Bowdun Offshore Wind Farm, Onshore EIA Report

Volume 2, Appendix 15.2: Climate Change Risk Assessment

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Glossary

Defined term	Definition
Additional Mitigation	Also referred to as secondary mitigation which is defined by Institute of Environmental Management and Assessment (IEMA) as: Actions that will require further activity in order to achieve the anticipated outcome. These may be imposed as part of the planning consent, or through inclusion in the EIA Report (sic).
Array Area	The Array Area is the area in which the Offshore Generation Assets will be located.
Embedded Mitigation	Measures that are adopted as part of the Proposed Development and therefore assessed within the Environmental Impact Assessment (EIA). The proposed approach for the EIA for the Proposed Development is that embedded mitigation includes both primary mitigation and tertiary mitigation. These are defined by the IEMA as follows: Primary: Modifications to the location or design of the development made during the pre-application phase that are an inherent part of the project, and do not require additional action to be taken. Tertiary: Actions that would occur with or without input from the EIA feeding into the design process. These include actions that will be undertaken to meet other existing legislative requirements, or actions that are considered to be standard practices used to manage commonly occurring environmental effects.
Environmental Impact Assessment (EIA)	Assessment of the potential likely significant effects of the Proposed Development on the physical, biological, and human environment during construction, operations and maintenance and decommissioning.
Inter-Array Cables (IACs)	Cables which link the wind turbines to each other and with the Offshore Substation Platforms (OSPs).
Intertidal Area	The area between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS).
Interconnector Cables	Cables which will connect individual OSPs to each other to provide redundancy against cable failure elsewhere.
Landfall	The area in which the Offshore Export Cables make landfall and is also the transitional area between the Offshore Transmission Assets and the Onshore Transmission Assets. Located in the Intertidal Area (see definition above) at Benholm.
Marine Application Boundary	The boundary within which all offshore elements of the Project will be located. The Marine Application Boundary comprises the Offshore Generation Assets and Offshore Transmission Assets which end at mean high water springs.
Mean Low Water Springs (MLWS)	The average tidal height throughout the year of two successive low waters during those periods of 24 hours when the range of the tide is at its greatest.
National Grid	The national electricity transmission network.
Offshore Environmental Impact Assessment (EIA) Report	Document prepared to report the findings of the EIA for the offshore elements of the Project.

Defined term	Definition
Offshore Export Cable	Subsea cables used to transmit electricity generated offshore by the Wind Turbines from the OSPs to shore. The Transition Joint Bay (TJB) is the location where the Offshore Export Cable terminates, and the onshore cabling begins.
Offshore Generation Assets	The infrastructure of the Project required to generate electricity comprising of the Wind Turbines, Wind Turbine foundations and associated infrastructure (e.g. IACs).
Offshore Infrastructure	All of the Offshore Infrastructure associated with the Project that is located seaward of MHWS, comprising the Offshore Generation Assets and the Offshore Transmission Assets.
Offshore Substation Platform(s) (OSPs)	OSPs comprise the support structure, topside and electrical components used for collecting and/or converting electricity generated by the wind turbines for transmission by the Offshore Export Cables.
Offshore Transmission Assets	The infrastructure of the Project required to transmit the generated electricity comprising of the OSPs, Offshore Export Cables and associated infrastructure up to MHWS.
Onshore Environmental Impact Assessment (EIA) Report	Document prepared to report the findings of the EIA for the Proposed Development and produced in accordance with the EIA Regulations. An Onshore EIA will be submitted to support the Onshore Application for the Proposed Development.
Onshore Export Cable	The cables (220/275 kV) that transfer electricity from Landfall to the Substation.
Onshore Transmission Assets	The transmission infrastructure associated with the Project above MLWS which is covered in the Onshore EIA Report.
Operation and Maintenance	The phase of the Proposed Development following completion of construction. This phase of development includes routine inspections, repairs and replacement of infrastructure and equipment and general upkeep of the Proposed Development through its operational lifespan.
Physical Processes	The collective term for the following: hydrodynamics (water levels and currents); winds and waves; stratification and frontal systems; geology and seabed sediments (including sediment transport); seabed geomorphology; and coastal geomorphology.
PPP Application Boundary	The red line boundary representing the extent of the planning permission in principle application.
Project (The)	An overarching term for the Bowdun Offshore Wind Farm (Bowdun OWF) comprising the offshore and onshore infrastructure required to generate and transmit electricity from the Array Area to the onshore Grid Connection Point (GCP). The Project includes the Offshore Generation Assets, the Offshore Transmission Assets and the Onshore Transmission Assets.
Scour Protection	Protective materials to avoid sediment being eroded away from the base of the foundations due to the flow of water.
Significance	Effect factor that is determined by the magnitude of impact along with the sensitivity of the receptor.

Defined term	Definition
Study Area	For each environmental topic, the baseline environment will be characterised, and the potential environmental impacts will be described within a topic-specific study area. Specific study areas are defined for each topic and are based on the maximum spatial extent across which potential impacts of the Proposed Development may be experienced by the relevant receptors (i.e. Zone of Influence).
Substation	The onshore Substation to be constructed as a component of the Proposed Development Part. The Substation would transform voltage from low to high by means of electrical transformers to ensure the electrical energy provided from the Offshore Generation Assets is at a voltage suitable for connection to the National Grid.
Sustainable Drainage Systems (SuDS)	Drainage systems designed to manage water systems in close alignment to natural hydrology processes.
Transition Joint Bay (TJB)	Used to connect the Onshore Export Cables with the Offshore Export Cables. These are typically concrete lined and will be located above MHWS.
Wind Turbines	Structures comprising of a tubular tower, rotor blades, and a nacelle which houses the Wind Turbine generator.

Acronyms

Acronym	Definition
BEIS	Department for Business Energy and Industrial Strategy
$CaCO_3$	Calcium Carbonate
CCC	Climate Change Committee
CCRA	Climate Change Risk Assessment
CCRA3	United Kingdom's third Climate Change Risk Assessment
CO_2	Carbon Dioxide
EIA	Environmental Impact Assessment
GHG	Greenhouse Gas
HM	His Majesty's
IAC	Inter-Array Cable
IEMA	Institute of Environmental Management and Assessment
IPCC	Intergovernmental Panel on Climate Change
MDS	Maximum Design Scenario
MLWS	Mean Low Water Springs
MOHC	Met Office Hadley Centre
MSL	Mean Sea Level
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PPP	Planning Permission in Principle
RCP	Representative Concentration Pathway
TJB	Transition Joint Bay
UK	United Kingdom
UKCP18	United Kingdom Climate Projections 2018

Table of Units

Units	Definition
km	Kilometre
km^2	Square kilometre
kn	Knots
kV	Kilovolt
m	Metres
mm	Millimetres
m/s	Metre per second
°C	Degree Celsius
%	Percent

1 Introduction

1.1.1 This Climate Change Risk Assessment (CCRA) Technical Report presents an assessment of the likely significant effects of climate change on the Bowdun Offshore Wind Farm (OWF) (hereafter referred to as the Project). The report has informed the assessment of climate change impacts reported in Volume 1, Chapter 15: Climate Change of the Onshore Environmental Impact Assessment (EIA) Report and the Climate Change chapter of the Offshore EIA Report.

1.1.2 The information from this technical report informs the assessment of the likely significant environmental effects on the Project from climate-related impacts. It identifies and assesses the anticipated risks throughout its 30-year lifetime.

1.1.3 It is important to note that the offshore and onshore elements of the Project will not operate in isolation, therefore this technical report presents the climate change baseline and risk assessment for both the onshore and offshore elements. The onshore elements of the Project are referred to throughout as the 'Onshore Transmission Assets' and will be located within the Planning Permission in Principle (PPP) Application Boundary. The offshore elements are referred to collectively as the 'Offshore Infrastructure' and will be located within the 'Marine Application Boundary.' When referring to both the onshore and offshore elements, reference is made to 'the Project'.

