the WTGs when viewed from the north coast. The PFOWF Array Area in relation to the previously consented Dounreay Trì Project boundary is shown in Figure 3.2.

The refinement of the PFOWF Array Area reduces the footprint available to locate the WTGs and associated offshore infrastructure by 50%, demonstrating HWL's commitment to reducing potential visual impacts from the WTGs on land-based receptors. The smaller footprint also benefits additional receptors, including commercial fisheries and shipping and navigation users whilst reducing direct impacts on the seabed.

Additionally, the maximum number of WTGs that may be installed has been reduced from 10 (as presented in the Scoping Report) down to seven, further reducing potential visual impacts (see Table 3.3 for details).

Additional refinement of the Design Envelope has also occurred as the understanding of site conditions and design requirements for the Offshore Development has advanced. These refinements are set out in Table 3.3 below.

3.3.2 Offshore Export Cable and Landfall Design Evolution Process

An OECC to landfall for the Dounreay Trì Project received consent in 2017. HWL reviewed this information to determine whether the consented OECC was in the most suitable location for the Offshore Development and remained a viable option. Alternative locations were also considered, as shown in Figure 3.3.

The location and potential suitability of an OECC are influenced by many factors. The aim is to reduce the overall length of the offshore export cable(s) whilst reducing installation risk and risk to the long-term integrity of the Offshore Export Cable(s). Doing so has multiple benefits, including lower costs and energy losses as well as fewer potential environmental impacts by reducing the overall seabed footprint.

Therefore, in undertaking the review, HWL considered proximity to suitable grid connection locations and any associated onshore cable routeing and substation locations, as well as cable stability and integrity.

In selecting an OECC for the Offshore Development, the following factors were considered and weighted:

- Suitability of landfall options;
- Minimisation of potential environmental impact(s):
- Cable stability and protection;
- Minimisation of the number of cable and pipeline crossings;
- A route that is as direct as possible, when considering the above; and
- The potential onshore route to the grid connection point.

When assessing OECC options, potential routeing through environmentally sensitive areas was necessarily balanced against potential routeing through seabed areas which could result in an increased risk to other users of the sea, the integrity of the offshore export cable(s), and the route for the cable onshore to a potential substation location, to allow connection into a suitable grid connection point.

These considerations are shown in Figure 3.3. A summary of the different OECC options, features, and environmental constraints is provided in Table 3.2.

