Fred. Olsen Renewables

Chapter 16

Climate Change

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Glossary

Term	Definition
Environmental Impact Assessment	Environmental Impact Assessment (EIA) is a means of drawing together by the developer, in a systematic way, a description of the development and information relating to the likely significant environmental effects arising from a Proposed Development.
Environmental Impact Assessment Report	A document reporting the findings of the EIA and produced in accordance with the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 Regulation 5
The Applicant	Fred. Olsen Renewables Limited
The Proposed Development	The Proposed Windy Standard I Repower Wind Farm

Term	Definition
The Proposed Development Area	The area shown delineated by the red line boundary shown on Figure 1.2.
Windy Standard Complex	The 'present Windy Standard Developments' refers collectively to the operational existing Windy Standard I Wind Farm, Windy Standard II Wind Farm and the consented Windy Standard III Wind Farm.

List of Abbreviations

Abbreviation	Description
CO_2	Carbon Dioxide
DOC	Dissolved Organic Carbon
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
FORL	Fred. Olsen Renewables (Ltd)
GHG	Greenhouse Gas
ha	Hectare
IEMA	Institute of Environmental Management and Assessment
MW	Mega watt
MWh	Mega watt per hour
MWh yr^{-1}	Mega watt per hour per year
POC	Particulate Organic Carbon
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
tCO_2 yr^{-1}	Tonnes of CO_2 per year

16.1 STATEMENT OF COMPETENCE

16.1.1 This Environmental Impact Assessment Report (EIAR) chapter has been prepared by a suitably qualified and experienced Principal Consultant following a scoping process culminating in a scoping report[1] (see Technical Appendix 1.1 of this EIAR) which was issued on 13 August 2021. All data were collected by suitably qualified and experienced surveyors.

16.1.2 The author of the carbon balance assessments has over 10 years of experience in undertaking carbon balance assessments and has been involved in Scottish Government and Scottish Environment Protection Agency (SEPA) workshops relating to the development of the online tool. The author is a Principal Consultant in the renewable sector with over 12 years' experience. During this time, she has been involved with the co-ordination and production of scoping reports, environmental impact assessment reports, as well as client and consultee liaison and has authored several carbon balance assessments.

16.1.3 The author was assisted by an Assistant Project Manager who has been working as a consultant in the renewable development sector for over a year and a half.

16.2 INTRODUCTION

16.2.1 This chapter of the EIAR evaluates the effects of the Proposed Windy Standard I Repower (the Proposed Development) on climate change via carbon balance assessment.

16.2.2 This chapter of the EIAR is supported by the following Technical Appendix provided in Volume 4 Technical Appendices:

- 16.1: Carbon Balance Assessment Input Data.

16.2.3 This chapter includes the following elements:

- Statement of Competence;
- Legislation, Policy and Guidance;
- Scoping Responses and Consultations;
- Climate Change Impacts;
- Effects of Future Climate Change; and
- Carbon Balance Assessment.

16.3 LEGISLATION, POLICY AND GUIDANCE

16.3.1 Scotland has legislated to achieve net-zero carbon emissions. In October 2019, The Climate Change (Emissions Reduction Targets) (Scotland) Bill received Royal Assent. The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 builds on a number of energy policy documents that recognise the Scottish Governments commitment to tackling climate change and promoting the growth of renewable energy.

16.3.2 Carbon balance assessments are undertaken to support the requirements within the EIA Regulations within Scotland which transpose the EIA Directive into law stating broadly that the following should be included within environmental statements/environmental impact assessment reports;

"*…A description of the likely significant effects of the project on the environment resulting from, inter alia …*

The impact of the project on climate (for example the nature and magnitude of greenhouse gas)emissions) and the vulnerability of the project to climate change…"

[1] Windy Standard 1 Repowering Scoping Report. Natural Power (2021). Document ref: 1253057-1-A

16.3.3 In the UK, Scotland is at the forefront in terms of providing a guidance framework through which the impact of development upon peatlands can be minimised. The carbon balance assessment reveals the likely nature and magnitude of greenhouse gas (GHG) emissions resulting from proposed wind developments through employing the Scottish Government's Carbon Calculator Tool [2], which is currently the best method to date to undertake this kind of assessment and is endorsed by SEPA and the Scottish Government.

16.3.4 The carbon balance assessment has been undertaken in accordance with guidance[3] 'Calculating Carbon Losses & Savings from Wind Farms on Scottish Peatlands – Technical Note 2.10.0'[4]. As well as Technical Note 2.10.0, this report has been produced giving consideration to the following guidance documents:

- D.R. Nayak *et al.* Calculating Carbon Budgets of Wind Farms in Scottish Peatlands (May 2010);
- Calculating carbon savings from wind farms on Scottish peat lands - A New Approach by Nayak *et al.,* 2010;
- Smith *et al.* Carbon Implications of Windfarms Located On Peatlands – Update Of The Scottish Government Carbon Calculator Tool (2011);
- Scottish Natural Heritage (SNH) (now NatureScot): Carbon rich soil, deep peat and priority peatland habitats map (2016);
- NaturScot (2020) Advising on carbon-rich soils, deep peat and priority peatland habitat in development management[5].
- CCW Guidance Note: Assessing the impact of windfarm developments on peatlands in Wales (Jan 2010);
- Natural England Commissioned Report: Investigating the impacts of windfarm development on peatlands in England (Jan 2010);
- Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste. Scottish Renewables (2014);and
- Scottish Government, SNH and SEPA - Peatland Survey - Guidance on Developments on Peatland – 2017.

16.3.5 In addition, advice from the authors of the carbon calculator tool sought for previous assessments has been employed, and the completion of the carbon balance assessments for the Proposed Development has required input from hydrology, peat, ecology and site investigation specialists.

16.4 SCOPING RESPONSES AND CONSULTATIONS

16.4.1 Consultation for this EIA Report topic was undertaken with the organisations shown in Table 16.1.

Table 16.1: Consultation responses

Consultee	Type and Date	Summary of Consultation Response	Response to Consultee
Scottish Environmental Protection Agency (SEPA)	Scoping Response 04 August 2021	We welcome the initial information to demonstrate the project will be designed to avoid development on deep peat (Figure 14.1: Interpolated Peat Depth). We recommend the proposed Phase 2 peat surveys further inform site design to minimise impacts on peat (particularly around Turbine 1 and 2 which are in proximity of greater depths that the other wind turbines). It is our preference that the developer utilises existing infrastructure (e.g. existing access roads) as far as possible. We therefore welcome the commitment to do this. Scottish Planning Policy states (Paragraph 205) that "*Where peat and other carbon rich soils are present, applicants must assess the likely effects of development on carbon dioxide (CO_2) emissions. Where peatland is drained or otherwise disturbed, there is liable to be a release of CO2 to the atmosphere. Developments must aim to minimise this release*."	Chapter 10: Hydrology of the EIAR, Subsection 10.7 details the peat and soil depth surveys results (Phase 1 and Phase 2) and the depths measured at the proposed infrastructure locations. Furthermore, focussed peat probing was carried out in some identified areas (including near T1 and T2) due to the proximity to depths greater than 0.5 m identified through the 100 m grid probing. This additional phase 2 peat depth surveying was undertaken at T1, T2 and selected infrastructure, using a 10 m by 10 m grid, to confirm placement or repowering infrastructure had avoided areas of peat. Chapter 5: Project Description details the infrastructure re-use and Chapter 4: Site Design and Design Evolution further describes how the design evolved to utilise as much infrastructure as possible and to minimise the use of any virgin land/ground.
NatureScot	Scoping Response 08 December 2021	Encourage an Outline Habitat Management Plan (outline HMP) be submitted with the EIA that includes restoration of wet and dry modified bog habitat.	Due to the low quality of habitats present, with only a thin layer of peat and limited amount of blocked ditches, there are limited opportunities for active management work such as ditch blocking within the Proposed Development Area. Suitable offsite projects for bog restoration are being identified in discussion with the client and suitable local parties in order to develop a HMP in offsite locations which will provide a more significant positive impact to the local environment that would be possible on the limited