1.1.4 This technical report considers the potential climate-related impacts on the following offshore and onshore elements of the Project:

- Onshore:
  - Offshore Export Cables above Mean Low Water Springs (MLWS) and terminating at the Transition Joint Bays (TJBs) within Landfall;
  - Landfall area including the TJBs;
  - Onshore Export Cables from the TJBs to the Substation; and
  - Substation and an onward connection via 400 kV Cables to the National Grid electricity transmission network.
- Offshore:
  - Fixed foundation Wind Turbines;
  - Inter-Array Cables (IACs);
  - Offshore Substation Platforms (OSPs);
  - Interconnector Cables and any necessary scour/cable protection; and
  - Offshore Export Cables up to MLWS.

2 Climate Change Risk Assessment Study Area

2.1.1 The CCRA Study Area for the Onshore Transmission Assets is presented in Figure 2.1 (Annex B). It is defined as the PPP Application Boundary.

2.1.2 The CCRA Study Area for the Offshore Transmission Assets and Offshore Generation Assets is presented in Figure 2.2 (Annex B). It is defined as the Offshore Marine Application Boundary.

3 Methodology

3.1 Overview

3.1.1 This report identifies and assesses the potential adverse effects from climate change on the Project through four key stages:

- review the baseline climate and how this climate baseline is projected to change in future;
- identify the potential impacts to the Project components due to climate change
- assess the vulnerability of the Project components to the identified impacts (including embedded design measures) based on the likelihood and consequence; and
- identify additional mitigation measures if any significant effects were determined.

3.1.2 It is recognised that climate change is already taking place in the UK, according to academic research (Intergovernmental Panel on Climate Change (IPCC), 2021) and in legislation and policy (His Majesty's (HM) Government, 2008; Scottish Government, 2009; HM Government, 2022; Department for Business, Energy and Industrial Strategy (BEIS), 2022). The risks associated with rising temperatures, more frequent extreme weather patterns and rising sea levels in Scotland and impacts on energy infrastructure are presented in evidence reports developed for the UK Climate Change Risk Assessment (CCRA3) (UK Climate Risk, 2021a, 2021b). The assessment set out in Section 5 has drawn on potential climate change risks identified in these evidence reports.

3.2 Current Baseline

Onshore

3.2.1 Current baseline onshore climatic conditions have been sourced from Met Office gridded observational data for the 25 km grid cell within which the majority of the Onshore Transmission Assets are located, to align with spatial extents of the climate projections data used (see Section 3.3 below). The observational data has been collected and averaged over 30 years from 1981 to 2010 (Met Office *et al.*, 2025). This time period is used as the 'present-day' baseline for consistency with the baseline used in the future UK climate projections produced by the Met Office (referred to as the UK Climate Projections 2018 (UKCP18)). These are discussed further in the future baseline section below. Other baseline climate data have also been obtained from the

Met Office (Met Office, undated) for the nearest climate observation station (Inverbervie No. 2).

Offshore

3.2.2 Current baseline offshore climatic conditions have been sourced from observational data collated within the UK Offshore Energy Strategic Environmental Assessment ((BEIS), 2022) and the IPCCs Sixth Assessment Reporting of the physical science (IPCC, 2021). Information has also been drawn from the Physical Processes Baseline Environment, which will be published in the Offshore EIA Report, where relevant, in order to provide baseline information specific to the offshore CCRA Study Area.

3.3 Future Baseline

Onshore

3.3.1 The Met Office Hadley Centre (MOHC) publishes both probabilistic climate change projections and downscaled global circulation model outputs for the UK at various spatial scales. These are obtained from the UKCP18 dataset, first published in November 2018 and at version v2.14.0 (MOHC, 2018a) at the time of writing. The projections are based on Representative Concentration Pathway (RCP) scenarios used by the IPCC. The RCP scenarios (the four scenarios presented in the IPCC fifth Assessment report which are included within the UKCP18 database, namely RCP2.6, RCP4.5, RCP6.0 and RCP8.5) describe different potential climatic futures, all of which are considered possible depending on the volume of greenhouse gases (GHGs) emitted (IPCC, 2014). These scenarios assume a low-high range in potential global GHG emissions and resulting rate of climatic effects over a given period and provide the basis for future assessments of climate change and possible response strategies.

3.3.2 The onshore and offshore climate projections outlined below have been informed by the RCP8.5 emissions scenario, which is a high-emissions scenario assuming ‘business as usual’ growth globally, with little additional mitigation of GHG emissions. This is a conservative approach for the assessment, consistent with guidance set out in the Institute of Environmental Management and Assessment (IEMA) (2020) ‘*Environmental Impact Assessment Guide to: Climate Change Resilience and Adaptation*’.

3.3.3 The probabilistic projections published at a 25 km grid cell scale are considered the most useful for this assessment when considering the Onshore Transmission Assets, being designed to show a range of projection values that reflect uncertainty in modelled outcomes. The UKCP18 Science Overview Report (MOHC, 2018b) and supporting factsheets for the wider regional and UK context have also been drawn upon.

3.3.4 For the purposes of this assessment, the Project is expected to become fully operational by 2036 and have an initial 30-year operating lifetime, but as a key piece of energy infrastructure could also operate in the longer term (and the design life of the Project would support this). Therefore, climate projections for the mid- and late century have been considered using average conditions during the 30-year time periods 2030 to 2059 and 2060 to 2089, respectively.

Offshore

3.3.5 Probabilistic local climate projections consistent with those referenced above and used to illustrate future possible onshore climate trends are not available for offshore regions. As such, climate projections specific to offshore UK waters have been sourced from the UKCP18 Marine Report (Palmer *et al.,* 2018) and are interrogated within the UK's Third Climate Change Risk Assessment (CCRA3), Chapter 4: Infrastructure (Jaroszweski *et al.,* 2021). The climate projections contained in these reports have been used to examine future trends for wind speed, wave height and sea levels for offshore UK waters. Additional information at a regional (northern European) and global level has been taken from the IPCC Sixth Assessment Report (IPCC, 2021), where national or sub-national (e.g. regional, local) information is not available, such as sea surface temperatures, surface pH and storm occurrence.

3.3.6 The assessment of future climate has been informed by climate projections based on RCP scenarios used by the IPCC. Data is largely available for the end of the 21st century. Whilst this is outside of the lifetime of the Project, these climate projections display climate trends that will begin to be experienced throughout this century.

3.4 Risk Assessment

3.4.1 An initial screening exercise has identified the relevant climate change risks on the Project based on information sourced from the CCRA3 (Jaroszweski *et al.,* 2021), and from the available design information for the Project (see Volume 1, Chapter 2: The Proposed Development). Further information on the Offshore Infrastructure will be available in the Offshore EIA Report.

3.4.2 In overview, a climate change risk occurs when a projected climate change hazard has a potential impact on a Project receptor. The overall degree of risk is determined by the likelihood of the impact and the degree of consequence to the Project from the impact. These are both influenced by the sensitivity of receptor to the climate change hazard. The following are therefore key components in the identification and determination of climate change risks to the Project:

- **Climate change hazard** – a climate change-related event that has the potential to generate an impact on a receptor, for example, increased frequency or magnitude of flooding events or heatwave events. These have been identified by considering the current baseline and future climate projections.
- **Receptor** – the subject of the climate change hazard, for example the physical infrastructure or personnel operating the Project. Given the variability in the nature of the potential effects of climate change on the Project, receptors have been identified on a risk-specific basis, whereby all receptors relate to the continued safe and effective operation of the Project.