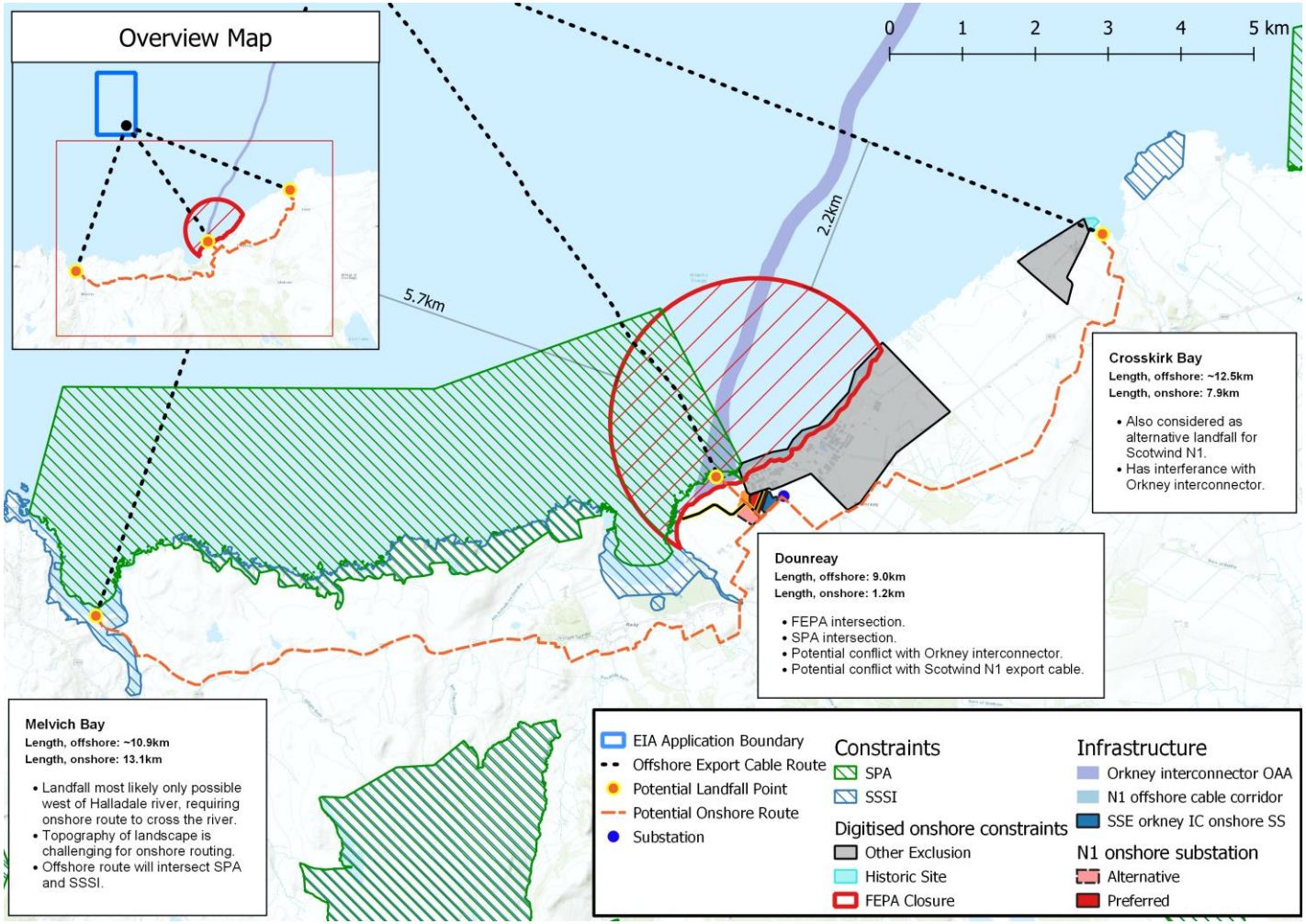

Figure 3.3 Offshore Export Cable Corridor and landfall options

Table 3.2 Summary of OECC Options

Consideration	Melvich Bay	Dounreay	CrossKirk Bay
Offshore Export Cable Length (approximate)	10.9 km	9.0 km	12.5 km
Onshore Export Cable Length (approximate)	13.1 km	1.2 km	7.9 km
Landfall topography/character	Complex topography and requires crossing Halladale River	In close proximity to landfall location on relatively flat ground, next to industrialised setting of Dounreay and Vulcan NRTE	Requires crossing several fields and roads
Designated Sites	Intersects with an SPA and a Site of Special Scientific Interest	Intersects with an SPA	In proximity to a historic site
Food and Environment Protection Act (FEPA) Closure zone	Avoids	Intersects	Avoids
Orkney-Caithness Project (Interconnector) Option Agreement Area (OAA)	Avoids	Potential conflict (likely to be avoided through micrositing)	Interference with interconnector
Disturbance to onshore communities during construction	Due to the length of the onshore cable route and the topography of the land, this is likely to cause the greatest disturbance to local communities.	Minimal disturbance to local communities due to the location adjacent to Dounreay and minimal length of cable.	This is the second-longest route option to the grid connection point. Road crossings would also be required and cause disturbance to local communities.

Following this review process, the preferred landfall location was identified as the previously consented Dounreay location, adjacent to the Vulcan NRTE site. Whilst this location requires crossing the Dounreay Food and Environment Protection Act Closure zone and intersects an SPA designated for ornithology features, these risks can be managed through careful planning and the implementation of suitable controls and mitigations, such as tailored construction techniques and methods. The alternative options required crossing environmentally designated sites or features, and significantly increased the length of the onshore and offshore export cable corridors, thereby increasing potential environmental impacts as well as costs, transmission losses, and delivery risk.

Additional refinements to the OECC have been made in line with the reduction in the footprint of the PFOWF Array Area and reduce the area within which the offshore export cable(s) may be installed. The revised OECC boundary is presented in Figure 3.2.

