5. Introduction

5.1 Non-Technical Summary

5.1.1 This assessment uses the Scottish Government's Carbon Calculator for wind farms on peat to estimate the benefit of displacing conventionally generated electricity in the grid compared to the predicted direct and indirect emissions of carbon resulting from the construction and operation of the Proposed Development over its lifetime, including losses of stored carbon affected peatland. The Carbon Calculator provides an estimate of the carbon payback time for the Proposed Development.

5.1.2 The results of the Carbon Calculator for the Proposed Development show that the Proposed Development is estimated to produce annual carbon savings of approximately 30,000 tonnes of CO_2e per year through the displacement of grid electricity, based on the current average grid mix.

5.1.3 The assessment of the carbon losses and gains has estimated total project emissions of around 65,000 tonnes of CO_2e, mainly due to embodied losses from the manufacture of the turbines and provision of backup power to the grid. Ecological carbon losses account for 24 % of the total emissions resulting from the Proposed Development construction and operation.

5.1.4 The estimated payback time of the Proposed Development, using the Scottish Government Carbon Calculator, is estimated at 2.2 years. There are no current guidelines about what payback time constitutes a significant impact, but 2.2 years is around 7% of the anticipated lifespan of the Proposed Development. Compared to fossil fuel electricity generation projects, which also produce embodied emissions during the construction phase and significant emissions during operation due to combustion of fossil fuels, the Proposed Development has a very low carbon footprint and after 2.2 years, the electricity generated is estimated to be carbon neutral and will displace grid electricity generated from fossil fuel sources.

5.1.5 The carbon intensity of the electricity produced by the Proposed Development is estimated at 0.014 $kgCO_2e/kWh$. This is below the outcome indicator for the electricity grid carbon intensity of 0.05 $kgCO_2e/kWh$ required by the Scottish Government in the Climate Change Plan (2018-2032). Therefore, the Proposed Development is evaluated to have an overall beneficial effect on climate change mitigation.

5.2 Purpose of this Carbon Balance Assessment

5.2.1 The Carbon Balance Assessment has been undertaken by Fluid Environmental Consulting for the proposed Tom na Clach Wind Farm Extension (the 'Proposed Development') on behalf of the Applicant, Nan Clach Extension Limited.

5.2.2 Increasing atmospheric concentrations of greenhouse gases (GHGs), including carbon dioxide (CO_2) – also referred to as carbon emissions – is resulting in climate change. A major contributor to this increase in GHG emissions is the burning of fossil fuels. With concern growing over climate change, reducing its cause is of utmost importance. The replacement of traditional fossil fuel power generation with renewable energy sources provides high potential for the reduction of GHG emissions. This is reflected in UK and Scottish Governments climate change and renewable energy policy.

5.2.3 However, no form of electricity generation is completely carbon free; for onshore wind farms, there will be emissions resulting from the manufacture of turbines, as well as from both construction and decommissioning activities and transport of materials and labour.

5.2.4 In addition to the lifecycle emissions from the turbines and associated wind farm infrastructure, where a wind farm is located on carbon rich soils such as peat, there are potential emissions resulting from direct action of excavating peat for construction and the indirect changes to hydrology that can result in losses of soil carbon. The footprint of a wind farm's infrastructure will also decrease the area covered by carbon-fixing vegetation. Conversely, restoration activities undertaken post-construction or post-decommissioning could have a beneficial effect on carbon uptake through the restoration of modified bog habitat. Carbon losses and gains during the construction and lifetime of a wind farm and the long term impacts on the peatlands on which they are sited need to be evaluated to understand the consequences of permitting such developments.

5.2.5 This chapter presents the carbon balance assessment using the Scottish Government's web-based Carbon Calculator and explains the policy basis for assessing carbon balance, explains the Scottish Government Carbon Calculator methodology used, details all the inputs into the model and provides an estimate of the expected carbon payback over the lifetime of the Proposed Development, once carbon losses from materials and ecological disturbance have been taken into account.

5.3 Legislation, Policy and Guidelines

Legislation

5.3.1 One of the key drivers for the development of renewable energy is the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019, which sets a net-zero target for the Scottish emissions account by 2045 and challenging interim targets for emission reductions compared to the baseline. The update to the Climate Change Plan (Scottish Government, 2020) recognises the need to continue the process of decarbonising the electricity grid and increasing generation capacity to support the delivery of electric heating and transport. However, the Climate Change Plan Update also recognises the importance of maintaining and restoring carbon storage in peat.

Policy

5.3.2 Relevant strategies and policies for Scotland include:

- The Scottish Energy Strategy (Scottish Government, 2017) which set a whole-system target to supply the equivalent of 50% by 2030 of all the energy for Scotland's heat, transport and electricity consumption from renewable sources. The strategy also reiterates that one of Scotland's energy priorities is renewable and low carbon solutions.

- National Planning Framework 3 (2014) (NPF3) which specifies that onshore wind will continue to play a significant role in de-carbonising the energy sector and diversifying energy supply. It also states that peatlands are an important habitat for wildlife and a very significant carbon store, containing 1,600 million tonnes of the 3,000 million tonnes in all Scottish soils (Scottish Government, 2014).

- National Planning Policy Framework 4 (NPF4) is currently under consultation but will replace NPF3 and Scottish Planning Policy (SPP). The NPF4 'Position Statement' was published in November 2020 and indicates that key opportunities to achieve net zero targets include supporting renewable energy developments, including the re-powering and extension of existing wind farms but also restricting peat extraction and development on peatland. The NPF4 consultation draft was published in November 2021.

- SPP (2014) which states that proposals for energy infrastructure developments should always take account of spatial frameworks for wind farms. Considerations will vary according to the size and location but include, among other impacts, the impacts on carbon rich soils, using the carbon calculator.

- Onshore wind turbines: planning Advice (Scottish Government, updated 2014) which under the heading of Securing Sufficient Information to Determine Planning Applications, for wind turbines proposed on peatland, refers to guidance on carbon calculations.

Guidance

5.3.3 One of the key impacts identified for onshore wind farms in Scotland is for sites on areas of peat, where stored carbon can be released through the extraction and drainage of these soils. In 2008 the Scottish Government funded a research report called Calculating carbon savings from wind farms on Scottish peat lands: a new approach (Nayak et al, 2008) and associated excel tool (referred to henceforth as the "Carbon Calculator") which utilises a life cycle methodology approach to estimating the wider emissions and savings of carbon associated with wind farms and for calculating how long the development will take to 'pay back' the carbon emitted during its construction. This methodology and approach is consistent with the Climate Change Mitigation & EIA Principles of the Institute of Environmental Management and Assessment (IEMA, 2010). The principles state that the assessment should aim to consider whole life effects including, but not limited to:

- embodied energy in the manufacture of materials used for the development;

- emissions related to construction - from materials delivery to on-site machinery;

- operational emissions related to the functioning of the development- including appropriate off-site emissions; and
- decommissioning, where relevant.