- **Potential impact** – the potential impact that could occur to the receptor from the climate change hazard. Impacts can be chronic (e.g. less severe and which may occur more frequently or develop over a longer term) or acute (more severe, sudden which may occur from a single event).
- **Likelihood** – the probability that the potential impact would occur, based on the probabilistic climate change projections (Annex A). Further details on the definition of likelihood are provided in Table 3.1.
- **Consequence** – The scale or the severity and complexity of the impact, including how it impacts on the Project in terms of damage, disruption of operation, maintenance and repair requirements. Further details on the definition of exposure are provided in Table 3.1.

3.4.3 A high-level assessment of the identified risks has been undertaken, considering the climate change hazards, resulting potential impact on the receptors, and the likelihood and consequence of the potential impacts on the relevant receptors. Table 3.1 presents the definitions and levels of likelihood and consequence used to assess risk in the CCRAs for both the Onshore Transmission Assets and the Offshore Infrastructure. The sensitivity of the receptors is factored into the consideration of the likelihood and consequence as appropriate. Sensitivity is based on the importance/value of the receptor, and its susceptibility (ability to be affected by a change in climate) and vulnerability (the potential exposure to a change in climate).

3.4.4 The matrix for determining the significance of effect is presented in Table 3.2 and considers the likelihood and consequence of the potential climate change impacts to the receptor(s) affected. The assessment of effects has considered the Embedded Mitigation adopted as part of the Project (reported in Section 5 of this report, Table 5.1 and Table 5.2).

3.4.5 Should an effect be significant after Embedded Mitigation, Additional Mitigation is presented where relevant to reduce the residual effect to not significant in EIA terms.

Table 3.1: Likelihood and Consequence Scoring Definitions

Factor	Score Definition
Likelihood **The likelihood of the potential impact occurring**	**High**: the event/impact occurs multiple times during the expected operational life (e.g. annually)
	Medium: the event/impact occurs several times during the expected operational life (e.g. approximately every 3 – 5 years)
	Low: the event/impact occurs a limited number of times during the expected operational life (e.g. approximately every 10 – 15 years)
	Negligible: the event/impact is unlikely to occur during the expected operational life
Consequence **The magnitude/severity of the potential impact, taking into account the sensitivity**	**Large**: Acute impact to functionality; or A large measurable decrease in receptor lifespan following the occurrence of a climate impact; or Major increase in the need for maintenance and repairs; or

Factor	Score Definition
(susceptibility/vulnerability) of the receptor to the climate change hazard where appropriate	Wide scale disruption to operation of the project or loss of function and usability that is long-term (e.g. greater than one week).
	Moderate: Measurable decrease in receptor performance or lifespan; or Large increase in necessary maintenance and repairs following the occurrence of a climate impact; or Localised disruption to operation of the project or loss of function and usability that is medium-term (up to one week).
	Minor: A small measurable effect on a receptor's performance or lifespan due to a chronic impact; or Small but measurable increase in necessary maintenance and repairs following the occurrence of a climate impact; or Minimal disruption to operation of the project or loss of function and usability that is short-term (less than one day).
	Negligible: Very small or no quantifiable impact to a receptor's performance following acute impact, or No measurable deterioration of a receptor's lifespan due to a chronic impact; or No measurable increase in necessary maintenance and repairs; or No disruption in function and usability of the project.

Table 3.2: Scoring Matrix for Physical Risk

		Likelihood			
Consequence		**Negligible**	**Low**	**Medium**	**High**
	Negligible	Not Significant (Negligible)	Not Significant (Negligible)	Not Significant (Minor Adverse)	Not Significant (Minor Adverse)
	Minor	Not Significant (Negligible)	Not Significant (Minor Adverse)	Not Significant (Minor Adverse)	**Significant (Moderate Adverse)**
	Moderate	Not Significant (Minor Adverse)	Not Significant (Minor Adverse)	**Significant (Moderate Adverse)**	**Significant (Major adverse)**
	Large	Not Significant (Minor Adverse)	**Significant (Moderate Adverse)**	**Significant (Major Adverse)**	**Significant (Major Adverse)**

3.5 Assumptions and Limitations

3.5.1 At the end of the 30-year operational lifetime of the Project, subject to relevant additional consents and legislative requirements, it is anticipated that potential refurbishment and operational life extension of the Project may occur. If the operation of the Project does not continue beyond 30 years, the Project would be decommissioned. The operational lifetime of the electricity infrastructure is currently considered to be 30 years. For the purposes of this assessment, the Project is expected to become fully operational by 2036 and have an initial 30-year operating lifetime, but as a key piece of energy infrastructure could also operate in the longer term (and the design life of the Project would support this). Therefore, climate projections for the mid- and late century have been considered: average conditions during 2030 to 2059 and 2060 to 2089.

3.5.2 The climate projections used to inform this assessment are contemporary at the time of writing. It can be expected that projections of future climate will evolve due to improvements in climate modelling and scientific understanding of climate systems, alongside improved data regarding the rate of change of global atmospheric carbon dioxide (CO_2) and other GHGs. As such, there is some inherent uncertainty in the projections used. However, in line with relevant guidance (IEMA, 2020), a MDS has been used to account for such uncertainty. Ensuring the Project is resilient to more conservative future climate projections will mean that it will likely be resilient to any shorter-term climate fluctuations or variations in the climate not identified by projections (e.g. more extreme events or fluctuations in climate in the shorter term).

4 Baseline Characterisation

4.1 Current Baseline

Onshore

4.1.1 The nearest climate observation station (Inverbervie No.2) is located to the north east of Inverbervie on the east coast of Scotland. It is located approximately 3 km to the east of the southern end of the onshore CCRA Study Area (PPP Application Boundary) at its closest point, close to where the Offshore Export Cable makes landfall on the North Sea coast. The Study Area experiences a temperate climate, with annual average maximum and minimum monthly average temperatures respectively of 10.9°C and 5.3°C recorded at the Inverbervie No.2 climate station in the baseline period 1981 to 2010 (Met Office, undated). During the 1981 to 2010 baseline period, average monthly maximum temperatures reached 16.9°C in the month of August, and minimum temperatures fell to an average of 1.2°C in February. The highest maximum monthly temperatures are slightly colder than regional climate patterns for East Scotland (17.8°C) and Scotland (17.2°C) with the lowest minimum monthly temperatures being slightly warmer than East Scotland (-0.6°C) and Scotland (-0.1°C).

4.1.2 The gridded observation data for the 25 km grid cell (centred on E 387500 N 787500) which encompasses the majority of the onshore CCRA Study Area

(PPP Application Boundary) indicates that, on average, the maximum and minimum monthly temperatures are slightly warmer and slightly colder, respectively, compared to the temperatures recorded at the Inverbervie No.2 climate station. The Inverbervie No.2 climate station and the 25 km grid cell centred on E 387500 N 787500 are shown in Figure 4.1 (Annex B).

4.1.3 For the baseline period of 1981 to 2010, the annual average precipitation recorded at the Inverbervie No.2 climate station was 683 mm. The gridded observational data for the 25 km grid cell centred on E 387500 N 787500 indicates that the annual precipitation across the majority of the onshore CCRA Study Area is higher than that recorded at the Inverbervie No.2 climate station, at 871 mm. The average annual precipitation reported for the East Scotland region was 1,165 mm. Regional precipitation in East Scotland is similar to the UK annual average, which totals 1,165 mm and lower than the overall Scotland average of 1,551 mm. The onshore CCRA Study Area is in a slightly drier area compared to the wider East Scotland region and Scotland average.