3.3.2.1 Alternative option at Sandside Bay

An alternative landfall location option was also considered within Sandside Bay, further to the west of the Dounreay landfall. This option would require bringing the offshore export cable(s) ashore through open-cut trenching. This alternative location was excluded on the following basis:

- A cable landfall on the eastern flank of Sandside Bay beach would be complicated by the orientation of the proposed landfall location (facing across as opposed to straight out the bay) and the presence of exposed rock in the foreshore area;

- Storm events are known to periodically expose the bedrock at Sandside Bay and could therefore expose/damage the offshore export cable(s);
- Access to the beach is limited (narrow access track at the far western end of the bay), thus it is likely that a temporary access track would need to be established to allow vehicle access;
- Features of archaeological interest located immediately to the east of Sandside Bay would need to be avoided thereby complicating cable routeing;
- Sandside Bay and the land to the east above mean high water springs is a Site of Special Scientific Interest (SSSI). A portion of the SSSI includes the foreshore and the banks of the Burn of Isauld (i.e. the land immediately to the east of Sandside Bay). Scottish Natural Heritage[i] (2016) has stated a preference for either HDD or pinning options rather than trenching in this area; and
- Historic radioactive particles have been found on the beach at Sandside Bay. Works within this area could unearth additional particles. Whilst the probability of coming into contact with a relevant particle at Sandside Bay is one in 80 million (DSRL, 2016), it seemed unnecessary to continue with an option which was already technically and environmentally unfavourable (for the reasons described above).

3.3.3 Grid Connection

The Onshore Site (the area where the onshore works associated with the PFOWF Onshore Transmission Infrastructure [the 'Onshore Development'] will be located) at Dounreay was primarily chosen due to the availability of options to connect to the existing grid network in the immediate vicinity of Dounreay.

An assessment of viable grid connection options was undertaken by Arcadis Ltd on behalf of HWL (Arcadis, 2021). Their assessment concluded that there is sufficient capacity to accommodate the power output of the Offshore Development without the need for significant enhancement works to the onshore transmission network. Enhancement works would result in increased environmental impacts and overall cost, which would not be as economically efficient for the UK consumer. Two options were identified for connection at Dounreay:

- Option 1: Onshore electrical infrastructure to connect the Project at, or near, the Scottish and Southern Energy (SSE) Networks (SSEN) Dounreay 132/33/11-kV Substation (the 'Dounreay Substation').
- Option 2: A grid connection at, or near, the consented SSEN Dounreay West 275/132-kV Substation, which is currently in the development stage, with a planned completion date of Q3 2022.

At the Dounreay Substation, which currently operates at 132 kV and 33 kV, there is established infrastructure that could be utilised for the connection of the Offshore Development. The Dounreay Substation is located in close proximity to the identified landfall location, at the east of the Onshore Site, as shown in yellow in Figure 3.4.

As both options listed above were viable, with little difference in terms of key environmental considerations, the Dounreay 132 kV option has been selected as the preferred grid connection to be taken forward. HWL has also secured a grid connection agreement for a 132 kV connection at the Dounreay Substation for 100 MW.

The OECC, landfall location, and Onshore Development infrastructure have been designed to reduce cable length and footprint area to connect to this location. In doing so, environmental, physical, technical, and other considerations have been taken into account. The proposed application boundary balances these considerations and represents the optimal location for the Project.

[i] Scottish Natural Heritage now operates under the name of NatureScot.