5.3.4 When evaluating significance, all new greenhouse gas (GHG) emissions contribute to adverse environmental effects; however, some projects will replace existing developments that have higher GHG profiles. The significance of a project's emissions should therefore be based on its net GHG impact, which may be beneficial or adverse.

5.3.5 In determining whether an application to build and operate a wind farm should be consented, the assessment of potential carbon losses and savings is a material consideration. It is one important consideration among many, and currently there are no official guidelines about what constitutes an acceptable or unacceptable payback time.

5.4 Consultation

5.4.1 A scoping opinion was issued by the Scottish Government Energy Consents Unit (**Appendix 2.B**), on behalf of the Scottish Ministers, to Infinergy Ltd with respect to the scoping report on Tom na Clach Wind Farm Extension Under the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017. A number of consultees mentioned carbon or climate in their response, and these are summarised below:

- **The Highland Council**. A statement is required which outlines the main development alternatives studied by the Applicant and an indication of the main reasons for the final project choice. Such assessment should also highlight sustainable development attributes including for example assessment of carbon emissions / carbon savings. Carbon balance calculations should be undertaken and included within the EIAR with a summary of the results provided focussing on the carbon payback period for the wind farm.
- **NatureScot**. Based on the initial information provided in the scoping report, we advise that the proposed development raises the following key issues relevant to our interests; potential impacts to peat, peatland habitats and carbon rich soils.
- **SEPA**. 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 CO_2 to the atmosphere. Developments must aim to minimise this release*." Please note we do not validate carbon balance assessments except where requested to by Scottish Government in exceptional circumstances.

5.4.2 The response to these scoping responses has been to undertake a carbon balance assessment using the standardised Scottish methodology (the Carbon Calculator).

The results demonstrate the overall carbon payback of the scheme and also the site-based soil carbon losses and gains, which can be influenced through design layout and post-construction restoration activities.

5.5 Methodology

5.5.1 GHG emissions and savings are both ultimately a global 'pool' and therefore this assessment is not restricted solely to those emissions or savings that occur within the boundary of the Proposed Development site. Land-based emissions from peat and habitat losses are based on the site footprint, but other activities, for example, emissions resulting from the extraction and production of steel for turbines, are still attributable to the Proposed Development even though they are likely to occur in other parts of the world.

5.5.2 GHG emissions are measured in tonnes of carbon dioxide equivalents (tCO_2e) which is a quantity that describes, for a given mixture and amount of greenhouse gas, the amount of carbon dioxide (CO_2) that would have the same global warming potential (GWP), when measured over a 100-year timescale. These units therefore enable comparison of different greenhouse gases emitted, or saved, at different project stages.

5.5.3 The temporal scope for savings is set as the same period as the lifespan requested in the application for the construction and operation of the Proposed Development, i.e. 40 years but, unless it is specified that the Proposed Development site will be restored with respect to hydrology and habitat upon decommissioning, the losses through the indirect effects on peat will continue on until the Carbon Calculator estimates that there is no more oxidisable peat within the vicinity of the infrastructure.

5.5.4 The climate change assessment will cover the following potential sources, and savings, of carbon emissions from the three key project stages shown in Table 5.1.

Table 5.1 Carbon emissions and savings included in assessment

Project phase	Included in assessment	Excluded from assessment
Construction	Carbon emissions resulting from the extraction, production and manufacture of turbine components. The exact boundary of the lifecycle assessment used is not known as it is the result of a number of different academic studies but it is assumed that it is a cradle to grave assessment including all stages from extraction of materials through to end of life disposal.	Carbon emissions resulting from manufacture and transport of other materials required for foundations and tracks e.g. steel, sand, rock and geotextile. These materials are not explicitly included in the Scottish Government Carbon Calculator for wind farms on peat.
	Carbon emissions resulting from the manufacture of concrete required for foundations	Carbon emissions resulting from the transport of labour to the construction-site. This element is not included in the Scottish Government Carbon Calculator for wind farms on peat.
	Carbon emissions resulting from the direct excavation of peat on-site for building tracks, hardstanding, turbine foundations and other infrastructure.	Carbon emissions resulting from the use of plant and equipment during construction. This element is only included in the Scottish Government Carbon Calculator if the detailed forestry felling calculations are used.
Operation	Carbon emissions from the indirect impact of drainage on peat surrounding the Proposed Development infrastructure.	Carbon emissions resulting from manufacture and transport of spare parts and materials for repair required throughout the lifetime of the Proposed Development. This element is not explicitly included in the Scottish Government Carbon Calculator for wind farms on peat.
	Carbon savings resulting from the displacement of grid electricity generated by fossil fuels.	Carbon emissions resulting from the transport of operational personnel to the Proposed Development site. This element is not explicitly included in the Scottish Government Carbon Calculator for wind farms on peat.
	Carbon emissions resulting from the provision of back up generation	
	Carbon emissions resulting from the loss of active carbon-absorbing habitat, including forestry.	
	Carbon gains resulting from the restoration of carbon-absorbing habitat.	

Decommissioning		No explicit assessment of decommissioning emissions has been carried out as these are not included within the Carbon Calculator.

5.5.5 The assessment has used the following methodologies to estimate the overall impact of the Proposed Development on climate change:

the baseline assessment for carbon stored in soils at the site has been calculated using site-based data and standard conversion factors; and

the carbon payback of the site has been estimated using the Scottish Government's Carbon Calculator, (online version 1.6.1).

The Scottish Government's Carbon Calculator for Wind Farms on Peatlands

5.5.6 The Scottish Government methodology, titled 'Calculating potential carbon losses and savings from wind farms on Scottish Peat lands: a new approach (Nayak, et al, 2008), was designed in response to concerns on the reliability of methods used to calculate reductions in greenhouse gas emissions arising from large scale wind farm developments on peat land. The calculator looks at the benefit of displacing conventionally generated electricity in the grid compared to the predicted direct and indirect emissions of carbon from construction, operation and decommissioning of a wind farm. It provides an estimate of the carbon payback time for the Proposed Development.