4.1.4 Regional annual average wind speeds in the East Scotland and Scotland Met Office reporting regions are marginally higher than the annual average for the UK, equalling 10.3 kn, and 10.8 kn, respectively. Wind speeds recorded at the Inverbervie No.2 climate station are higher than the East Scotland regional speeds, at 12.8 kn. However, this climate station is located on an elevated location adjacent to the North Sea coastline and is likely to experience higher wind speeds than locations further inshore. The Onshore Transmission Assets are adjacent to the North Sea coastline where the cable route makes landfall, however, the remainder of the cable route and Substation (the onshore part of the CCRA Study Area) is located more inland.

Offshore

4.1.5 The Offshore Transmission Assets and Offshore Generation Assets lie in Regional Sea 1 (BEIS, 2022). Climate baseline data is provided for this region in the following paragraphs.

4.1.6 Air temperatures in the central North Sea do not tend to vary beyond the range of 0°C to 19°C, with the exception of extended periods of easterly winds which can lead to extreme cold in winter and warm conditions in summer. Mean air temperatures range from lows of 1°C in January to 16°C in July (BEIS, 2022). Global air temperatures rose by 0.85°C between 1880 and 2012, and continue to rise, with each of the last four decades warmer than any decade that preceded it since 1850. Temperatures have risen more slowly over the oceans than over land (IPCC, 2021).

4.1.7 Annual precipitation across the North Sea varies between 340 mm and 500 mm, averaging 425 mm. Precipitation rates follow a seasonal trend with April to June tending to be the driest months, and October to January being wetter. Thunderstorms are infrequent, and snow showers vary from approximately ten to 12 days in the central North Sea (BEIS, 2022).

4.1.8 The prevailing winds in the central North Sea are from the south-west and the north-north-east, and tend to be stronger over the open sea than at the coast owing to the lack of shelter. South and south-easterly winds may also arise and remain for as long as several weeks if an anticyclone develops over Europe. Wind strengths in winter are typically in the range of Beaufort scale four to six (6 m/s to 11 m/s) with higher winds of force eight to 12 (17 m/s to 32 m/s) being much less frequent. Winds of Force 5 (8 m/s) and greater are recorded 60% to 65% of the time in winter and 22% to 27% of the time in summer. In April and July, winds are highly variable, with a greater incidence of north-westerly winds (BEIS, 2022). The maximum observed wind speeds in the records are 32.30 m/s in the Array Area, 29.90 m/s along the Export Cable Corridor and 28.37 m/s at the Landfall.

4.1.9 The wave regime is dominated by locally generated wind waves across the wider North Sea region. The Array Area is exposed to longer wave fetches (distances of open water over which waves can develop) from the north to north-east. Analysis shows that the largest significant wave height observed at Landfall was 6.93 m, while in the Array Area, the largest significant wave height was 12.72 m. At the Export Cable Corridor, the largest significant wave height observed was 11.22 m.

4.1.10 Extremes analysis of the long-term wave hindcast record shows that waves within the Array Area reach significant wave heights of approximately 8.4 m for a 1:1 year event, increasing to 12.2 m for a 1:50 year event. Equivalent extreme values for the Landfall are 4.8 m and 7 m, respectively, and at the Export Cable Corridor, these are 7.5 m and 10.9 m, respectively.

4.1.11 Further detailed commentary can be found for the Physical Processes Study Area (see the Offshore EIA Report).

4.1.12 Mean Sea Level (MSL) is a crucial element of climate change related risks for OWFs, as increased sea level has the potential to both increase water damage and corrosion of components above the water line at time of construction. MSL rise also has the potential to cause increased damage from storm surge. Global MSL rose by 0.2 m between 1901 and 2018, and continues to rise (IPCC, 2021). The average rate of sea level rise increased from 1.3 mm per year between 1901 and 1971, to 1.9 mm per year between 1971 and 2006, and further to 3.7 mm per year between 2006 and 2018 (IPCC, 2021). Ice sheet and glacier mass loss were the main contributors to such global MSL rise between 2006 and 2018 (IPCC, 2021).

4.2 Future Baseline

Onshore

4.2.1 Within the last two decades, annual average temperature and precipitation records have been consistently set in the UK relative to the preceding baseline period, although generally wetter rather than drier summers have been seen in this period. These natural variations are likely to continue to be the most visible year-to-year changes in climate over the next decade, amplifying over this century, but in subsequent decades within the operating lifetime of the Project, the anthropogenic climate changes are expected to become more apparent as evidenced by the climate projections discussed below.

4.2.2 The potential climate changes from the UKCP18 probabilistic dataset (averaged over the 2030 to 2059 and 2060 to 2089 30-year time periods) relative to the 1981 to 2010 baseline for the same 25 km grid square (centred on E 387500 N 787500) are shown in full in Annex A (MOHC, 2018a).

4.2.3 Generally, these indicate that temperatures are projected to increase across all seasons, up to 2.5°C on an annual average basis and up to 3.9°C for the hottest month maximum temperature (based on the median values, i.e. the 50th percentile).

4.2.4 In summary, precipitation is expected to decrease in summer (up to -18%) and increase in winter (up to 23%), with a slight increase on an annual basis (up to 5%) (based on the medium values).

4.2.5 Probabilistic projections do not provide wind speed data, therefore, no clear trend for change in wind speed during this time period is shown in the projections data in Annex A. Depending on the climate models used, these show no clear trend in wind speed or show small increases which are much lower than the normal year-to-year variability in wind speed (MOHC, 2019). Trends in windstorm numbers are difficult to detect, due to their natural year-to-year variation. Projections indicate that winter windstorms will increase slightly in number and intensity over the UK (i.e. more winter storms), however there is limited confidence in this projection due to inconsistent results from climate models.

Offshore

4.2.6 It is virtually certain that sea surface temperatures will continue to increase in the 21st century, with global mean sea surface temperatures predicted to increase by approximately 2.9°C by 2100 under RCP8.5. Sea temperatures in northern Europe (including the North Sea) are predicted to rise at a greater rate than the global average, with temperatures predicted to increase by approximately 3.4°C under RCP8.5 in the same time period. Marine heatwaves (periods of extreme high sea temperature, defined as temperatures warmer than the 99th percentile of mean sea temperatures for the region) are also expected to increase around Europe over the 21st century (IPCC, 2021).

4.2.7 Similarly, it is virtually certain that CO_2 uptake by the ocean surface will increase (due to increased atmospheric CO_2 concentrations), resulting in increased ocean acidification. CO_2 uptake drives changes in seawater and Calcium Carbonate ($CaCO_3$) chemistry, resulting in an overall decrease of ocean pH. Northern European sea surface pH is predicted to fall by 0.4 units by 2100 under RCP8.5 (IPCC, 2021).

4.2.8 The average wave height is predicted to decrease around much of the UK at a factor of about 10% to 20% over the 21st century, with average wave heights in the North Sea decreasing by approximately 0.1 m. This could partially compensate for the rise in sea level. However, owing to variation between different models, confidence in projected sea wave height changes is low (Jaroszweski *et al.,* 2021).

4.2.9 Changes in maximum wind speeds associated with storm surges vary across UK waters, with changes in the order of +/- 1.5 m/s. There is little consensus between models regarding the extent and pattern of such winds in relation to climate change, though some models anticipate an increase in the days of strong winds over the UK by the end of the 21st century, compared to the start of the century (Palmer *et al.,* 2018). As such, conservatively an increase in maximum wind speed and an increase in the number of days with strong winds should be anticipated.

4.2.10 The frequency and intensity of storms is anticipated to slightly increase by the middle of the 21st century and beyond for northern Europe. Clustering of storms over time may also increase in many areas in Europe. However, projections of smaller scale hazardous weather have low confidence, due to the inability of climate models to accurately simulate these phenomena (IPCC, 2021).