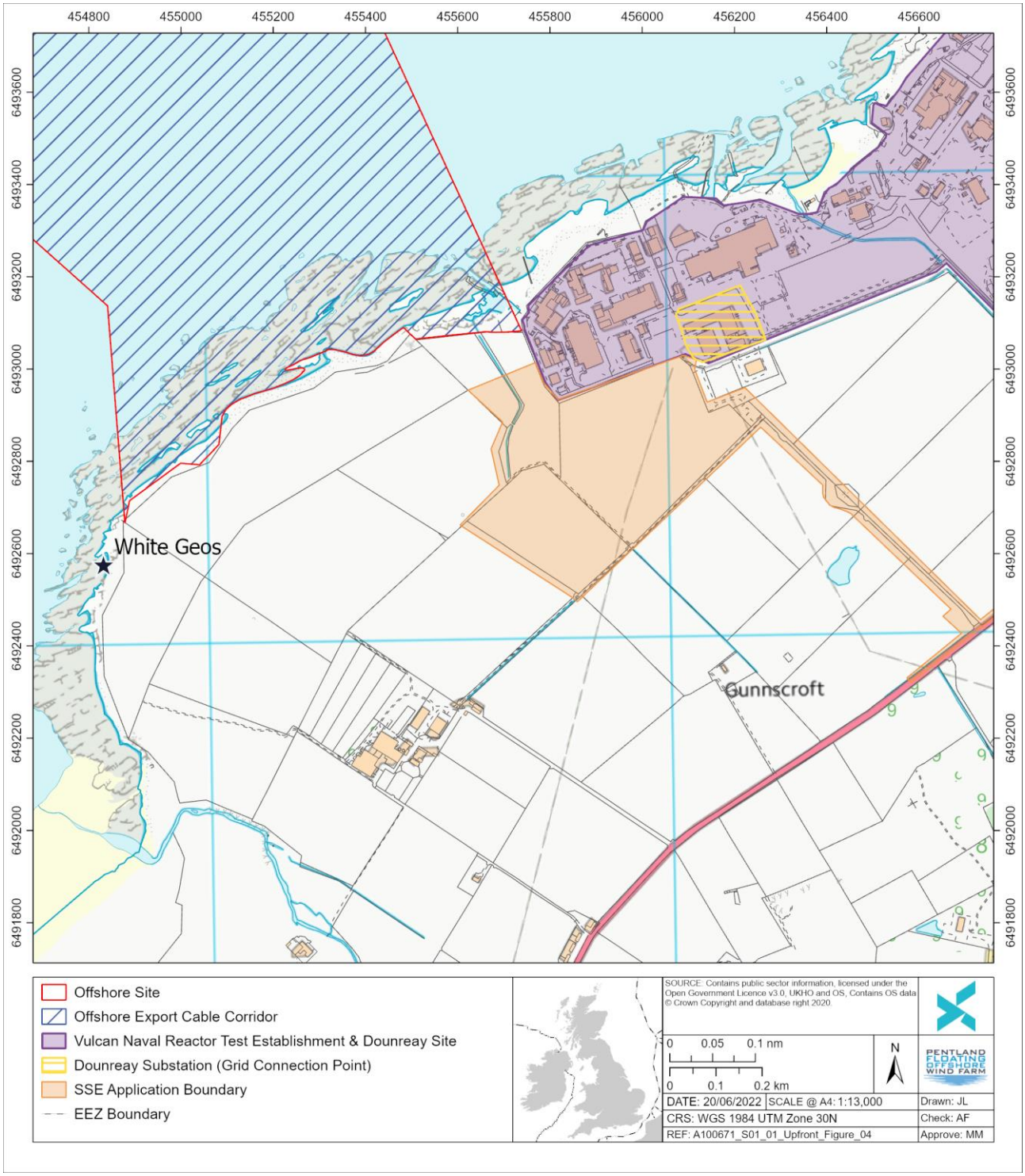

Figure 3.4 Grid connection options at the Onshore Site

3.3.4 Technical Alternatives

The Design Envelope for the Offshore Development is set out in Chapter 5: Project Description. Given that floating offshore wind is a new and novel technology, the Design Envelope is necessarily broad to allow for emerging technologies to be deployed. Detailed engineering work and discussions with technology providers have been ongoing throughout the Environmental Impact Assessment (EIA) process to refine the Design Envelope wherever possible. Geophysical and geotechnical campaigns of the Offshore Site and OECC were undertaken in 2021; further surveys are planned for 2022 to help refine the engineering requirements and define the detailed design.

From this work, refinement of the technical alternatives for the Offshore Development has been undertaken wherever possible as shown in Table 3.3 Offshore Development Design Evolution and refinement of technical parameters below. For completeness, a summary of the technical parameters for which refinement has not been possible – at least at this stage of the development process – is also presented in Table 3.4 Technical elements of the Offshore Development where refinement has not been possible.