[2] Available online from: https://informatics.sepa.org.uk/CarbonCalculator/index.jsp (last accessed 13/05/2022)

[3] Available online from: http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCguidance2-10-0 (accessed 19/04/2022)

[4] Available online from: https://www.gov.scot/publications/calculating-carbon-savings-wind-farms-scottish-peat-lands-new-approach/pages/13/ (accessed 19/04/2022)

[5] Available online from: https://www.nature.scot/doc/advising-carbon-rich-soils-deep-peat-and-priority-peatland-habitat-development-management (last accessed 19/04/2022)

Consultee	Type and Date	Summary of Consultation Response	Response to Consultee
			features present within the Proposed Development Area.
Marine Scotland	Scoping Response 16 December 2021	Marine Scotland concur with the advice provided by SEPA in relation to the use of existing infrastructure, appropriate hydrological buffer zones, and micro siting to avoid sensitive locations including watercourses and greater peat depths.	Chapter 10: Hydrology of the EIAR Subsection 10.11 presents the mitigation through design which details the distances between the hydrological features and proposed infrastructure. Chapter 10: Hydrology Subsection 10.7 details the peat and soil depth surveys results (Phase 1 and Phase 2) and the depths measured at proposed infrastructure locations.

16.5 CLIMATE CHANGE IMPACTS

16.5.1 The most relevant climate change impacts are considered through the assessment of the likely magnitude of GHG emissions resulting from proposed wind developments in comparison to the baseline scenario with no development (where no emissions are produced as no construction takes place).

16.5.2 Current best practice and advice from consultees (Table 16.1) includes undertaking carbon balance assessments to assess effects with reference to the magnitude of carbon emissions released from peat by the construction of proposed wind developments on upland peat and the period of time it takes to payback those carbon emissions.

16.5.3 The carbon balance assessment employs the Scottish Government's Carbon Calculator Tool[6] and quantifies the CO_2 emissions savings over the life of the Proposed Development against the release of Carbon Dioxide (CO_2) from other energy generation methods as a result of implementing the project. It also reports on the time it takes to pay back any carbon debt and the potential effects of the Proposed Development on climate change in terms of carbon savings produced.

16.6 EFFECTS OF FUTURE CLIMATE CHANGE

16.6.1 The potential for environmental receptors to be impacted by the Development is assessed in Chapters 6-15 of this EIAR. Of these, ornithological, ecological and hydrological receptors are the most sensitive to climate change and are discussed further in Table 16.2:

Table 16.2: Climate change effects on environmental receptors

EIAR Report Baseline	Receptor	Climate Change Effect	Effect on Receptor
Chapter 8	Ornithology	Temperature – up to + 2ºC Shift to wetter winters and dryer summers.	A rise in temperature has the potential to impact on habitats which in turn may affect the behaviour of bird interests. Uncertainties are high and the type and significance of effects identified from
		Negligible change in wind speeds.	the Development are not anticipated to alter as a result.
Chapter 9	Ecology – Habitats, Protected Species	Temperature – up to + 2ºC Shift to wetter winters and dryer summers. Negligible change in wind speeds	While changes in temperature could affect the composition and growth rates of plant communities and invertebrates, and hence protected species and habitats, the uncertainties are high and it is not clear that the effect of the Development on those receptors would alter substantially as a result.
Chapter 10	Geology, Hydrology and Hydrogeology	Shift to wetter winters and dryer summers.	Limited change to future baseline and to the identified effects of the Development.

16.6.2 Given the relatively limited magnitude of change in climate parameters predicted over the operation of the Proposed Development, negligible changes to the baseline for environmental receptors are anticipated during this period. This is incorporated into the assessments undertaken in other chapters of this EIAR.

16.6.3 In terms of the potential effects of climate change on the Proposed Development to ensure adequate resilience of the project to climate change, it is considered that many of the key climate trends[7] such as increased temperature, changes in rainfall and sea level rise will not affect the Proposed Development due to its location and high elevation. And during severe windstorms, turbines engage installed braking mechanisms to shut turbines down.

16.7 CARBON BALANCE ASSESSMENT

16.7.1 This section describes the climate impact assessment undertaken for the Proposed Development which consists of 8 turbines and ancillary infrastructure.

16.7.2 This assessment is informed by baseline data collected for the hydrology, forestry and ecology disciplines. The assessment should be read in conjunction with the Geology, Hydrology and Hydrogeology (Chapter 10), Ecology (Chapter 9), and Project Description (Chapter 5) chapters and relevant appendices of the EIAR which describe the Proposed Development in more detail and provide important information on the peat resource within the area.

Scope

16.7.3 Version V1.6.1 of the carbon calculator is currently the latest version of the online tool available (as of 13 May 2022). The inputs from the online carbon calculator tool are presented in Appendix 16.1 of this report (Reference: PDB9-R1U1-OZNO v6). As the online tool does not allow any amendments to functionality and cannot be changed, the carbon balance assessment was undertaken subject to the specifications that the tool dictates. The tool does not currently allow users to describe the sources of the input data or the detailed information that is inserted to conduct the analysis. Therefore, Table 16.3 presents this source information for the assessment. The data and infrastructure dimensions used have been based on the best data available at the time and, in cases where infrastructure design or construction methods were not yet clear, the worse-case values were used to ensure that the assessment presented a worse-case scenario in any areas of uncertainty. This carbon balance assessment is based on the data and infrastructure dimensions that reflect the final design of the Proposed Development, as far as is possible, as provided by Fred. Olsen Renewables Ltd (FORL, the Applicant). Some of the infrastructure dimensions may vary slightly to those presented in Chapter 5: Project Description as dimensions also include working and disturbance areas.

[6] Available online from: https://www.gov.scot/publications/carbon-calculator-for-wind-farms-on-scottish-peatlands-factsheet/ (last accessed 13/05/2022)

[7] Available online from: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index (last accessed 13/05/2022)

16.7.4 This assessment has focussed on the potential impacts on peat resulting from the construction of new or upgraded infrastructure that will be located only on areas of the site that have not already undergone development or disturbance due to previous development. As a repowering, much existing infrastructure is present on site and in areas where previous development has taken place, it has been assumed that additional impacts from the repowering will be negligible. Accordingly, this assessment does not include assessment for the two proposed laydown and storage areas, two of the borrow pit search areas, the batching plant location, the existing grid connections/substations and the existing tracks not being upgraded (as shown in Figure 1.3 in Volume 3, of the EIAR). This approach has been undertaken because these infrastructures are either already built (for previous Windy Standard projects) or are located on land that has already been subject to previous development such as laydown areas, borrow pits or construction compounds. In these areas, site investigation and aerial imagery shows that these locations are bare ground or already covered with gravel/hardcore. All other infrastructure that is located, or part located, on land that has *not* undergone previous development (considered to be virgin ground) has been included in the assessment.