4.2.11 Global MSL will continue to rise throughout the 21st century, a change that is projected within all future climate change scenarios. Under RCP8.5, the UK can expect to see sea level rise of approximately 1 m by 2100. This change is regionally variable, with a lesser impact anticipated in the north of the UK. The east coast of Scotland can expect to see a MSL rise of between approximately 0.5 m and 0.6 m by 2100 (Palmer *et al.,* 2018), broadly comparable to an anticipated global MSL rise of approximately 0.7 m by 2100 (IPCC, 2021).

5 Climate Change Risk Assessment

Onshore

5.1.1 Table 5.1 below shows the climate change risks to the Onshore Transmission Assets that have been identified and the risk scores assigned, following the approach set out in Table 3.1 and Table 3.2.

5.1.2 Considering the Embedded Mitigation measures within Table 5.1, the potential risk posed to the Onshore Transmission Assets would be Not Significant in EIA terms.

Table 5.1: Climate Change Risk Scores for the Onshore Transmission Assets During Operation and Maintenance Phase

Climate Change Hazard	Receptor	Potential Impact	Embedded Mitigation Measures	Likelihood	Consequence	Significance After Design Measures
Increases in average and extreme temperatures, particularly during summer	Substation and associated electrical equipment	Consistently heightened or very high temperatures could lead to efficiency losses due to overheating, or the failure of electrical equipment.	Substation components may be located outside or within a building. Should it be located within a building, appropriate cooling plant/equipment will be designed to account for a range of temperature conditions. These are not likely to be required should the Substation be located externally given the temperature ratings of equipment and adequate airflow would reduce the risk. Design of Substation and components in line with relevant design standards and with reference to projected temperature rises, with appropriate safety margin.	Low	Moderate	Minor Adverse (Not Significant)
	Offshore Export Cables above MLWS, Onshore Export Cables and 400 kV Cables	Overheating causing damage to cabling resulting in disruption to operations.	Cabling to be buried at an appropriate level below ground to limit and avoid potential risk. Cabling to include fibre optic cable to include temperature sensing, providing indication of overheating risk.	Negligible	Moderate	Minor Adverse (Not Significant)
Changes to rainfall patterns, leading to increased annual precipitation	Substation and associated electrical equipment	Damage to Substation and associated electrical equipment resulting in disruption to operations.	Design of Substation structures in line with appropriate design standards, with safety margin. Employing a flexible operation and maintenance strategy will aid in reducing this risk. Allowing for flexible scheduling will mean the frequency of maintenance can be scaled by need, accounting for factors such as an increased intensity and frequency of rainfall, if necessary. This will enable a reduction in disruptions through quick and effective identification of issues.	Negligible	Moderate	Minor Adverse (Not Significant)
	Offshore Export Cables above MLWS, Onshore Export Cables and 400 kV Cables	Damage to cabling resulting in disruption to operations.	Cabling is water resilient and to be buried at an appropriate level below ground to reduce the potential risk.	Negligible	Moderate	Minor Adverse (Not Significant)
Increased frequency of flood events resulting from increased precipitation intensity	Substation and associated electrical equipment	Damage to Substation and associated electrical equipment resulting in disruption to operations.	Surface water flood risk for the Substation is assessed in Volume 1, Chapter 11: Water Quality and Flood Risk and Volume 2, Appendix 11.1: Flood Risk and Drainage Assessment, which details suitable attenuation and drainage design to manage flood risk. This includes: - Implementation of SuDS measures (i.e. settlement and storage ponds) to manage and treat surface water runoff. - Appropriate sizing and positioning of drainage infrastructure to accommodate predicted rainfall events, including allowances for climate change. - Consideration of ground levels and landscaping to direct surface water away from critical infrastructure.	Low	Moderate	Minor Adverse (Not Significant)
	Onshore Export Cables and 400 kV Cables and other onshore infrastructure (joint bays / link boxes)	Damage to cabling resulting in disruption to operations.	Cabling and infrastructure is water resilient and to be buried at an appropriate level below ground, leading to no notable change in drainage patterns and surface water runoff rates, thereby reducing the risk of any flooding and standing water at the onshore infrastructure areas (e.g. joint bays / link boxes).	Negligible	Moderate	Minor Adverse (Not Significant)
Increased frequency and intensity of extreme weather i.e. storms	Substation and associated electrical equipment	Extreme storm events, including cold weather events, may cause structural damage to Substation and associated electrical equipment, through increased loading and ice accretion, resulting in disruption to operations.	Design of Substation structures in line with relevant design standards, with appropriate safety margin. Employing a flexible operation and maintenance strategy will aid in mitigating this risk. Allowing for flexible scheduling will mean the frequency of maintenance can be scaled by need, accounting for factors such as an increased number of storm events, if necessary. This will enable a reduction in disruptions through quick and effective identification of issues.	Low	Moderate	Minor Adverse (Not Significant)

Climate Change Hazard	Receptor	Potential Impact	Embedded Mitigation Measures	Likelihood	Consequence	Significance After Design Measures
	Offshore Export Cables above MLWS, Onshore Export Cables and 400 kV Cables	Extreme storm events, including cold weather events, may cause structural damage to cabling, resulting in disruption to operations.	Cabling to be buried at an appropriate level below ground to limit and avoid potential risk.	Negligible	Moderate	Minor Adverse (Not Significant)
Increased wind speeds and changes to wind patterns	Substation and associated electrical equipment	Substation infrastructure may be subject to physical damage from extreme wind forces.	Design of Substation structures in line with relevant design standards, with appropriate safety margin. Consideration of the potential impacts from nearby trees being felled by high winds (known as wind throw) (e.g. appropriate stand-off distance for replanting around the Substation or, where visual screening is required, planting with native broadleaves and appropriate species which are less prone to wind throw).	Negligible	Moderate	Minor Adverse (Not Significant)
Increase in MSL, coastal flooding and storm events	Offshore Export Cables above MLWS, Onshore Export Cables and other onshore infrastructure at Landfall (Transition Joint Bays)	May result in the increased frequency of coastal flooding, which may damage the associated electrical equipment, including Onshore Export Cables and other Landfall infrastructure, resulting in disruption to operations.	Coastal flood risk for the landfall and associated infrastructure is assessed in Volume 1, Chapter 11: Water Quality and Flood Risk and Volume 2, Appendix 11.1: Flood Risk and Drainage Assessment, which details appropriate mitigation. This includes requirements for the design and location of ground level infrastructure (e.g. Transition Joint Bays), and for these to be designed to remain operational and accessible during extreme flood events (0.1% annual probability, 1 in 1000 year flood).	Negligible	Moderate	Minor Adverse (Not Significant)

Offshore

5.1.3 The climate change risks to the Offshore Transmission Assets and Offshore Generation Assets that have been identified and assessed are presented in Table 5.2. These risks relate to consistently heightened air and sea surface temperatures, MSL rise, changes to rainfall patterns, increased wind speeds, increased wave heights and increased frequency and severity of extreme events such as storms. Embedded Mitigation measures are identified for each risk.

5.1.4 Considering the Embedded Mitigation measures detailed within Table 5.2, the potential risk posed to the offshore elements of the Project would be reduced to not significant in EIA terms.