5.5.7 This method built further on the Technical Guidance note produced by Scottish Natural Heritage (SNH) in 2003 for calculating carbon 'payback' times for wind farms. However, this guidance did not take account of the wider impacts on the hydrology and stability of peat lands. The current methodology provides a straightforward way to model the impacts of installation and operation of wind farms on peat soils, taking into account the wider potential impacts on peat land hydrology and decomposition of organic matter.

5.5.8 The most recent version of the Carbon Calculator is a web-based application and central database, where all the data entered is stored in a structured manner. This web-based tool replaces all earlier versions of the Excel-based calculator and incorporates high-level automated checking, detailed user guidance and cells for identification of data sources and relevant data calculations. Individual aspects of the methodology will be discussed further within this Chapter of the EIA Report, in the context of actual inputs and outputs of the model.

Study Area

5.5.9 The baseline assessment looks at the estimated stored soil carbon within the red line boundary under existing conditions, as this will enable the percentage loss of this carbon through the project development to be estimated. As the red line boundary includes both access routes (northern and western), and given neither route has specifically been selected, this has resulted in some of the infrastructure, including but not limited to borrow pits and access tracks, being overestimated.

5.5.10 For the carbon payback assessment, since GHG emissions and savings are both ultimately a global 'pool', this assessment is not restricted solely to those emissions or savings that occur within the boundary of the Proposed Development site. Land-based emissions from peat and habitat losses are based on the site footprint, but other activities, for example, emissions resulting from the extraction and production of steel for turbines, are still attributable to the Proposed Development even though they are likely to occur in other parts of the world.

Desk Study

5.5.11 Table 5.2 details the site-based parameters and conversion factors used for the baseline assessment and Table 5.3 details all the input parameters and assumptions used within the carbon calculator. Two of the parameters have been estimated using data collected from peat cores by Fluid Consulting and published equations in the literature. Detailed methodology describing the data and equations are provided below.

Methodology for Estimating Dry Soil Bulk Density

5.5.12 Within Lindsay's Peatbogs and Carbon; A critical synthesis (2010), several studies document the relationship between bulk density and Von Post scale of humification. Work by Päiväinen in 1969 documented linear relationships for different types of peat. The relationship for Sphagnum-based peat is described as

$Y = 0.045 + 0.011\ x$, where x is the Von Post score for humification.

5.5.13 Cores were taken at 19 locations and Von Post scores for both humification (H score) and saturation (B score) were recorded in the acrotelm and at metre intervals down through the catotelm. The coverage of Von Post data across the Proposed Development site meant that it was possible to use this equation to estimate the overall bulk density at the site. The methodology used was:

- Calculate the average Von Post scores for acrotelm layer (mean = 2.9, count 17 – 2 cores had no acrotelm);
- Calculate the average Von Post scores for catotelm layer (multiple measurements per core) (mean = 7.0, count 24);
- Calculate an average weighted Von Post score, using the average depth of acrotelm and catotelm to weight the score (weighted average score = 6.5)
- Use this weighted average score to estimate bulk density using Päiväinen's equation, calculating a minimum and maximum range as +/-25%

Estimating Average Drainage Distance from Drainage Features

5.5.14 The calculated estimate of dry soil bulk density has been used to estimate the hydraulic conductivity of the peat, according to the relationship curve described within Peatbogs and Carbon (Lindsey, 2010). Hydraulic conductivity describes the ease with which a fluid can move through pore spaces and fractures in soils. There are two equations for hydraulic conductivity, where y is hydraulic conductivity in m/day and x is bulk density:

- If the bulk density if less than 0.13 g/cm3, the equation is

y = 7683.3*(exp(-74.981*x))

- If the bulk density is greater than 0.13 g/cm3, the equation is

y = 10^-8*(x^-8.643)

5.5.15 The value of hydraulic conductivity given by this equation is then used to estimate the average drainage distance, using the equation given in Nayak et al (2008). This equation is given as

y=11.958x – 9.361, where x is the log value of hydraulic conductivity measured in millimetres per day (mm/day).

5.5.16 It should be noted that the minimum value for bulk density produces the highest estimate for hydraulic conductivity (the less densely packed material allows freer movement of water) and therefore drainage distance. Therefore, the Carbon Calculator is modelling a worst case scenario, as it is highly unlikely that the maximum bulk density of peat (with the greatest amount of stored carbon) would also have the maximum average drainage distance.

Baseline assessment methodology

5.5.17 The stored carbon within the red line boundary was estimated from the volume of peat at the site, multiplied by the percentage of carbon content and dry soil bulk density, using the equation:

Stored carbon (tC) = size of site (m2) * average peat depth (m) * dry soil bulk density (in g/cm3) * stored carbon content (%)

5.5.18 Tonnes of carbon were converted to tCO_2e by multiplying using the factor of 3.67, which converts from the atomic weight of C to the molecular weight of CO_2. The Carbon Calculator for wind farms on peat lands requires a range to be entered into the model which is shown as the minimum and maximum values. Table 5.2 shows the parameters used for this estimate.

Table 5.1 Parameters used to estimate baseline stored carbon within red line boundary

Parameter	Expected	Minimum	Maximum
Size of site based on red line boundary (ha)	399	379	418
Average peat depth across site (m)	1.17	1.05	1.29
Carbon content of dry peat (% by weight)	56	49	62
Dry soil bulk density (g/cm3)	0.12	0.09	0.15

5.5.19 Table 5.3 below outlines the input parameters used in the Carbon Calculator.

Table 5.3 Carbon Calculator input parameters

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Wind Farm Characteristics					
Dimensions					
No. of turbines	7	7	7	Chapter 3 states that the Proposed Development comprises of 7 turbines.	None
Life time of wind farm (years)	40	40	40	Chapter 3 states an operational lifetime of 40 years from the first date of final commission.	None
Performance					
Turbine capacity (MW)	4.5	4.5	4,5	Chapter 3 states the turbines would have a capacity of up to 4.5 MW (based on the Vestas V136 turbine), giving a total installed capacity of up to 31.5 MW.	None
Capacity factor – using direct input of capacity factor (percentage efficiency) %	43	38.7	47.3	Estimate of 43% provided by the Applicant, based on the neighbouring operational scheme.	A range of +/- 10% has been used to calculate the likely maximum and minimum.
Backup					
Extra capacity required for backup (%)	5	5	5	The Carbon Calculator indicates that if over 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant. SEPA has indicated that, for this parameter, the electricity generation capacity of Scotland, rather than the UK, should be considered. In 2020, Scotland generated	This input parameter assumes no improvement in grid management techniques, including demand side management, smart metering or storage over the lifetime of the wind farm.