16.7.5 As well as use of recent peat depth survey data collected, this assessment has also cross-referenced and employed historical peat depth data collected for previous developments at Windy Standard where appropriate to do so. Historical peat depth data has not been employed for those infrastructure areas that have already undergone development and/or where new peat data is not possible to collect due to the ground conditions. However, some historical data has been used to inform this assessment in areas that have not been compromised by subsequent development. Therefore, the assessment has used a robust and comprehensive peat depth dataset that was collected in accordance with consultation advice and design work for the Proposed Development and which provides a fair representation of peat depths across the site as well as under the final layout infrastructure, as described in Chapter 10: Hydrology, Geology and Hydrogeology.

Table 16.3: Record of data sources

Input	Source of Information
Turbine capacity and lifespan	**FORL:** Vestas V162 (indicative): 8 turbines each with a rated output of up to 6.2 mega watts (MW). Fixed life-span is expected to be up to 35 years.
Capacity factor	BEIS Scottish onshore wind average of 2017-2021 data with minimum and maximum average annual values across this period (Energy Trends March 2022, Table 6.1 Renewable electricity capacity and generation, Scotland Qtr dataset). Load factor statistics obtained from https://www.gov.uk/government/statistics/energy-trends-section-6-renewables (accessed on 19/04/2022). **It is important to note that the capacity factors used here will not typically reflect the final capacity factor of the Proposed Development and are much lower than energy yield assessments for this Proposed Development and candidate turbines indicate. The actual capacity factor would be anticipated to be greater, as modern turbines are more efficient and taller than many of the older turbines on operational wind farms where the BEIS data is derived from.**
Fraction of output to backup	The extra capacity that would be needed for back-up power generation is currently estimated at 5 % of the rated capacity of wind plant as UK wind power regularly contributes more than 20 % of demand (this includes offshore and onshore wind)[8].
Type of peatland	**Ecology Department, Natural Power Consultants Ltd.** In the tool, the choice of peatland habitats is limited to acid bog or fen. In this case, acid bog was selected as no other relevant option is available. Habitat surveys in 2019 and 2020 identified similar habitats to those previously noted as being present at the Proposed Development and in the wider Windy Standard Complex. Unimproved acid grassland is the main habitat found in the open areas around the turbines of the operational Windy Standard I Wind Farm. There are patches of mire habitat such as marshy grassland however, these are in small patches along seepage lines and shallow gullies cutting down the hill sides and smaller patches of wet modified bog in damp hollows near the highest elevations of the site. As described in Chapter 10: Hydrology, Geology and Hydrogeology, according to the National Soil Map of Scotland[9] (shown in Figure 10.2 found in Volume 3) soil types expected within the Proposed Development Area includes peat, peaty gleys, mineral gleys, peaty podzols, and mineral podzols. Peat is typically found at the lower elevations around the Water of Deugh. Within the Proposed Development Area, the Scotland's Carbon and Peatland Map (2016)[10] shows that the majority of the site is of Class 5 (indicative peat soil – no peatland vegetation) with smaller areas of Class 3 (occasional peatland habitats found) and mineral soils. There are two small pockets of Class 1 priority peatland habitat (Figure 10.3).
Average air temp. at site	Site specific temperature based on 29 years (1991-2020) data collected from the closest **Met Office** weather station to the Proposed Development. The Saughall Climate Station is positioned approximately 34 km north of the Proposed Development. The expected value is the average annual temperature over the data collection period. The minimum value is the minimum average annual temperature and maximum value is the maximum average annual temperature. https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcuurcfer (accessed 19/04/2022).
Average depth of peat on site	**Hydrology Department, Natural Power Consultants Ltd.** Informed by peat probe data collection illustrated in the interpolated peat depth map in Figure 10.4 (found in Volume 3). The average of all the peat probe data collected across the site during Phase 1 surveys in April and May 2020, total number of probes for Phase 1 was 398. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from the Phase 1 data to represent peat depths across the site as the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95 % confidence intervals of the sample data collected.
C content of dry peat	As described in Chapter 10, owing to the lack of peat, cores were unable to be collected at the areas highlighted through scoping as requiring further investigation, specifically T1 and T2. This was due to these locations featuring peat depths below 0.5 m and is therefore, as previously mentioned, classified as peat soils rather than peat. Accordingly, for the purposes of this assessment, the generic values provided within the online tool have been employed. **It is important to note that these generic values will not reflect accurately the carbon characteristics of the soils across the site (generic values are more representative of actual peatland) and are employed to represent a worst-case scenario.**
Extent of drainage	**Hydrology Department, Natural Power Consultants Ltd.**

[8] Available online from: https://www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021 (last accessed 19/04/2022)

[9] National Soil Map of Scotland, available online: http://map.environment.gov.scot/Soil_maps/?layer=1 (accessed 13/05/2022)

[10] Available online from: https://map.environment.gov.scot/Soil_maps/?layer=10 (accessed 13/05/2022)