Table 5.2: Risk Scores for the Offshore Transmission Assets and Offshore Generations Assets During Operation and Maintenance Phase

Climate Hazard	Receptor	Potential Impact	Embedded Mitigation Measures	Likelihood	Consequence	Significance After Design Measures
Increases in average and extreme air temperatures, both in winter and summer	Wind Turbines	Heating/overheating of Wind Turbine mechanisms may result in failure of electrical equipment and gear boxes. Heating/overheating may inhibit power infrastructure performance and export.	The Offshore Generation Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Safety margin within the Wind Turbine design to be fitted with automatic shutdowns/lockdowns with regards to spinning too fast.	Low	Moderate	Minor Adverse (Not Significant)
	Offshore Substation Platforms (OSP)	Consistently heightened temperatures could lead to efficiency losses due to overheating, or the failure of electrical equipment within the offshore substations.	The Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. The OSP electrical plant will be located within an internal structure. Appropriate cooling plant will be designed to account for a range of temperature conditions.	Negligible	Moderate	Minor Adverse (Not Significant)
Increases in sea surface temperatures and ocean acidification	Subsea infrastructure (IACs and Interconnector Cables, OSP foundations and Wind Turbine foundations)	Increased temperatures and ocean acidification may lead to accelerated corrosion of submerged structures, including IACs and Interconnector Cables, OSP foundations and Wind Turbine foundations.	The Offshore Generation Assets and Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Application of anti-corrosion protective coatings.	Negligible	Minor	Negligible (Not Significant)
Changes to rainfall patterns, leading to increased annual precipitation	Wind Turbines	Increased wear and tear resulting in erosion and degradation of blade surfaces, increased drag and thereby decreased energy production.	The Offshore Generation Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Additionally, Offshore Infrastructure is typically designed to be resilient to climate risks such as storms and waves with factors of safety incorporated into the design. Regular inspections to be carried out to assess Wind Turbine condition, where conditions allow.	Low	Minor	Minor Adverse (Not Significant)
	Offshore Substation Platforms	Increased wear and tear resulting in erosion and degradation of the OSPs, increasing repair and maintenance requirements.	The Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Additionally, Offshore Infrastructure is typically designed to be resilient to climate risks such as storms and waves with factors of safety incorporated into the design. Use of durable materials within the OSP structures.	Low	Minor	Minor Adverse (Not Significant)
Increased frequency and intensity of extreme weather i.e. storms	Wind Turbines, Offshore Substation Platforms	More frequent and higher loads on Wind Turbine foundations and OSP foundations and platforms causing structural damage from storm waves. Increased wear and tear of mechanical systems from high wind speeds. Increased loading from ice build-up.	The Offshore Generation Assets and Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Additionally, Offshore Infrastructure is typically designed to be resilient to climate risks such as storms and waves with factors of safety incorporated into the design. Wind Turbines to be fitted with automatic shutdowns/lockdowns with regards to spinning too fast from storms. Application of anti-corrosion protective coatings. Existing appropriate standards for safety. Modelling suggests negligible change in accessibility (Jaroszweski *et al.*, 2021).	Low	Moderate	Minor Adverse (Not Significant)

Climate Hazard	Receptor	Potential Impact	Embedded Mitigation Measures	Likelihood	Consequence	Significance After Design Measures
		Increased wear and tear resulting in erosion and degradation of the OSP. Reduced accessibility for maintenance and inspection due to worse weather conditions.				
Increased wind speeds and changes to wind patterns	Wind Turbines	Increased wear and tear of mechanical systems from high wind speeds. Increased occurrence of wind speeds beyond the cut-off point of the Wind Turbines leading to a more frequent shut down of Wind Turbines	The Offshore Generation Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Additionally, Offshore Infrastructure is typically designed to be resilient to climate risks such as storms and waves with factors of safety incorporated into the design. Regular inspections to be carried out to assess Wind Turbine condition, where conditions allow. Wind Turbines to be fitted with automatic shutdowns/lockdowns with regards to spinning too fast from storms. Use of durable materials within the OSP structures.	Low	Moderate	Minor Adverse (Not Significant)
	Offshore Substation Platforms	Increased wear and tear resulting in erosion and degradation of the OSPs.	The Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Additionally, Offshore Infrastructure is typically designed to be resilient to climate risks such as storms and waves with factors of safety incorporated into the design. Use of durable materials within the OSP structures.	Low	Moderate	Minor Adverse (Not Significant)
Increase in MSL	Above-sea infrastructure (OSPs and Wind Turbines)	Damage to OSP platforms and foundations owing to increased water damage and corrosion. Additional loading on the Wind Turbine and OSP structures, resulting in structural stress and additional corrosion.	The Offshore Generation Assets and Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea with allowance for increased MSL. Application of anti-corrosion protective coatings, accounting for MSL rise.	Negligible	Minor	Negligible (Not Significant)
Increased wave height	All Offshore Infrastructure	Degradation of Wind Turbine and OSP structures and foundations due to additional loading. Degradation to Wind Turbine foundations, OSP foundations, and Interconnector Cables and Inter-Array Cables due to scour from sediment transfer. Failure at cable joints may also result.	The Offshore Generation Assets and Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Additionally, Offshore Infrastructure is typically designed to be resilient to climate risks such as storms and waves with factors of safety incorporated into the design. Regular inspection of offshore structures for any weaknesses or potential failure points. Integrated scour protection.	Negligible	Moderate	Minor Adverse (Not Significant)
Changes in the tidal range	Subsea infrastructure (IACs and Interconnector Cables, OSP foundations and Wind Turbine foundations)	Degradation to Wind Turbine foundations, OSP foundations, and undersea cabling due to scour from sediment transfer. Failure at cable joints may also result.	The Offshore Generation Assets and Offshore Transmission Assets will be constructed to appropriate design standards for structural safety of offshore wind in the North Sea. Integrated scour protection and regular inspection for condition of scour protection.	Negligible	Moderate	Minor Adverse (Not Significant)

6 Summary

6.1.1 This technical report assesses the potential adverse effects on the Project from climate change through assessing potential climate-related impacts throughout its 30-year operational lifetime.

6.1.2 Consistently heightened temperatures, changes to rainfall patterns, and increased frequency of extreme events such as floods and storms could lead to efficiency losses due to overheating, the failure of electrical equipment or damage to infrastructure which would result in an increase in operation and maintenance activities.

6.1.3 The key risk from climate change to the Onshore Transmission Assets is likely to arise from flooding. Flood risk is also assessed separately in detail in Volume 1, Chapter 11: Water Quality and Flood Risk and Volume 2, Appendix 11.1: Flood Risk and Drainage Assessment of the Onshore EIA Report and appropriate embedded flood management and resilience measures have been taken into account. Other keys risks to the Substation include increases in summer temperatures and increased frequency and intensity of extreme weather events (storms).

6.1.4 The key risks from climate change to the Offshore Transmission Assets and Offshore Generation Assets are likely to arise from increased extreme temperatures and increased frequency and intensity of extreme weather events (storms) and winds.

6.1.5 The risk assessment considered in its scoring the influence of embedded mitigation upon the likelihood and consequence of climate risks. When considering the each of the impacts detailed within Table 5.1 and Table 5.2 above, taking into account embedded mitigation, the potential risks posed to the Project would be not significant.