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
				about 60% of gross electricity consumption via onshore wind (Scottish Renewables Statistics, 2021)	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Suggested Carbon Calculator literature value for scenario where extra capacity for backup is required.	Extra emissions due to reduced thermal efficiency of the reserve power generation ≈ 10 % (Dale et al 2004).
Carbon dioxide emissions from turbine life - (e.g. manufacture, construction, decommissioning)	Calculate with installed capacity option selected			There is no direct Life Cycle Assessment available at this point in time, therefore the inbuilt Carbon Calculator option which allows for emissions to be calculated according to turbine capacity has been selected. The equation for turbines with greater than or equal to 1 MW capacity was derived by regression analysis against 7 measurements, and has an associated R^2 value of 85 %.	
Characteristics of peat land before wind farm development					
Type of peat land	Acid Bog	Acid Bog	Acid Bog	The best habitat description available is 'acid bog', which is fed primarily by rainwater and often inhabited by sphagnum moss, thus making it acidic.	
Average air temperature at site (oC)	7.5	7.3	7.7	Based on average annual temperature data for north Scotland for the time period 2001 – 2021. The data is sourced from the Meteorological Office (2021). Mean: 7.5 Count: 20 Standard Error: 0.09	A 95 % confidence level has been calculated as the mean +/- 2 SE to estimate the likely minimum and maximum values of the range. Although, it is probable that average site temperatures are rising due to impacts of global climate change, the overall payback is not sensitive to temperature and therefore this parameter is not included in the sensitivity analysis.

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Average depth of peat at the site (m)	1.17	1.05	1.29	Based on 100m grid peat probes from within the red line boundary. Mean: 1.17 Count: 202 Standard Error: 0.06	A 95 % confidence level has been calculated as the mean +/- 2 SE to estimate the likely minimum and maximum values of the average.
Carbon (C) Content of dry peat (% by weight)	56	49	62	The default values for carbon content of peat 49% and 62% is provided in the Carbon Calculator.	Upper and lower range provided as default. Midpoint calculated as mean.
Average extent of drainage around drainage features at site (m)	28	17	39	The average extent of drainage has been estimated using Von Post data from 19 cores on-site. Von Post scores were recorded at each metre depth down the peat core. The average score for acrotelm and catotelm was calculated and used to estimate the bulk density of the peat on the site, which was then used to estimate hydraulic conductivity and consequently estimated drainage distance using equations from Nayak et al (2008). More detail is provided in the section on Methodology for specific parameters.	The minimum and maximum values are based on an estimated input range of +/-25 % for the bulk density. The wide range of values reflects the difficulty in measuring this parameter with accuracy.
Average water table depth at site (m)	0.05	0.00	0.10	The water table was observed on-site at the Proposed Development during peat cores taken to observe Von Post scores. On average the wetness score in both the acrotelm and catotelm was between B3 (moderate moisture content) and B4 (high moisture content). On average the acrotelm/catotelm boundary was at 0.10 m below the surface although this varied across the site. It can be assumed that this boundary represents the lowest point of the water table and therefore the average water table depth has been set at the midpoint of 0.05 m.	The minimum value has been set at 0.0 m, and the maximum value 0.10 m to represent the average range of the acrotelm/catotelm boundary.

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Dry soil bulk density (g/cm^3)	0.12	0.09	0.15	Scottish average bulk density values are unpublished data from the National Soil Inventory of Scotland (2007-2009) for amorphous, well decomposed peat. The range provided by SEPA for use in the Carbon Calculator for blanket peat is 0.132 (0.072 – 0.293 g/cm^3) The bulk density for the site has been estimated from the Von Post scores of peat cores on-site using the equation described by Päiväinen (1969). The estimated bulk density of 0.12 g/cm^3 sits within the estimated range provided by SEPA for blanket peat.	A range of +/- 25 % has been used to calculate the likely minimum and maximum.
Characteristics of bog plants					
Time required for regeneration of bog plants after restoration (years)	22.5	15	30	This parameter needs to be estimated and there are relatively few studies available on the average time taken for bog plant communities to regeneration following restoration. Rochefort *et al* (2003) estimate that a significant number of characteristic bog species can be established in 3–5 years, a stable high water-table in about a decade, and a functional ecosystem that accumulates peat in perhaps 40 years.	The overall Proposed Development site payback is not particularly sensitive to this parameter due to the slow rate of carbon fixation by bogs. The maximum value has been set at the limit of 40 years. The estimated value has been estimated at -25 % of the maximum and the minimum at -50 %.
Carbon accumulation due to C fixation by bog plants in un-drained peats ($t\ C\ ha^{-1}\ yr^{-1}$)	0.215	0.12	0.31	Suggested acceptable literature values from Carbon Calculator. The overall result is not very sensitive to this input, so the default value can be used if measurements are not available.	The range suggested in the methodology from the literature for apparent C accumulation rate in peatland is 0.12 to 0.31 $t\ C\ ha^{-1}\ yr^{-1}$ (Turunen et al., 2001, Global Biogeochemical Cycles, 15, 285-296; Botch et al., 1995, Global Biogeochemical Cycles, 9, 37-46).

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
					The SNH guidance uses a value of 0.25 t C ha^{-1} yr^{-1}. Range of 0.12 to 0.31 t C ha^{-1} yr^{-1}.
Forestry Plantation Characteristics					
Area of forestry plantation to be felled (ha)	0	0	0	There is no forestry to be removed on-site.	
Counterfactual emission factors					
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.920	0.920	0.920	The values in the page of the tool are fixed.	
Grid-mix emission factor (t CO_2 MWh^{-1})	0.25358	0.25358	0.25358		
Fossil fuel- mix emission factor (t CO_2 MWh^{-1})	0.450	0.450	0.450		
Borrow Pits					
Number of borrow pits	1	1	1	Chapter states that the borrow pit used for the Operational Scheme is intended to be reopened for the Proposed Development. Geotechnical investigation works, carried out for the Operational Scheme, strongly suggest there is sufficient winnable material available here for the construction of the Proposed Development	None