Input	Source of Information
	Based on site observation, literature review and previous experience on similar sites. Given the soils on site, not much water is stored within the soil.
Average water table depth	**Hydrology Department, Natural Power Consultants Ltd.** Based on water table depth observations across the site during site visits, literature review and previous experience on similar sites. As described within Chapter 10, the site consists of groundwater flowing from high to low elevation, where the hilltops are outcrops and water is percolating down rather than being stored in the thin superficial deposits resulting in low water table depths.
Dry soil bulk density	As described in Chapter 10, owing to the lack of peat, cores were unable to be collected at the areas highlighted through scoping as requiring further investigation, specifically T1 and T2. This was due to these locations featuring peat depths below 0.5 m and is therefore, as previously mentioned, classified as peat soils. Accordingly, for the purposes of this assessment, the generic values provided within the online tool have been employed. **It is important to note that these generic values will not reflect accurately the carbon characteristics of the soils across the site (generic values are more representative of actual peatland) and are employed to represent a worst-case scenario.**
Time for regeneration of bog plants	**Ecology Department, Natural Power Consultants Ltd.** The time period for successful regeneration of bog plant species is dependent on numerous factors including relevant seed source, successional rate, the level of herbivore disturbance and the successful stabilisation of the water table in a restoration area. This parameter has been estimated to be 7 years (5 years minimum and 10 years maximum). As little peat exists under any infrastructure of the Proposed Development, the values provided are based on the dominant habitats on site (very limited bog plants and more dominant acid grasslands), professional experience of project ecologists and the quality of the existing vegetation. Opportunities for habitat management and potential bog restoration have been investigated and are presented in Chapter 9: Ecology of the EIAR. To present a worst-case scenario for this assessment, it is assumed that no restoration measures will take place.
Carbon accumulation due to C fixation by bog plants	Values have been inserted from the online tool notes that quote published primary literature and NatureScot guidance values. **It is important to note that these generic values will not reflect accurately the carbon accumulation by bog plants on the site and are employed to represent a worst-case.**
Coal-fired emission factor	Fixed value of the carbon calculator tool.
Grid mix emission factor	Fixed value of the carbon calculator tool.
Fossil fuel mix emission factor	Fixed value of the carbon calculator tool.
No. of borrow pits and dimensions	Although five borrow pit search areas are proposed, this assessment considers only the three borrow pit areas that are located on areas that have not already been developed. The expected scenario represents the average area across the three borrow pits. The maximum scenario represents the expected scenario allowing for any additional working areas and the minimum scenario is based on the preliminary design indications that there may be enough material won from the hardstandings and track upgrades on site to not warrant the requirement for the proposed borrow pits. Borrow pits are primarily located on acid grassland but dimensions have been included to represent a worst-case scenario.
Average depths of peat removed from infrastructure	**Hydrology Department, Natural Power Consultants Ltd.** Informed by Phase 1 peat probe data collected in April and May 2020 and the subsequent targeted Phase 2 data collected 2022. In addition, this assessment has also cross-referenced and employed historical peat depth data collected for previous developments at Windy Standard where appropriate to do so. Historical peat depth data has not been employed for those infrastructure areas that have undergone previous development as new peat data is not possible to collect due to the ground conditions (these areas are assumed to not be located on peat). However, some historical data has been used to inform this assessment in areas that have not been compromised by subsequent development. Peat depth values are derived from interrogation of the peat depth data collected across the site and underlying each type of infrastructure including a 100 m micrositing allowance for turbines and hardstandings. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95 % confidence intervals of the sample data collected.
No. of foundations/ hardstandings and dimensions	**FORL and Natural Power Consultants Ltd.:** The expected values are based on gravity foundations to be conservative however, further site investigations may indicate that rock anchor foundations are viable (as these were what was used for some of the previous turbines).Therefore, expected and maximum values are based on use of gravity foundations and the minimum scenario is based on rock anchor foundations. Similarly, dimensions for hardstandings consider the permanent crane hardstanding area and include the temporary hardstanding blade /laydown areas around the turbines.
Volume of concrete	**FORL and Natural Power Consultants Ltd.:** Volumes inserted into the detailed construction input page provide allowance for transformer elements if they are external to the turbine on the turbine foundation.
Total length of track	**FORL and Natural Power Consultants Ltd.:** 27,800 m of total track includes the new tracks (4,900 m) and upgraded tracks (2,200 m) on site, the length of existing track from the car park to the wind farm area (14,200 m) as well as 6,500 m existing track used to access the grid connection points (see Figure 1.3). The length of existing tracks from the car park to the wind farm area and to the grid connections will only require minor works to the running surfaces and minor local adjustments. The Proposed Development site layout in the wind farm area has primarily employed existing tracks on site. However in order to be precautionary, the length (4,900 m) of existing tracks requiring widening and cut/fill to change the level of the track (such that the existing track will need to be widened and possibly replaced or removed completely), has been entered into the tool as 'new' track. The length (2,200 m) of

Input	Source of Information
	existing tracks that only require minimal level change and some widening has been considered as 'upgraded' tracks.
Length of floating roads	**FORL and Natural Power Consultants Ltd.:** No floating roads are proposed.
Excavated road length	**FORL and Natural Power Consultants Ltd.:** As the tool does not allow specific inputs for upgraded tracks, this value includes the 4,900 m of proposed 'new' track as well as the 2,200 m of tracks to be 'upgraded' and the values for excavated road widths and peat depths for both are weighted according to the different lengths for new and upgraded tracks.
Excavated road width	**FORL and Natural Power Consultants Ltd.:** See Paragraph 16.7.28 which shows the calculation for weighted road width which takes into account new access tracks and upgrading of existing access tracks.
Average peat depths for excavated roads	**Hydrology Department, Natural Power Consultants Ltd.** Informed by Phase 1 peat probe data collected in April and May 2020 and the targeted Phase 2 data collected in 2022. In addition, this assessment has also cross-referenced and employed historical peat depth data collected for previous developments at Windy Standard where appropriate to do so. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95% confidence intervals of the sample data collected. See also Paragraph 16.7.28 which shows the calculation for weighted road peat depth which takes into account new access tracks and upgrading of existing access tracks.
Length of rock filled roads	**FORL:** There will be no rock filled roads.
Length of cable trenches	**FORL and Natural Power Consultants Ltd.:** It is assumed that all cables will follow tracks and an allowance for cable trenches has been made when calculating excavated and upgraded road widths.
Additional peat excavated	**FORL and Natural Power Consultants Ltd.:** An expected volume of 4,011 m^3 of additional peat will be excavated. This input accounts for both construction compounds which are located on acid grassland and in part, woodland. Not all infrastructure is located on peat however all additional infrastructure that is not located on already developed ground has been included in the tool to represent a worst-case scenario. Calculations are shown in Table 16.4 of this chapter.
Area of improvement of felled plantation land	**DGA**: Chapter 11 Forestry reports that a total of 18.5 ha will be felled for the Proposed Development. However, 11 ha of this felled area will be re-stocked and 7.5 ha will undergo compensatory planting. Therefore, in accordance with the carbon balance guidance, no value has been inserted into the tool for felling as all woodland will be replaced through restocking or compensatory planting.
Area of degraded bog to be improved	**Ecology Department. Natural Power Consultants Ltd.** Opportunities for habitat management and potential peat restoration have been investigated and are reported in in Chapter 9 Ecology of the EIAR. To present a worse-case scenario for this assessment however, it is assumed that no peat restoration/improvement of degraded bog will take place.
Area of borrow pits to be restored	**FORL and Natural Power Consultants Ltd.:** As the borrow pits are not located on peat habitats, inputs for peat restoration have not been included to represent the worst-case scenario.
Water table depth around foundations and hardstandings before and after restoration	**Hydrology Department. Natural Power Consultants Ltd.** The 'before restoration' water table depth is based on the scenario whereby drainage is not removed but left in situ. It assumes that the drainage left in place would cause some draw down on the existing water table. The 'after restoration' water depths are based on backfilling of the drainage which would bring the water table depth back up to previous levels before construction.
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	**Hydrology Department., Natural Power Consultants Ltd.** Values of 2, 1 and 5 years used. Based on professional judgement.
Will the hydrology of the site be restored on decommissioning?	**Hydrology Department. Natural Power Consultants Ltd.** Yes. Upon the decommissioning of the wind farm, best practice principles will be adopted.
Will the habitat of the site be restored on decommissioning?	**Ecology Department. Natural Power Consultants Ltd.** No. At the moment it is assumed that upon decommissioning, restoration of habitats will not be undertaken. There are no plans to control grazing or to reintroduce species using nurse crops or fertilisation, therefore a worst-case scenario of "no restoration" has been inputted into the carbon calculator tool.

16.7.6 The following paragraphs report on the results of the carbon calculator calculations that are present within the online tool. For clarification of the calculations, the reader will need to view the online submission (Reference: PDB9-R1U1-OZNO v6).