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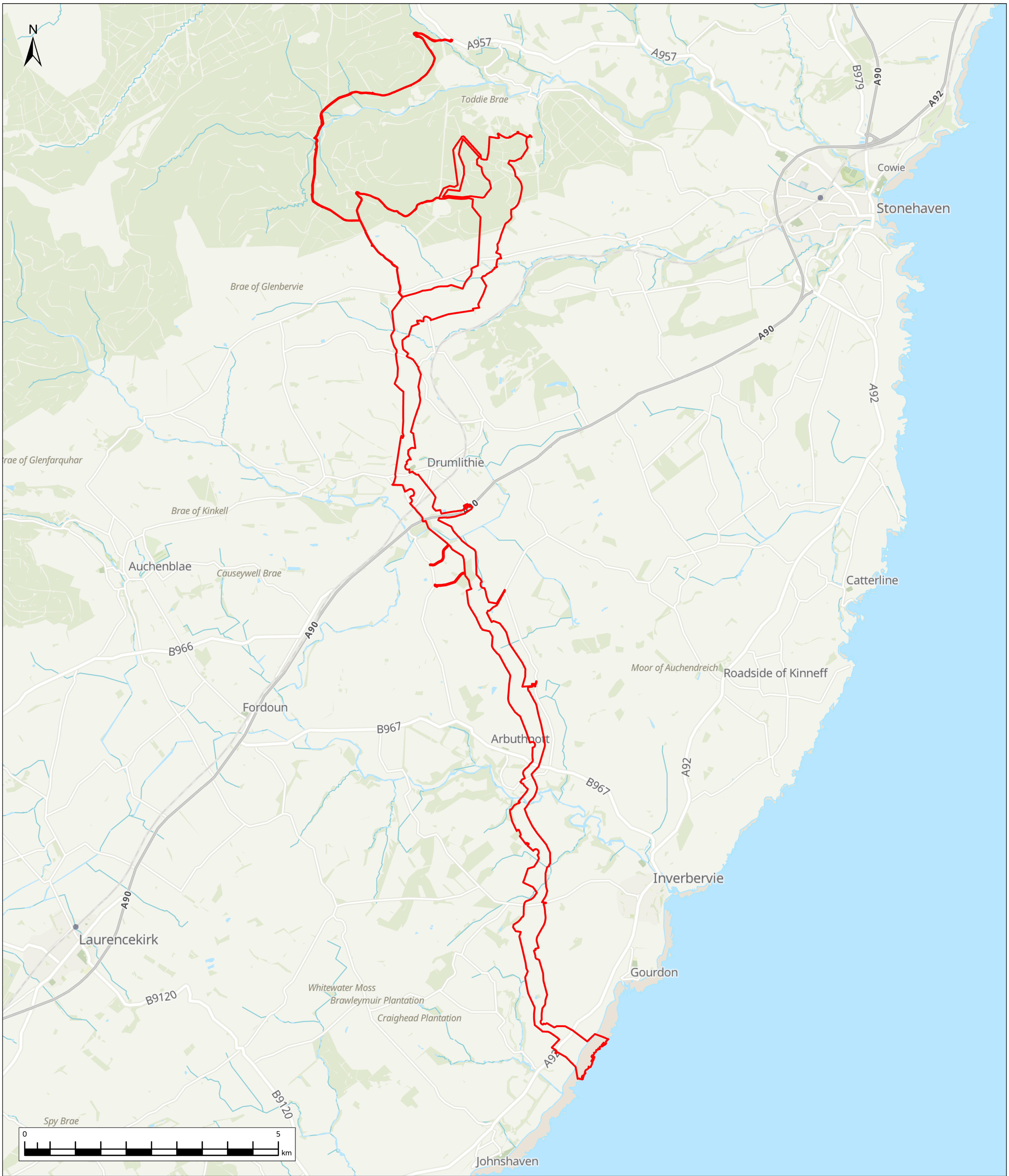
ANNEX A. CLIMATE PROJECTION DATA

Table A1.1: Climate Parameter Baseline 1981 to 2010 and Projections 2030 to 2059 and 2060 to 2089 (25 km cell centred E 387500 N 787500)

Parameter†	Observed baseline (1981 – 2010)	Projected Change (scenario RCP8.5) 2030 to 2059			Projected Change (scenario RCP8.5) 2060 to 2089		
		10th Percentile	Median Value	90th Percentile	10th Percentile	Median Value	90th Percentile
Precipitation - annual average	871	-1.6%	+5.1%	+12.1%	-4.6%	+4.7%	+15.0%
Precipitation - summer	194	-20.9%	-4.8%	+12.1%	-39.0%	-17.7%	+6.6%
Precipitation - winter	216	-1.7%	+15.7%	+36.7%	-3.1%	+23.1%	+55.9%
Precipitation - driest summer month (Jun)	62	-25.5%	+3.4%	+34.6%	-43.3%	-10.0%	+28.2%
Precipitation - wettest winter month (Dec)	79	-9.8%	+9.8%	+31.1%	-8.2%	+18.3%	+46.9%
Temperature - annual average	7.9°C	+0.6°C	+1.2°C	+1.9°C	+1.3°C	+2.5°C	+3.8°C
Temperature - hottest season (summer) average	13.1°C	+0.3°C	+1.2°C	+2.1°C	+1.0°C	+2.7°C	+4.6°C
Temperature - hottest season (summer) maximum	17.0°C	+0.1°C	+1.2°C	+2.3°C	+0.7°C	+2.9°C	+5.1°C
Temperature - coldest season (winter) average	3.1°C	+0.2°C	+1.1°C	+2.1°C	+0.7°C	+2.2°C	+3.9°C
Temperature - coldest season (winter) minimum	0.4°C	+0.2°C	+1.2°C	+2.4°C	+0.6°C	+2.4°C	+4.4°C
Temperature - hottest month average (Jul)	13.9°C	+0.4°C	+1.6°C	+2.8°C	+1.2°C	+3.6°C	+5.9°C
Temperature - hottest month maximum	17.8°C	+0.2°C	+1.7°C	+3.2°C	+1.1°C	+3.9°C	+6.7°C
Temperature - coldest month average (Jan)	2.9°C	+0.1°C	+1.3°C	+2.5°C	+0.5°C	+2.5°C	+4.7°C
Temperature - coldest month minimum	0.2°C	+0.1°C	+1.3°C	+2.7°C	+0.4°C	+2.6°C	+5.1°C

† daily mean, maximum or minimum, as applicable, averaged over time period specified

ANNEX B. FIGURES



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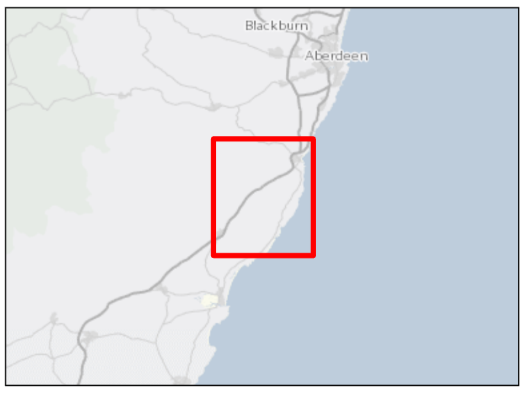

Jacobs

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Project: Bowdun Offshore Wind Farm Onshore EIA Report