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Average length of pits (m)	185	176	194	The borrow pit area has been measured in GIS; the average length and width of the borrow pit has been calculated using the square root.	A range of +/- 25 % has been used to calculate the likely minimum and maximum.
Average width of pits (m)	185	176	194		
Average depth of peat removed from pit (m)	0.14	0.13	0.15	The average peat depth has been estimated from the probes within the borrow pit area plus a 25 m buffer. Mean: 0.14 Count: 491 Standard Error: 0.01	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and maximum values of peat volume for each borrow pit. The total maximum and minimum volumes were divided by the total area to get an estimate of the range of the maximum and minimum average depth.
Foundations and hard-standing area associated with each turbine					
Method used to calculate CO_2 loss from foundations and hard-standing	Rectangular with vertical walls			The simple method of calculation for turbine foundations was used for this application because this is no clear groups of turbines in terms of different peat depths, structures or use of piling.	None
Average length of turbine foundations (m)	16.0	15.2	16.8	The total area for the turbine hardstanding, which includes crane pad, turbine foundations and hardstanding (both temporary and permanent excavations) has been measured in GIS from the shape file. The turbine foundation diameter of 18 m has been used for these measurements (using geometry to get an equivalent sized rectangular shape).	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Average width of turbine foundations (m)	16.0	15.2	16.8		
Average depth of peat removed from turbine foundations (m)	0.98	0.88	1.08	The volume of peat at each turbine/hardstanding location was calculated from the turbine area multiplied by the average peat depth at each location (averaged from all the peat probes within a 50 m buffer of each	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and maximum values of peat volume for each turbine

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
				turbine/hardstanding location). The total volume of peat was divided by the total foundation area to provide an average peat depth across all 7 turbine locations.	foundation. The total maximum and minimum volumes were divided by the total area to get an estimate of the range of the maximum and minimum average depth.
Average length of hard-standing (m)	148	141	155	The remaining area after removing the turbine shape was all included in the hardstanding. The real shape will be irregular and contains both temporary and permanent construction areas. To fit into the carbon calculator parameters, this assessment assumes the worst case that all the peat will be excavated and not restored post construction and that the shape is regular. Where the track is next to the turbine hardstanding and there are laydown areas either side, the track area has been included in the turbine hardstanding area but not double counted in the track.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Average width of hard-standing (m)	40	38	42		
Average depth of peat removed from hard-standing (m)	0.98	0.88	1.08	The volume of peat at each turbine/hardstanding location was calculated from the turbine area multiplied by the average peat depth at each location (averaged from all the peat probes within a 50 m buffer of each turbine/hardstanding location). The total volume of peat was divided by the total foundation area to provide an average peat depth across all 7 turbine locations.	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and maximum values of peat volume for each hardstanding. The total maximum and minimum volumes were divided by the total area to get an estimate of the range of the maximum and minimum average depth.
Volume of concrete					
Volume of concrete used (m^3) in the entire area	2,800	2,660	2,940	Chapter 3 states that each foundation is made up from approximately 400 m^3 of concrete. The total volume is estimated by multiplying by the number of turbines.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Access tracks					
Total length of access track (m)	3,386	3,047	3,725	The length of the access track has been estimated from the GIS shape file total area for access track, assuming an average road width of 5.5 m (5.0 m but with additional widening on bends) There might be minor discrepancies between the length and width of tracks used in the Carbon Calculator and stated in the Chapter 3: Proposed Development. This is due to the method of calculation – the Carbon Calculator uses shapefile areas from which the length is then calculated, using a standard average width. Furthermore, where the track runs through the hardstanding area at a turbine location it is included within the hardstanding calculations and excluded here to avoid double counting.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Existing track length (m)	0	0	0	The existing access track for the Operational Scheme, which will be utilised for the Proposed Development. This track requires no upgrading and have been excluded from this assessment.	None
Length of access track that is floating road (m)	1,500	1,350	1,650	The length of the floating access track has been estimated from the GIS shape file total area for floating roads, assuming an average road width of 5.5 m (5.0 m but with additional widening on bends).	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Floating road width (m)	5.5	5.0	6.1	The average width has been set at 5.5 m (5.0 m but with additional widening on bends).	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Floating road depth (m)	0	0	0.60	This parameter accounts for sinking of floating road. The Carbon Calculator states that it should be entered as the average depth of the road expected over the lifetime of the	Zero value for expected and minimum values. The maximum is estimated at 50 % of the average

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
				Proposed Development. If no sinking is expected, enter as zero It is not anticipated that sinking of the floating track would be minimal and therefore this parameter has been set as zero for the expected and minimum values. A cautious estimate of 50 % of the average peat depth has been entered for the maximum to represent the worst case scenario.	peat depth for all the floating road locations on-site.
Length of floating road that is drained (m)	1,500	1,350	1,650	The full length of floating road access track will be drained.	A range of +/- 10 % has been used to calculate the likely minimum and maximum
Average depth of drains associated with floating roads (m)	0.43	0.39	0.47	**Appendix 13.C** states that the average depth of the drains for floating roads is estimated as 0.43 metres (assuming a v-shaped cut with sides of length 0.5m).	A range of +/- 10 % has been used to calculate the likely minimum and maximum
Length of access track that is excavated road (m)	1,886	1,697	2,075	The length of the excavated access track has been estimated from the GIS shape file total area for excavated roads, assuming an average road width of 5.5 m (5.0 m but with additional widening on bends).	A range of +/- 10 % has been used to calculate the likely minimum and maximum
Excavated road width (m)	5.5	5.0	6.1	The average width has been set at 5.5 m (5.0 m but with additional widening on bends).	A range of +/- 10 % has been used to calculate the likely minimum and maximum

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Average depth of peat excavated for road (m)	0.76	0.68	0.84	The average peat depth under excavated track has been calculated using the peat probe data within the track shape and within a 25 m buffer each side. Count = 304 Mean = 0.76 m SE = 0.04 m	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and maximum values.
Cable Trenches					
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable membrane (e.g. sand) (m)	0	0	0	Chapter 3 states that trenches and cable laying would be adjacent to site roads.	Assume all cable trenches follow access track routes.
Additional peat excavated (not accounted for above)					
Volume of additional peat excavated (m^3)	12,995	11,696	14,295	The volume of additional peat excavated has been calculated from the main site compound and the excavated part of the control building/substation. The area of this component and the average peat depth at the location (area of component + 50 m buffer) was calculated from GIS.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Area of additional peat excavated (m^2)	16,919	15,227	18,610	The area of additional peat excavated includes the infrastructure components above and the part of the control building/substation that will be floated.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Improvement of C sequestration at site by blocking drains, restoration of habitat etc.					