Wind Farm CO_2 Emission Savings

16.7.7 The amount of CO_2 emissions produced during energy production varies with the type of fuel used; therefore, the potential CO_2 savings from the Proposed Development depends on the type of fuel it replaces. The wind farm CO_2 emission savings over other types of generation (i.e. coal-fired, grid-mix, fossil fuel-mix) is calculated by multiplying the energy output of the Proposed Development by the emissions factor of the other type of generation.

16.7.8 Based on an averaged 6.2 MW turbine model scenario, the expected potential annual energy output of the Proposed Development is 112,969 MWh yr^{-1} (3,953,914 MWh over 35 years), with minimum and maximum potential outputs at 100,499 MWh yr^{-1} and 117,314 MWh yr^{-1}.

16.7.9 Based on the expected annual energy output of the Proposed Development (112,969 MWh yr^{-1}), the potential expected emissions saved over coal-fired electricity generation is 103,931 tonnes of CO_2 per year (tCO_2 yr^{-1}); and over grid-mix generation is 28,647 tCO_2 yr^{-1} and over fossil fuel-mix generation is 50,836 tCO_2 yr^{-1}.

Emissions due to Turbine Life

16.7.10 Energy is consumed and associated CO_2 emissions are released during manufacture of turbine components, site construction (including site tracks and turbine foundations etc.), and during decommissioning of a development.

16.7.11 The carbon calculator includes a module for assessing the carbon emissions due to turbine life. Nayak *et al*. (2010) explain that the turbine life calculation within the carbon calculator is based on generic data as it does not accommodate a site-specific full life-cycle analysis. Therefore, the turbine life emissions for the Proposed Development are estimated utilising an equation for ≥1 MW turbines that has been derived from data from numerous European sites, and which shows a significant relationship across the European sites examined.

16.7.12 The carbon calculator reveals an expected emissions figure of 43,265 tonnes of CO_2 (tCO_2) equivalent (equiv.) emitted due to the manufacture, construction and decommissioning of the turbines. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for turbine life is expected to take approximately 10 months.

Capacity Required due to Back Up

16.7.13 In order to maintain security of energy supply, a second-by-second balance between generation and demand must be maintained by the grid operators. It has been noted that the inherent variable nature of wind energy may affect this balance and therefore, a certain proportion of power is required to stabilise the supply to the customer. The electricity system, however, is designed and operated in such a way as to cope with large and small fluctuations in supply and demand. No power station is totally reliable, and demand, although predictable to a degree, is also uncertain. Therefore, the system operator establishes reserves that provide a capability to achieve balance, given the statistics of variations expected over different timescales. The variability of wind generation is but one component of the generation and demand variations that are considered when setting reserve levels.

16.7.14 It should also be noted that an individual wind turbine will generally generate electricity for 70-85 % of the time, and its electricity output can vary between zero and full output in accordance with the wind speed. However, the combined output of the UK's entire wind power portfolio shows less variability, given the differences in wind speeds over the country as a whole. Whilst the amount of UK wind generation varies, it rarely, if ever, goes completely to zero, nor to full output at the same time throughout the UK.

16.7.15 The extra capacity that would be needed for back-up power generation is currently estimated to be approximately 5 % of the rated capacity of the wind plant as UK wind power contributes more than 20 % to the National Grid. The carbon calculator assumes that all back-up power generation will be via fossil fuels or grid-mix which does not account for any back-up energy generation from renewable sources directly or from renewable energy that has been stored in batteries. As such, the emissions figure required from back-up power generation for the Proposed Development is considered to be conservative as the calculator assumes a very worst-case scenario.

16.7.16 The carbon calculator assumes that backup is provided by a fossil fuel mix of energy generation and reveals an expected emissions figure of 34,217 tCO_2 equiv. due to the back-up. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for back-up is expected to take approximately eight months.

Loss of Carbon Fixing Potential

16.7.17 Construction of the Proposed Development will involve the installation of infrastructure such as turbine foundations, access tracks and hardstandings etc. Where vegetation and/or peat is removed or covered, the vegetation will no longer be able to photosynthesise and therefore, its ability to fix carbon will be lost. In addition, changes to drainage can have an effect on the vegetation of peatlands. Accordingly, the carbon calculator assumes that the carbon-fixing potential is lost from both the area occupied by infrastructure as well as working areas used to install the infrastructure and areas affected by drainage. In the tool, the Proposed Development's impact on carbon fixing potential through drainage around infrastructure is given as 3.5 m expected and 2 m and 5 m as minimum and maximum values respectively. These values are considered to be reasonable as there is little peat present where infrastructure is located and little water held in the superficial soils (Table 16.3).

16.7.18 The carbon calculator also assumes that the footprint of the wind farm has 100 % coverage of bog plants that are still accumulating carbon for those areas where vegetation is either removed during construction or compromised due to disturbance or drainage. This assumption is considered to be very much a worst-case scenario as 100 % bog habitat cover is not an accurate representation of the site's total habitat characteristics.

16.7.19 Habitat loss calculations for the Proposed Development's infrastructure have been calculated and are discussed in Chapter 9 (Table 9.10) of the EIAR. The habitat surveys (Figure 9.4 in Volume 3 of the EIAR) reveal that the Proposed Development Area is largely comprised of acid grassland, woodland and areas of bare ground. Other habitats include areas of heath/acid grassland mosaic, marshy grassland and smaller areas of wet modified bog in damp hollows.

16.7.20 Of those habitats, peat habitat types (i.e. bog and wet modified bog habitats and assuming some potential mire within marshy grassland) represent approximately 24 hectares (ha) of the *c*.625 ha of habitat types recorded across the area surveyed. However, in the worst case assuming marshy grassland does include mire habitats, only a small area of these peat habitats will be directly impacted by preparation and construction activities; with permanent loss confined to only *c*.0.04 ha (0.2 %) of the total 24 ha recorded. Chapter 9 also explains that wet modified bog (8.55 ha) is a common and widespread habitat in south-west Scotland and is found to be rarely pristine when found in the agricultural plantation forestry setting. The heavy modification due to drainage and shading on site means that this habitat is unlikely to be important at a greater than local scale.

16.7.21 In accordance with the carbon calculator's methodology, the total emissions from loss of CO_2 fixing potential is based on the footprint area of the Proposed Development, plus the expected area affected by drainage which is based on the 3.5 m expected extent of drainage and assumes 100 % bog/mire habitat cover of the footprint and drainage area. As such, Sheet 4 of the online tool assumes that approximately 27 hectares of bog plants will be lost compared to the *c*.0.04 ha footprint of direct impact to habitats (including marshy grassland ad wet modified bog) identified through site specific survey work.

16.7.22 Therefore, it is considered that the carbon calculator's assumption that 100 % of the land lost through construction or drainage of the Proposed Development is covered in bog plants or peatland vegetation is considered to be highly precautionary in this instance as many other types of habitat exist.

16.7.23 The carbon calculator reveals that the expected total emissions attributable to the loss of carbon accumulation by bog plants is equivalent to 1,014 t CO_2 equiv. over the operational period of the wind farm. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for loss of carbon fixing potential is expected to be less than 1 month. However, as previously described above, it is important to recognise that 100 % bog/mire habitat cover is not an accurate description of the site's characteristics so the payback period is likely to be significantly shorter in reality.