Table 3.3 Offshore Development Design Evolution and refinement of technical parameters

Technical Parameter	Design Evolution and Alternatives Considered
WTGs	Following consultation events and throughout the progression of the EIA, the maximum number of WTGs under consideration for the Offshore Development has been reduced from 10 to seven. This reflects HWL's commitment to reducing potential visual impacts from the WTGs on land-based receptors. The reduction in the number of WTGs also minimises the overall footprint of the Offshore Development, which benefits additional receptors, including commercial fisheries and shipping and navigation users, whilst reducing direct impacts on the seabed. This reduction in the number of WTGs is reflective of advancements in WTG technology, which allows fewer larger-capacity WTGs to provide the same generating capacity. Following early-stage assessments, HWL have committed to increasing the minimum blade tip clearance from the sea surface from that which was presented in the Scoping Report and Scoping Report Addendum. The primary driver is to reduce potential impacts to seabirds in terms of collision with WTG blades. Increasing blade tip clearance has been shown to be an effective mitigation to reduce the number of potential collisions. The minimum blade tip clearance has now been increased from 22 m to 35 m above mean seal level. This commitment has been reflected in the collision risk modelling carried out as part of the Ornithology Assessment in Chapter 12: Marine Ornithology. The exact WTG size, model, and capacity have not yet been determined. The parameters presented within the Design Envelope will allow the deployment of the most efficient and economical WTGs available on the market at the time of procurement.
WTG Layout	During the progression of the EIA and following feedback from the public consultation events, the PFOWF Array Area has been reduced by 50%. This reduction in overall footprint will condense the potential distance between WTGs and will reduce the horizontal spread of WTGs across the horizon. Following early-stage assessments, there are a number of drivers for reducing the PFOWF Array Area. The reduction in the horizontal spread of WTGs will reduce the potential visual impacts of the Offshore Development on land-based receptors. In addition, the smaller footprint of the PFOWF Array Area will result in reduced impacts to benthic ecology, marine mammals, and fish receptors, and reduced impacts to other sea users, including commercial fisheries and shipping and navigation users, as there is a smaller area over which receptors will be displaced or disturbed. Whilst the WTG layout has not been finalised, the final layout will be subject to approval at the discharge of conditions stage, should the application receive consent. The WTG layout will take into account optimal wind conditions and conform to Search and Rescue requirements, and it will likely be in a grid or offset grid configuration, as shown in Chapter 5: Project Description. For the individual assessments presented within this Offshore EIAR, WTG layouts have been created so the assessments can be carried out on a worst case scenario basis.