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Improvement of degraded bog					
Area of degraded bog to be improved (ha)	7.1	6.4	7.8	A number of restoration areas have been identified on site where peat can be reused to block gullies, restore water table and provide nurse crops for bare areas. The total area expected to be used has been measured in GIS.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Water table depth in degraded bog before improvement (m)	0.5	0.38	0.63	The water table in these areas is assumed to be much lower than is ideal for peat forming conditions due to the degraded nature of the vegetation and peat. Therefore, it is assumed that it sits well below the peat surface at 0.5m.	A range of +/- 25 % has been used to calculate the likely minimum and maximum due to the uncertainty around this parameter.
Water table depth in degraded bog after improvement (m)	0.1	0.09	0.11	To restore the bog habitat, it is expected that the average annual water table depth needs to be restored to around 0.1 m from the surface.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10	5	15	It is estimated that due to the relatively small restoration areas and use of acrotelm layers with intact vegetation to restore these areas, the process should be relatively quick to restore hydrology and plant communities.	A range of +/- 50 % has been used to calculate the likely minimum and maximum due to the uncertainty around this parameter.
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	40	40	40	The Carbon Calculator states that if the time required for hydrology and habitat to return to its previous state is 15 years and the restoration can be guaranteed over the lifetime of the Proposed Development (40 years), the period of time when the improvement can be guaranteed should be entered as 40 years.	None.
Restoration of peat removed from borrow pits					

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Area of borrow pits to be restored (ha)	3.5	3.1	3.8	The borrow pits will be restored using excavated peat from the site. The size of the borrow pit area was measured in GIS.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.5	0.38	0.63	This is a difficult parameter to estimate; however, it is assumed that the water table would be significantly lowered by drainage prior to restoration. It is estimated that the water table would be at the middle of the peat column before restoration with respect to the restored surface. Around 1 m depth of peat is expected to be replaced in the borrow pits, therefore the water table has been estimated at 50% of this depth.	A range of +/- 25 % has been used to calculate the likely minimum.
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.1	0.09	0.11	In order to restore the bog habitat in the borrow pits, it is expected that the average annual water table depth needs to be restored to around 0.1 m from the surface.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	10	5	15	It is estimated that due to the relatively small restoration areas and use of acrotelm layers with intact vegetation to restore these areas, the process should be relatively quick to restore hydrology and plant communities.	A range of +/- 50 % has been used to calculate the likely minimum and maximum.
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	40	40	40	The Carbon Calculator states that if the time required for hydrology and habitat to return to its previous state is 10 years and the restoration can be guaranteed over the lifetime of the Proposed Development (40 years), the period of time when the improvement can be guaranteed should be entered as 40 years.	None.

Online calculator reference: XY8U-QA0L-1LFH					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Removal of drainage from foundations and hardstanding				Chapter 3 states that the crane hardstanding will be left in place following construction in order to allow for the use of similar plant should major components need replacing during the operation of the wind farm, therefore this section of the tool has been left blank. It should be noted that completing it with estimated values does not alter the overall payback time significantly.	
Restoration of Application Site after decommissioning					
Will hydrology of the Proposed Development site be restored on decommissioning?	No	No	No	Chapter 3 states that during decommissioning the bases would be broken out to below ground level. All cables would be cut off below ground level, de-energised and left in the ground. Access tracks would be left for use by the landowner. No stone would be removed from the Proposed Development. Therefore, the answer to all of these questions has been left as no. It should be noted that answering yes to these questions does not alter the overall payback time significantly.	
Will habitat of the Proposed Development site be restored on decommissioning?	No	No	No		
Choice of methodology for calculating emission factors	Site specific			As required for planning applications.	

5.6 Assessment of Potential Effect Significance

Baseline Conditions

5.6.1 It is not easy to set a simple baseline for climate change impacts because the impact is due to a global atmospheric pool of greenhouse gas emissions – each individual project has a very small overall impact on this pool, but there are many small projects and therefore effective climate change mitigation relies on reducing the impacts of all of these.

5.6.2 However, the key climate change impact of constructing a wind farm on peat land is the potential release of stored carbon and therefore the baseline looks at the estimated stored soil carbon on-site under existing conditions, as this will enable the percentage loss of this carbon through the Proposed Development to be estimated.

5.6.3 Table 5.4 shows the estimate stored carbon in peat within the red line boundary. Estimated volume and emissions have been rounded up to the nearest thousand cubic metres/tonnes.

Table 5.4 – Estimated stored carbon in peat at the proposed development site (based on red line boundary)

Parameter	Expected	Minimum	Maximum
Estimated volume of peat (m^3)	4,649,000	3,961,000	5,385,000
Estimated amount of carbon in soils (tC)	310,000	175,000	501,000
Estimated equivalent emissions of CO_2 (tCO_2)	1,136,000	641,000	1,838,000

5.6.4 Table 5.4 shows that there is approximately 310,000 tonnes of stored carbon on-site and if this was fully oxidised, this would equate to over 1 million tonnes of CO_2 emissions. It is hard to assess the future of this stored carbon on-site in the absence of the Proposed Development but it is probable that future climate change impacts would affect this store – if the site conditions became warmer or drier, it is likely that some of this carbon would be lost.

Carbon Balance Assessment - Emissions

5.6.5 The results from the Carbon Balance Assessment have been divided into losses from activities resulting in the emission of carbon, savings from the avoidance of carbon emissions by displacing grid electricity from other fuel sources and gains from site restoration activities that should result in uptake of atmospheric carbon.

5.6.6 This section looks at the three project stages of construction, operation and decommissioning and allocates emissions to those three stages, however, it should be noted that for some of the key sources of emissions such as oxidation of soil carbon, it is hard to be precise about when they will occur in the Proposed Development life cycle.

Table 5.5 – Estimated carbon emissions during the construction phase

Emission source	Estimated emissions (tCO_2e)			% of overall emissions (expected scenario)
	Expected	Minimum	Maximum	
Losses due to turbine life + construction materials	27,044	27,000	27,088	40 %
CO_2 loss from excavated peat	8,688	3,974	16,661	13 %
Subtotal of emissions during construction	**35,732**	**30,974**	**43,749**	**53 %**

5.6.7 Table 5.5 shows that 53 % of the total losses occur during the Proposed Development construction phase. The majority of these are from the manufacture of the turbines with a small proportion due to other materials used in construction (for example concrete for foundations). The potential oxidation of excavated peat contributes 13% to overall losses.