Loss of Carbon Dioxide from Removed Peat (Direct Loss)

16.7.24 The 2017 Peatland Survey Guidance states that peat is defined as the partially decomposed remains of plants and soil organisms which have accumulated at the surface of the soil profile. Peat accumulates where the rate of input of organic material from the surface exceeds the rate of decomposition and 'turn-over' of this new material. A peat layer does not include a mineral fraction (hence being differentiated from topsoil).

16.7.25 Peat deposits are made up on an organic soil which contains more than 60 % of organic matter and exceeds 50 cm in thickness. The peat depth data at the Proposed Development are taken from over 622 peat depth measurements collected across the Proposed Development. As advised by the authors of the tool, the arithmetic mean was calculated from this data to represent the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95 % confidence intervals of the sample data collected. Peat depths of less than 0.5 m are categorised as peat soils with peat deposits being >0.5 m in depth (JNCC, 2011[11]; Scottish Government *et al.,* 2017[12]).

[11] JNCC Report 445 (2011), Towards an assessment of the state of UK Peatlands.

[12] Scottish Government, NatureScot, SEPA (2017) Guidance on Developments on Peatland – Peatland Survey.

16.7.26 Peat survey methodology was conducted in accordance with the guidance documentation 'Guidance on Developments on Peatland – Peatland Surveys 2017'[7]. The interpolated peat depths are illustrated in Figure 10.4 in Volume 3 of the EIAR. The peat depth results show that the highest proportion of recorded peat depths were ≤0.5 m (74.2 %) and only 25.8 % were >0.5 m. Infrastructure elements for the Proposed Development have largely been placed on areas where mean soil depths are noted to be less than 0.5 m (Chapter 10, Table 10.9 and Figure 10.4). Accordingly, the requirement for a standalone peat management plan to be undertaken has been scoped out in Chapter 10 of the EIAR.

16.7.27 As stated in Table 16.1, it was not possible to obtain site-specific information relating to the characteristics of the peat/soils on site as owing to the lack of peat, cores were unable to be collected at the areas highlighted through scoping as requiring further investigation, specifically T1 and T2. This was due to these locations featuring peat depths below 0.5 m. Accordingly, for the purposes of this assessment, the generic values provided within the online tool have been employed. It is important to note that these generic values will not reflect accurately the carbon characteristics of the soils across the site (generic values are more representative of actual peatland) and are employed to represent a worst-case scenario.

16.7.28 The excavated volumes calculated and reported within the assessment accommodate realistic working and cut and fill areas with the assumption built into the model that all peat/habitat in working areas or excavation areas is lost. Within this assessment, in order to represent a worst-case scenario the following working areas and assumptions have been incorporated into the analysis:

- The carbon calculator does not accommodate inputs for upgrading tracks and only allows inputs for new excavated tracks. However, under advice provided by the authors of the calculator, instead of simply reporting the length and width of new tracks (excavated tracks), the widening/upgrading of existing access tracks has been accounted for in this assessment by calculating the weighted average width of tracks along the total length of new and upgraded tracks. The same approach has been applied for calculating the weighted peat depths for access tracks.

  For example, the calculations for expected weighted track widths were as follows:

  [4,900 m (expected length of new track) x 16 m (expected width)]

  + [2,200 m (expected length of upgraded track) x 10 m (expected width of upgrade)]

  = 100,400 m^2

  Then; 100,400 m^2 / 7,100 (total expected length of tracks) = 14.14 m expected weighted average width.

  The calculations for expected weighted peat depths were as follows:

  [4,900 m (expected length of new track) x 0.34 m (expected average peat depth)]

  + [2,200 m (expected length of upgraded track) x 0.34 m (expected average depth for upgraded tracks)

  = 2,414 m^2

  Then; 2,414 m^2 / 7,100 (expected total length of tracks) = 0.34 m expected weighted average peat depth.
- An expected value for excavated new roads width of 16 m is based on 6 m running width (as described in Chapter 5: Project Description), 3 m drainage/cable trench on one side and then 7 m allowance for cut/fill working areas. In some areas, cut/fill working areas may be narrower or wider therefore, the minimum and maximum values of 15 m and 21 m have been provided respectively.
- An expected value for upgrades to existing tracks of 10 m is based on an increase by 2 m in running width, 3 m drainage/cable trench on one side and then 5 m allowance for cut/fill working areas in the expected scenario (10 m), and then as cut/fill working areas may be narrower or wider, the minimum (7 m) and maximum (12 m) values have been provided.
- Working or cut/fill areas, excavation areas and batters have been included around turbine foundations and hardstandings and the detailed construction data has been used. The minimum values assume rock anchor foundations are employed with a 10 m diameter. The expected and maximum values assume use of a gravity foundation that has a considerably larger footprint. In most cases, the turbine foundation footprint and working areas will overlap with the tracks and hardstandings/working areas/laydown areas. As such, all dimensions included within this assessment for turbine foundations should be considered worst-case as there is a considerable element of double counting.
- Expected dimensions for hardstandings consider the permanent crane hardstanding area including the temporary hardstanding/blade laydown areas around the turbines, 1:2 batter slopes and an average of 1.5 m cut/fill area. The minimum and maximum values allow tolerance for smaller and larger cut/fill areas.

16.7.29 The working areas presented within this carbon balance assessment represent those areas where peat and/or peat vegetation may be removed or damaged/disturbed. As such, the peat volumes reported in the carbon balance assessment are considered to be highly precautionary and considered to be unrealistically worst-case. In fact, latest guidance[13] states that peat depth measurements of less than 0.5 m are not categorised as peat (rather peat soils), and peat deposits are considered being >0.5 m in depth.

16.7.30 The carbon calculator also requires information relating to other ancillary infrastructure not explicitly accounted for above, namely the two construction compounds. Other infrastructure such as the grid connections, laydown areas, batching plant, car park and gatehouse are not included as they are existing infrastructure or are not located on peat. Table 16.4 utilises the expected dimensions of the additional infrastructure and peat depths used to calculate the total area and total volume of excavations.

Table 16.4 Additional peat excavated calculations

Additional Peat Excavated			
	Expected	**Minimum**	**Maximum**
Construction Compounds (m^2)	21,112	15,000	26,912
Construction Compounds Average Peat Depth (m)	0.19	0.1	0.28
Total Area of Peat Removed (m^2)	21,112	15,000	26,912
Total Volume of Peat Removed (m^3)	4,011	1,500	7,535

16.7.31 The CO_2 release associated with the volume of peat excavated assumes a worst-case scenario that 100 % of the peat is lost. Sheet 5, Table 5a of the carbon calculator calculates the total expected area of land lost due to the wind farm construction as 19.6 ha (does not include drained peat areas) and expected volume of 'peat' removed over the footprint of the wind farm is expected to be 58,610 m^3. However, as previously described in paragraphs 16.7.19 to 16.7.21, only a small part of this area accommodates peat habitats that will be directly impacted by preparation and construction activities; with permanent loss confined to only *c.*0.04 ha in total, in the worst-case scenario. Therefore, it is considered that the carbon calculator's assumption that 58,610 m^3 of peat will be removed through construction of the Proposed Development is considered to be highly precautionary as many other types of habitats and soils exist within the wind farm construction area.