Drawing Title: CCRA Study Area - Onshore

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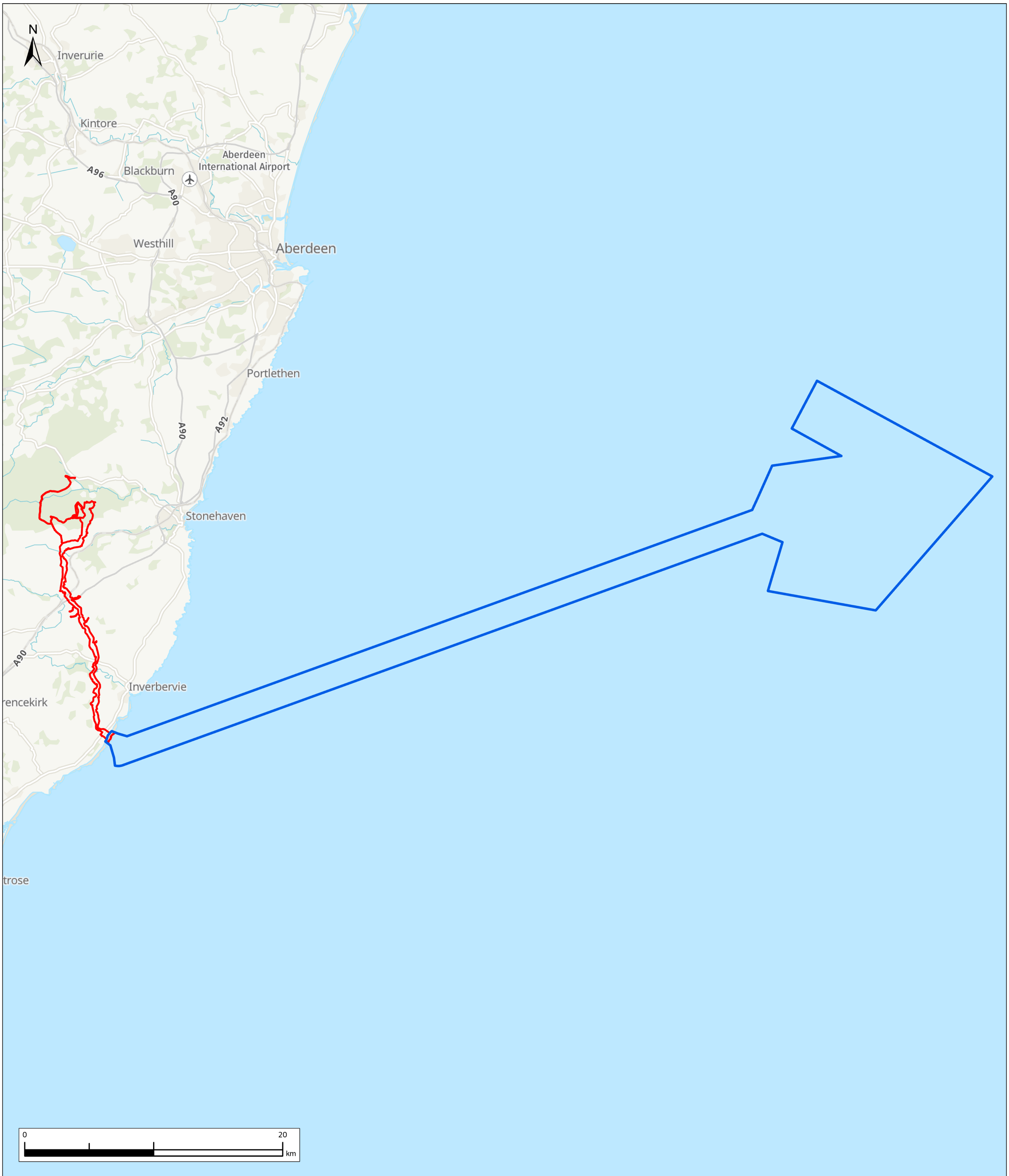
Figure 2.1

Sheet 1 of 1



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PPP Application Boundary

CCRA Study Area – Offshore

Jacobs

Client: TWP THISTLE WIND PARTNERS

Project: Bowdun Offshore Wind Farm Onshore EIA Report

Drawing Title: CCRA Study Area – Offshore

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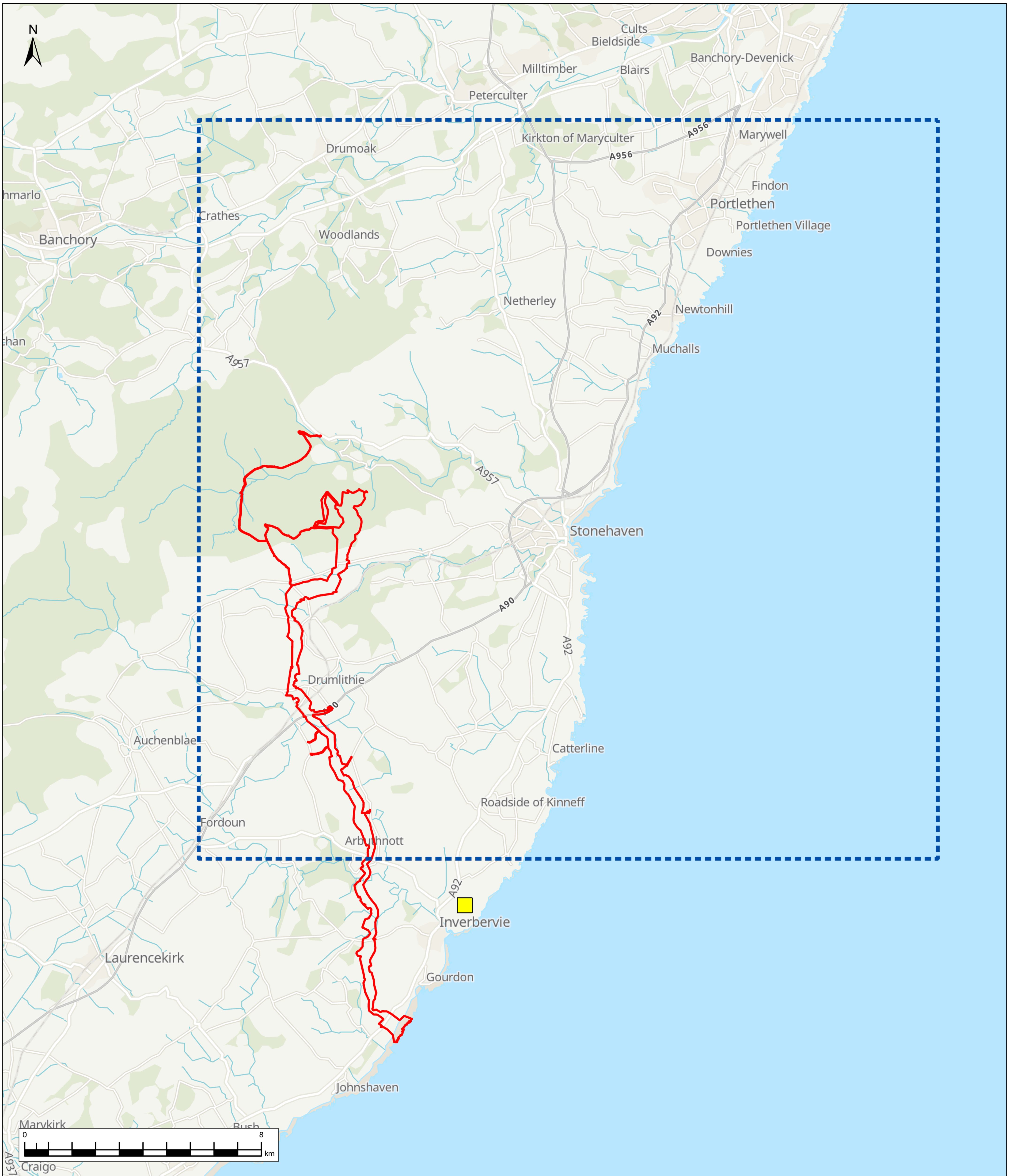
Sheet 1 of 1



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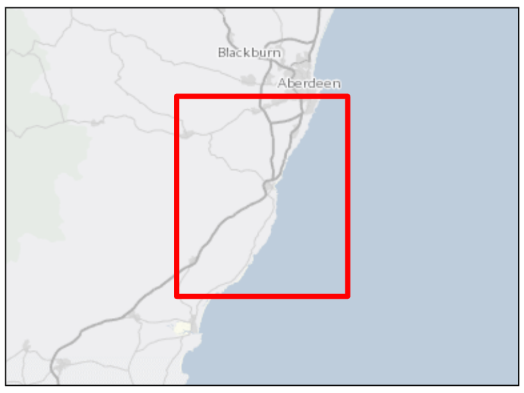
PPP Application Boundary

Inverbervie No.2 Climate Station

UKCP18 Climate Projections 25km Grid Square Centred on E 387500 N 787500



Client

THISTLE WIND PARTNERS

Project

Bowdun Offshore Wind Farm
Onshore EIA Report

Drawing Title

Climate Data Locations

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Figure 4.1

Sheet 1 of 1