Table 5.6 – Estimated carbon emissions during the operational phase

Emission source	Estimated emissions (tCO_2e)			% of overall emissions (expected scenario)
	Expected	Minimum	Maximum	
Losses due to backup	24,835	24,835	24,835	36 %
Losses due to reduced carbon fixing potential	2,258	703	5,217	3%
Losses due to Dissolved Organic Carbon (DOC) & Particulate Organic Carbon (POC) leaching	20	4	42	<1 %
CO_2 loss from drained peat	5,308	423	2,259	8%
Subtotal of emissions during operation	32,421	25,965	32,353	**47%**

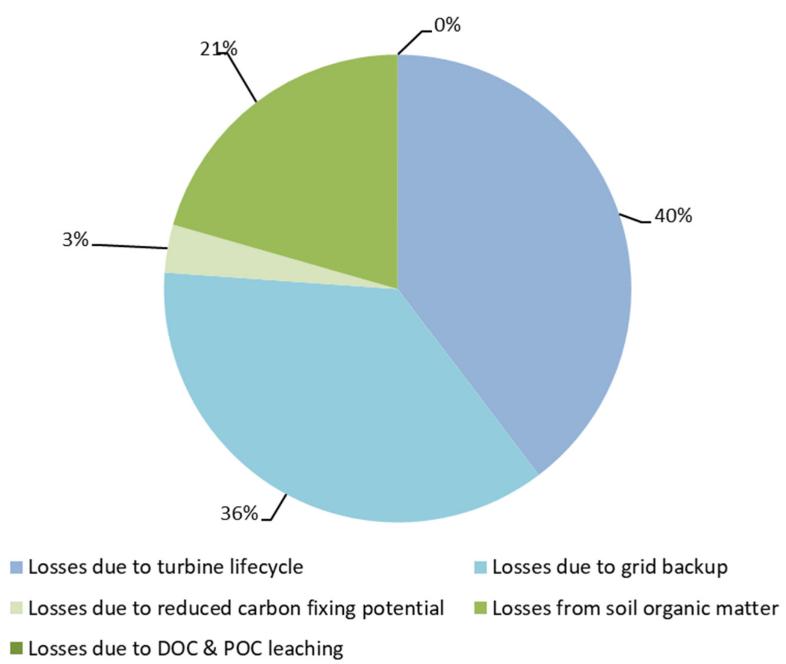
5.6.8 Table 5.6 shows that a further 47% of the emissions occur during the operational phase of the Proposed Development. The most significant of these is the requirement for back-up power in the grid, which is assumed to come from a fossil fuel source. Losses of carbon from the oxidation of drained peat account for 8% whereas losses of carbon due to reduced uptake or leaching are minimal.

5.6.9 Emissions produced during the decommissioning phase are not included separately in the Carbon Calculator assessment, as they are included in the overall lifecycle assessment of the turbines. Calculating emissions from this phase is difficult because the exact activities are not known but they are unlikely to be significant compared to the emission sources during construction and operation.

5.6.10 Graph 5.1 shows how the emissions are split between sources; the majority of emissions result from activities largely outside of the control of the Applicant (shown in blue); lifecycle emissions from the turbines can be potentially reduced through consideration at the procurement phase but availability and delivery timescales of appropriate turbines are usually more important factors in selection. The second largest emission source is from back-up generation to cover intermittency of supply, and this depends on both the grid mix and future grid management policies and is not under the control of the Applicant.

5.6.11 Emissions under the control of the Applicant are shown in green. These include the losses of carbon from extraction or drainage of peat for infrastructure. Therefore, mitigation measures for climate change include siting infrastructure away from deep peat areas where possible and floating infrastructure where this avoidance is not possible.

Graph 5.1 – Breakdown of emission sources for the proposed development



Carbon Balance Assessment – Gains

5.6.12 Table 5.7 shows the estimated carbon gains over the lifetime of the Proposed Development from improvements through restoration of degraded peat and restoring peat in the borrow pit. It should be noted that the Carbon Calculator is conservative about estimating the gains from restoration, only accounting for changes in the balance of methane to carbon dioxide emissions from the restoration of peat bog and not accounting for any additional carbon sequestration that might occur from restored vegetation.

Table 5.7 – Estimated carbon gains during the construction phase

Source of gains	Estimated gains (tCO_2e)			% of overall gains (expected scenario)
	Expected	Minimum	Maximum	
Change in emissions due to improvement of degraded bogs	-3,157	-1,777	-4,718	98%
Change in emissions due to restoration of peat from borrow pits	-58	-17	-114	2%
Total estimated gains	-3,215	-1,794	-4,832	**100%**

Comparison with the Baseline

5.6.13 The soil carbon losses from the Proposed Development are estimated at around 14,000 tonnes of CO_2e. This represents 1.2 % of the total stored carbon on-site (the estimated stored carbon is set out in Table 5.4) and includes anticipated losses from excavated and drained peat. In reality, this percentage is likely to be lower because the method used by the Carbon Calculator tool assumes that all excavated peat will be oxidised, whereas good management and re-use at site is likely to prevent at least a proportion of this oxidation.

Carbon Balance Assessment – Savings

5.6.14 Table 5.8 shows the estimated annual CO_2 savings, based on the three different counterfactual emission factors. The highest estimated savings are for replacement of coal-fired electricity generation but, while this could be the case in the short term, it is not the most probable scenario in the longer-term. The grid-mix of electricity generation represents the overall carbon emissions from the grid per unit of electricity and includes nuclear and renewables as well as fossil fuels.

Table 5.8 – Estimated annual carbon savings from the operation of the proposed development from the displacement of grid electricity

Counterfactual emission factor	Estimated savings (tCO_2e per year)		
	Expected	Minimum	Maximum
Coal-fired electricity generation	109,162	98,246	120,078
Grid-mix of electricity generation	30,088	27,079	33,097

Fossil fuel - mix of electricity generation	53,394	48,055	58,734

Payback Time and Carbon Intensity

5.6.15 There are two useful metrics for comparing different projects and different technologies. The Carbon Calculator tool calculates an estimated payback time, which is the net emissions of carbon (total of carbon losses and gains) divided by the annual estimated carbon savings. However, an alternative metric is the carbon intensity of the units of electricity that will be produced. This calculation divides the net emissions by the total units of electricity expected to be produced over the lifetime of the Proposed Development. This calculation is useful as it is independent of the grid emission factor of displaced electricity.

5.6.16 Table 5.9 shows the estimated payback time, if the electricity generated by the Proposed Development is assumed to displace electricity generated by the grid for a range of different displaced fuels, and also the carbon intensity of the units produced.