[13] Scottish Government, NaturScot, SEPA (2017) Peatland Survey. Guidance on Developments on Peatland, Available online from: Guidance+on+developments+on+peatland+-+peatland+survey+-+2017.pdf (www.gov.scot) (last accessed 13/05/2022)

16.7.32 Total volumes and areas have been stated within the results of the tool, and these values are not rounded which conveys a false accuracy and it should be borne in mind that these values are only highly indicative as not all of the volume and areas peat reported as removed will be peat habitat.

16.7.33 The total expected amount of CO_2 loss, attributable to peat removal only, (i.e. CO_2 emissions from peat that is excavated for the wind farm only, no impacts from drainage of peat) is 13,092 tCO_2 equiv. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for peat removal only is expected to be 3 months. However, as previously described above, it is important to recognise that 100 % bog/mire habitat cover is not an accurate description of the site's characteristics.

Loss of Carbon Dioxide from Drained Areas (Indirect Loss)

16.7.34 Carbon is also lost from peat habitats through drainage that occurs in the peat around the Proposed Development's infrastructure. The carbon calculator and associated guidance refers to this CO_2 loss as an "indirect loss". The extent of the site affected by drainage assumes an expected, minimum and maximum extent of drainage around each drainage feature e.g. turbine foundation, tracks etc. It is important to bear in mind that the extent of drainage is dependent on existing drainage conditions on site and also topography. The carbon calculator, however, assumes no existing drainage on site and flat terrain which is not representative of the actual site characteristics. Therefore, results using this parameter should only be considered as indicative at best.

16.7.35 Hydrological and site investigation specialists visually noted and recorded water table depths during surveys which informed the site design evolution. Extent of drainage is a reasonable estimation based on knowledge of the site (topography etc.), experience at similar sites and expert judgement. As such, a recommended average extent around the drainage feature of 3.5 m was considered as an appropriate expected average for the calculation. Values of 2 m and 5 m were inserted as inputs to represent best- and worst-case scenarios respectively (also see Table 16.3).

16.7.36 Sheet 5, Table 5 of the carbon calculator calculates the total expected CO_2 loss from drained peat as 0 tCO_2 equiv. This is likely because the site possesses little peat, low water table depths and little extents of drainage as water percolates down elevations on site rather than being stored in the soil. Accordingly, in Table 5d, the tool assumes that the emissions from drained and undrained peat have the same proportion over the emissions period and therefore the net emissions due to drainage from infrastructure installation is 0 tCO_2 equiv.

Loss of Carbon Dioxide from DOC and POC loss

16.7.37 Additional CO_2 emissions from organic matter can occur as carbon dioxide and methane, which can leach out of peat that is restored to conditions where the water table depth is higher after restoration than before restoration, and is a further consideration of the carbon calculator. Dissolved Organic Carbon (DOC) is defined as the organic matter that is able to pass through a filter (range in size generally between 0.7 and 0.22 µm). Conversely, Particulate Organic Carbon (POC) is the fraction of soil carbon that is larger in particle size. The assessment tool assumes that 100% of the losses due to leaching DOC and POC from restored drained and improved land are eventually lost as gaseous CO_2.

16.7.38 Only restored drained and improved land has been included in the calculations within the carbon calculator for DOC and POC, because if the land is not restored or improved, then the carbon loss has already been accounted for in the calculations for excavated and drained peat (i.e. the carbon assessment assumes that if land is not restored then 100 % of the carbon will be lost from the removed or drained volume of soil).

16.7.39 The tool calculates that there will be an expected 0 tCO_2 equiv. lost due to DOC and POC leaching over the operational life of the wind farm.

Total Loss of Carbon Dioxide from Impact on Peat

16.7.40 The following calculations on total loss of CO_2 from impacts on peat have been based on a number of key assumptions (some of which are built into the tool itself and cannot be changed), specifically in relation to peat, in order to demonstrate a worst-case (unrealistic) scenario using on-site data with input from ecology and hydrology specialists. In summary, these assumptions are:

- 100 % of the area potentially affected by the wind farm is covered in peat forming mire habitat;
- The terrain is relatively flat with no existing drainage;
- Infrastructure dimensions for foundations, tracks and hardstandings include working/laydown and cut/fill areas;
- 100 % of the carbon stored in the excavated peat will be lost as carbon dioxide and not reinstated on site;
- 3.5 m metre expected average extent of drainage to demonstrate a conservative expected scenario and 5 m worst-case scenario;
- The average extent of drainage assumes that the depth of peat affected by drainage is equal to the depth of peat removed;
- Emissions from drained and undrained land have the same proportion over the emissions period;
- The peat depth data used to inform the volumes of peat removed assume that all recorded depths are in peat; and
- The model assumes no micrositing to further reduce impacts on peat.

16.7.41 The combined expected impact of the Proposed Development on peat and vegetation over the operational lifetime for the proposed layout is calculated as shown in Table 16.5.

Table 16.5: Total CO_2 (tCO_2 eq.) loss/gains on peat

	CO_2 loss from plants +	CO_2 loss from removed peat + CO_2 loss from drained peat (i.e. soil organic matter loss)	+ CO_2 DOC & POC loss
	1,014	13,092	0
Total CO_2 loss/gains equiv.		14,106	

Source: Online Tool Reference PDB9-R1U1-OZNO 6

16.7.42 Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for loss of soil organic carbon is expected to be less than 4 months.

Loss of Carbon Fixing due to Forest Felling

16.7.43 Chapter 11 Forestry proposes that a total of 18.5 ha will be felled for the Proposed Development. However, 11 ha of this will be re-stocked and 7.5 ha will undergo compensatory planting. Therefore, in accordance with the guidance for the carbon calculator, no value has been inserted into the tool for felling as all woodland will be replaced through restocking or compensatory planting.

Carbon Gain Due to Site Improvement and Restoration

16.7.44 Restoration of areas within a proposed site can reverse emissions and act as carbon storage, reducing the total CO_2 emissions as a result of the Proposed Development. The carbon calculator takes into account reductions for emissions resulting from the improvement of degraded bog, felled plantation land as well as the restoration of borrow pits and early removal of drainage from turbine foundations.

16.7.45 The drainage associated with the hardstandings and foundations will have an expected draw down on the water table during the construction period until such a time when they are removed/backfilled. This work will where

possible, intend to raise the water table depth above or the same as what was already present before construction. All construction ditches and drainage on site will be blocked to minimise indirect habitat damage and loss through drainage.

16.7.46 Opportunities for habitat management and potential peat restoration have been investigated and are presented in Chapter 9 Ecology of the EIAR. To present a worst-case scenario for this assessment however, no values for improvement of degraded bog, felled plantation or peat restoration of borrow pits have been entered into the tool.

16.7.47 The results report -347 tCO_2 equiv. in carbon gains from the removal of drainage measures in the expected scenario and -744 tCO_2 equiv. in carbon gains in the maximum (best-case) scenario. It is important to note that the minimum scenario does not show any carbon gains accrued from improvements of the site as the tool has assumed that no improvement has occurred at all.