Technical Parameter	Design Evolution and Alternatives Considered
Offshore Export Cable(s)	Alternative locations for the Offshore Export Cable(s) were considered (as set out in Section 3.3.2). The final OECC selected will result in fewer environmental impacts overall by reducing the length of the Offshore Export Cable(s) required. The OECC has been further refined and reduced in line with the reduction in the footprint of the PFOWF Array Area. Cable voltage will fall within the UK distribution voltage range of below 132 kV. Up to two offshore export cables are being considered. The Offshore Export Cable(s) will be buried at a target burial depth of 0.6 m; where this burial depth cannot be achieved, remedial cable protection will be applied. This burial depth and any remedial protection will reduce the potential electromagnetic field effects of the Offshore Export Cable(s). A preliminary Cable Burial Risk Assessment suggests that burial is achievable for a majority of the OECC. Currently, the option of laying the cable directly on the seabed (rather than trenching, which is planned for the remainder of the OECC) and protecting the cables within the FEPA Closure zone is being considered. This would reduce seabed disturbance within this zone and reduce the potential disturbance of radioactive particles. As commercial fishing is banned within this zone, interactions with fishing activity resulting from cable laying and protection are unlikely.
Floating Substructures	In line with refining the total number of WTGs, the number of floating substructures has been reduced from a maximum of ten to a maximum of seven. In addition, through engineering work informed by site investigation surveys, the number of design options proposed for floating substructures has been reduced from what was presented in the Scoping Report and Scoping Report Addendum. Two floating substructure designs are now being considered within the Design Envelope for the Offshore Development: semi-submersible and tension leg platform. Design and engineering work currently suggests that both options could be viable, therefore, both options are considered within the assessments included in this Offshore EIAR (Chapters 7 to 21). Spar and barge substructures were previously considered within the Design Envelope for the Offshore Development presented at Scoping. These are no longer considered technically feasible as findings from the geophysical, metocean, and geotechnical surveys conducted by HWL in 2021 demonstrated that these are not compatible with the seabed and metocean characteristics. This reduction in the Design Envelope is aligned with the requirements in the Scoping Opinion. Fixed foundation options are not considered a reasonable alternative for the Offshore Development due to the water depths in the PFOWF Array Area. Additionally, the primary driver for the Offshore Development is to test and demonstrate novel floating offshore wind technology. As such, HWL holds a Test and Demonstrator seabed lease from Crown Estate Scotland.
Mooring Lines	As engineering design work has progressed, the total number of mooring lines per WTG has been refined and reduced from what was presented in the Scoping Report Addendum. A total of nine mooring lines are now being considered per WTG, which is a reduction from the maximum of 12 that were presented within the Scoping Report Addendum. This will reduce disturbance to the seabed and help reduce disturbance to other sea users and marine ecology receptors. Several different mooring systems, products, and materials remain under consideration from a technical and commercial perspective. The final mooring system will be dependent on the final floating substructure and anchor design. The options under consideration include chain, nylon, polyester, and other synthetic materials, some of which have the benefit of a potential local supply chain. Advancement of the viability of these options will continue throughout the Offshore Development's detailed design phase.

Technical Parameter	Design Evolution and Alternatives Considered
	The Offshore Development's engineering work continues to explore the potential to reduce the spread of the mooring lines to reduce interactions with commercial fishermen and other sea users whilst also reducing potential seabed disturbance.
Landfall	HDD is now the only option being considered in the Design Envelope for the landfall. Previously, pinning to an existing water intake for the Dounreay site (former nuclear facility) was considered in the Scoping Report. Further engineering, environmental, technical, and commercial considerations, however, have resulted in this option no longer being considered viable; it has therefore been removed from the Design Envelope for the Offshore Development.

Table 3.4 Technical elements of the Offshore Development where refinement has not been possible

Technical Parameter	Current Considerations
Inter-array Cables	The routeing of inter-array cables has not been finalised and is largely dependent on the WTG layout and selection of floating substructures. Several options exist for the configuration, voltage, and cross-section of the inter-array cables. The final option will be selected based on system studies that consider technical, environmental (including fisheries), and commercial factors. To allow for flexibility in the location of the WTGs, the overall length of inter-array cables included in the application has not decreased from that presented in Scoping, despite the reduction in the number of WTGs.
Anchoring Systems	Geophysical and geotechnical site investigation works in 2021 have confirmed that ground conditions vary across the PFOWF Array Area. This coupled with the challenging metocean conditions means that refinement of the anchoring solution has not been possible to date. Detailed engineering work is underway to determine the preferred anchoring solution. As per the Scoping Report and Scoping Report Addendum, the Design Envelope for the Offshore Development allows for drag embedment, gravity, vertical load, suction bucket, and driven and drilled pile anchors.
Decommissioning	The final decommissioning plan for the Offshore Development will be developed in line with best practice and will be subject to a new Marine Licence application. The basis of the principles of the approach is considered in Chapter 5: Project Description. Any alternatives to this approach will be informed by best practices and guidance.

3.4 Conclusion

The information presented within this chapter details the design evolution process and the approach taken to consider site alternatives as well as technical alternatives for the Offshore Development. As demonstrated by the existing consents for a floating offshore wind farm at this location, the fundamentals of this location and the use of floating offshore WTG technology have already been demonstrated as being suitable. The review undertaken and further engineering work completed in relation to the Offshore Development's design also considers it appropriate in comparison to alternatives.

This Offshore EIAR considers in detail the environmental effects associated with the proposed Offshore Development; these are set out within individual technical assessments of this Offshore EIAR (Chapters 7 to 21).

3.5 References

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