Table 5.9 – Estimated payback time in years and carbon intensity of the units of electricity produced

Counterfactual emission factor	Estimated time to payback (years)		
	Expected	**Minimum**	**Maximum**
Coal-fired electricity generation	0.6	0.4	0.8
Grid-mix of electricity generation	2.2	1.6	2.7
Fossil fuel - mix of electricity generation	1.2	0.9	1.5
Carbon intensity (kgCO_2e/kWh)	0.014	0.010	0.017

5.6.17 Table 5.9 shows that the Proposed Development is estimated to have a payback of 2.2 years based on the current grid mix and the carbon intensity of units produced would be significantly lower than the current grid mix (the value of 0.254 kgCO_2e/kWh is currently used in the Carbon Calculator). It should also be noted that the assessment boundary of the carbon intensity of electricity generated by the Proposed Development is far wider than the direct operational emissions included in the measurement of carbon intensity of the grid mix; if these were included, the impact of the Proposed Development would be shown to be even more beneficial.

Sensitivity analysis

5.6.18 The assessment of the payback of the Proposed Development is limited by both the Carbon Calculator and the parameters used to estimate the site characteristics. Within the Carbon Calculator there are several parameters known to have a potentially large impact on overall estimated payback time; for some of these parameters there is also a degree of uncertainty over the inputs due to data collection restraints. To demonstrate the robustness of the estimated payback, the sensitivity analysis below shows the impact of varying four of the key parameters on the payback time under a grid mix counterfactual emission factor, whilst holding all other parameters constant, as shown in Table 5.10.

Table 5.10 – Impact of changing individual parameters on expected payback in years

Sensitivity analysis	**Estimated time to payback (years) (based on expected scenario, grid mix electricity factor)**		
	As assessed: Expected	**Reduce parameter**	**Increase parameter**
Average extent of drainage around drainage features at site (m) – 28 m – impact of halving and doubling	2.2	2.0	2.5
Average water table depth at site (m) – 0.05 m – impact of decreasing and increasing by 50%	2.2	2.0	2.2
Carbon (C) Content of dry peat (% by weight) – 56% - impact of decreasing and increasing by 50%	2.2	1.8	2.5
Dry soil bulk density (g/cm^3) – 0.12 g/cm^3– impact of decreasing and increasing by 50%	2.2	1.8	2.5

5.6.19 Table 5.10 shows that, while the average drainage distance around drainage features on-site is a potentially important parameter in terms of the area of peat that would be drained by the Proposed Development infrastructure, doubling this parameter from 28 m to 56 m only increases the payback time by 0.3 years. Decreasing or increasing the water table depth has a very little impact. Increasing either the dry soil bulk density or carbon content parameters by 50% adds about 0.3 years to the overall payback

5.6.20 Overall, there is relatively little sensitivity to the overall outcome from changing the individual parameters below, which increases the confidence in the estimated payback time of approximately 2.2 years.

Mitigation

5.6.21 Although the results from the climate change assessment show that the impact of the Proposed Development on climate change mitigation is beneficial after an estimated 2.2 years of operation, there are ways to reduce this payback time further. A range of measures have already been applied as part of the iterative design development process (see **Chapter 2: EIA Process**) to avoid areas of deeper peat where possible.

5.6.22 The following activities will contribute to lower carbon emissions during the construction phase of the Proposed Development:

- implement a Site Waste Management Plan to reduce materials wastage;
- implement a vehicle idling policy to ensure that, where practicable plant and equipment are turned off when not in use, as part of the Construction and Decommissioning Environmental Management Plan; and
- implement a Peat Restoration Plan as part of the Construction Environmental Management Plan, including ditch blocking in order to allow peat habitats to be restored and groundwater levels to be raised to near surface. Appendix 13.C presents the areas where the peat that will be excavated from the infrastructure footprint will be reused to restore surfacing. These plans will enable the excavated peat to retain its integrity, retain carbon and allow areas of previous degraded and afforested peatland to regenerate and start to produce peat again.

5.7 Cumulative Assessment

5.7.1 The most significant cumulative effect of the Proposed Development is on the long-term grid electricity carbon factor. As the supply of renewable electricity increases, the overall average national grid carbon factor is predicted to decrease. The cumulative effect of these projects would be to reduce the projected emissions savings of an individual project as each unit of grid electricity would be worth less carbon. This effect will be higher as renewable energy develops further into the future; however, at the same time the exact generation composition of the grid and therefore the carbon emissions per unit of electricity is less predictable.

5.7.2 Although there is a great deal of uncertainty surrounding the future grid factor, the Department for Business, Energy and Industrial Strategy produce grid projections as part of the supplementary guidance for valuing energy usage and greenhouse gas emissions. The projections predict an average grid factor over the expected lifetime of the Proposed Development (2025 to 2063) of approximately 0.040 $kgCO_2e/kWh$ (BEIS, 2021). The impact of applying this average grid factor to the Proposed Development would be to reduce the overall average annual saving and therefore increase the expected payback period from 2.2 years to 13.7 years. However, this would not affect the carbon intensity of the project, estimated at 0.014 $kgCO_2e/kWh$, which would be well below the projected average of the grid for the lifetime of the Proposed Development and would therefore contribute towards this grid decarbonisation.

5.8 Summary

5.8.1 The results of the Carbon Calculator for the Proposed Development show that the Proposed Development is estimated to produce annual carbon savings of approximately 30,000 tonnes of CO_2e per year through the displacement of grid electricity, based on the current average grid mix. Displacement of existing sources of generating capacity depends on the time of day and how the grid needs to be balanced.

5.8.2 The assessment of the carbon losses and gains has estimated an overall loss of around 65,000 tonnes of CO_2e, mainly due to embodied losses from the manufacture of the turbines and provision of backup power to the grid. Ecological carbon losses account for 24 % of the total emissions resulting from the Proposed Development construction and operation and the baseline assessment demonstrated that around 1.2 % of the soil carbon within the site boundary would be lost.

5.8.3 The estimated payback time of the Proposed Development, using the Scottish Government Carbon Calculator, is estimated at 2.2 years, with a minimum/maximum range of 1.6 to 2.7 years. There are no current guidelines about what payback time constitutes a significant impact, but 2.2 years is around 7% of the anticipated lifespan of the Proposed Development. Compared to fossil fuel electricity generation projects, which also produce embodied emissions during the construction phase and significant emissions during operation due to combustion of fossil fuels, the Proposed Development has a very low carbon footprint and after 2.2 years, the electricity generated is estimated to be carbon neutral and will displace grid electricity generated from fossil fuel sources.

5.8.4 The carbon intensity of the electricity produced by the Proposed Development is estimated at 0.014 $kgCO_2e/kWh$. This is below the outcome indicator for the electricity grid carbon intensity of 0.05 $kgCO_2e/kWh$ required by the Scottish Government in the Climate Change Plan (2018-2032). Therefore, the Proposed Development is evaluated to have an overall beneficial effect on climate change mitigation.

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