16.8 CLIMATE CHANGE IMPACT SUMMARY

16.8.1 Table 16.5 reveals the carbon losses and carbon gains for each of the above parameters for the Proposed Development. Table 16.5 also reveals the expected net CO_2 emissions.

Table 16.5: Expected CO_2 losses and gains

Carbon Balance Input Parameter	Expected Results
1. Windfarm CO_2 emission savings over other types of energy generation per year	
Coal fired electricity generation (tCO_2yr^{-1})	103,931
Grid mix of electricity generation (tCO_2yr^{-1})	28,647
Fossil fuel mix of electricity generation (tCO_2yr^{-1})	50,836
Energy output from windfarm over lifetime (MWh)	3,953,914
Total CO_2 losses due to wind farm construction, operation and decommissioning (tCO_2 eq.)	
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	43,265
3. Losses due to backup	34,217
4. Losses due to reduced carbon fixing potential	1,014
5. Losses from soil organic matter	13,092
6. Losses due to DOC & POC leaching	0
7. Losses due to felling forestry	0
Total losses (tCO_2 eq.)	**91,587**
8. Total CO_2 gains due to improvement of site (tCO_2 eq.)	
8a. Gains due to improvement of degraded bogs	0
8b. Gains due to improvement of felled forestry	0
8c. Gains due to restoration of peat from borrow pits	0
8d. Gains due to removal of drainage from foundations and hardstandings	-347
Total gains (tCO_2 eq.)	**-347**
Net CO_2 emissions (tCO_2 eq.)	**91,240**

Source: Online Tool Reference PDB9-R1U1-OZNO v6: Payback Time and CO_2 emissions page.

16.8.2 The net emissions of CO_2 of the Proposed Development are calculated by deducting the total CO_2 gains produced by improvement and restoration of the site from the total CO_2 emissions from manufacture of, construction of, and impacts on peat from, the individual elements of the Proposed Development (described in the preceding paragraphs).

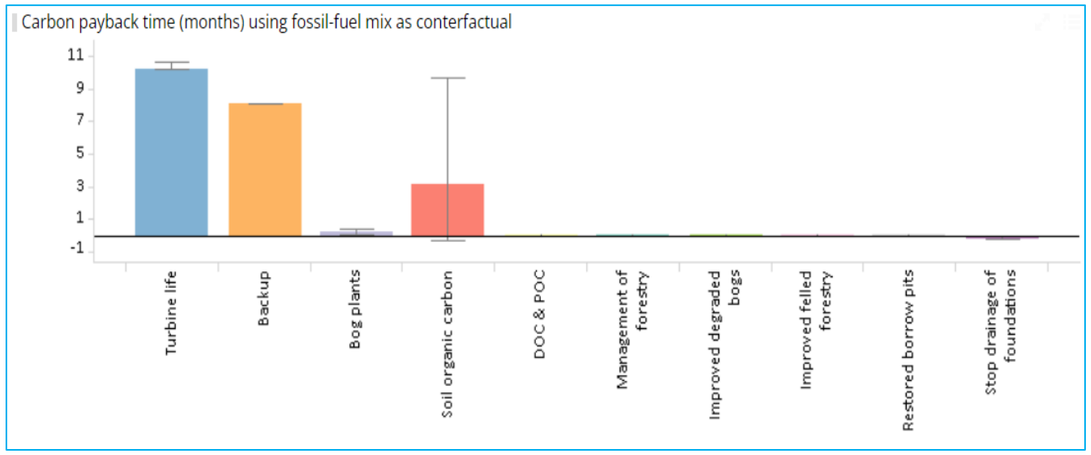
16.8.3 The wind farm CO_2 emissions savings of the Proposed Development over other types of generation (i.e. coal-fired, grid-mix, fossil fuel-mix) is calculated by multiplying the energy output of the Proposed Development by the emissions factor of the other type of generation. However, this parameter only takes into consideration the energy output of the Proposed Development and does not take into account any of the carbon losses or gains that are produced from manufacture of, construction of, and impacts on peat from, the individual elements of the Proposed Development. The parameter that takes all parameters into account is the carbon payback time and it is this value that provides an indication of the carbon balance of the Proposed Development.

16.8.4 The carbon payback time for the Proposed Development is calculated by comparing the net loss of CO_2 from the site due to wind farm development with the carbon savings achieved by the wind farm while displacing electricity generated from coal-fired generation, grid-mix generation or fossil-fuel mix electricity generation. Figures 16.1 and 16.2 below illustrate the payback times for the alternative Proposed Development in years.

RESULTS	Exp.	Min.	Max.
Carbon Payback Time			
...coal-fired electricity generation (years)	0.9	0.7	1.3
...grid-mix of electricity generation (years)	3.2	2.6	4.8
...fossil fuel-mix of electricity generation (years)	1.8	1.5	2.7

Source: Online Tool Reference PDB9-R1U1-OZNO v6

Figure.16.1: Carbon payback time for the Proposed Development



Source: Online Tool Reference PDB9-R1U1-OZNO v6

Figure 16.2: Carbon payback time for different elements of the assessment

16.8.5 The results from the carbon calculator reveal that the Proposed Development would have effectively paid back its expected carbon debt from manufacture, construction, impact on habitat and decommissioning within 1.8 years if it replaced the fossil fuel-mix electricity generation method. Based on the minimum and maximum scenarios however, the analysis shows that the payback time for fossil fuel-mix generation ranges between 1.5 to 2.7 years respectively.

16.8.6 The Institute of Environmental Management and Assessment (IEMA) has identified the online carbon calculator tool for wind farm carbon assessments. This tool provides a consistent and the most comprehensive method for carbon assessment for wind farm developments on peat lands to date. However, the online tool does not define

what level of impact on peat is considered to be a 'significant effect' as the existing carbon balance literature using this carbon assessment tool does not state this requirement.

16.8.7 In this regard, IEMA[14] concludes that:

"…when evaluating significance, all new Green House Gas (GHG) emissions contribute to a significant negative environmental effect; however; some projects will replace existing development that have higher GHG profiles. The significance of a project's emissions should therefore be based on its net impact, which may be positive or negative."

16.8.8 In this context, the results of this assessment reveal that the net impact of the Proposed Development will be positive overall, as over a 35-year lifespan, it is expected to generate over 33 years' worth of net carbon savings if it replaced fossil fuel-mix electricity generation and nearly 32 years' worth of net carbon savings even if it replaces cleaner grid-mix electricity generation. Therefore, over the expected 33 years that the wind farm is likely to be generating carbon-free electricity, this could result in expected CO_2 emission savings of over 1,677,588 tonnes[15] of CO_2 when replacing fossil fuel-mix electricity generation.

16.8.9 This illustrates a positive net impact on climate change through contributing significantly towards the reduction of GHG from energy production.

[14] Available online from: https://www.iema.net/preview-document/assessing-greenhouse-gas-emissions-and-evaluating-their-significance (last accessed 18/05/2022).

[15] Calculation is 33 years x 50,836 tCO_2 (as shown in Table 16.5 and online submission).