17 Carbon Calculator

Contents

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17 Carbon Calculator

17.1 Executive Summary

17.1.1 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 from felled forestry and affected peatland. The Carbon Calculator provides an estimate of the carbon payback time for the Proposed Development.

17.1.2 As set out in Chapter 3, two potential access routes (northern and western) have been identified, although only one route to site will be selected and utilised. Given that it is not certain at this stage which route will be used, the potential effects associated with construction and operation of both options have been assessed. This results in some parameters such as development footprint area and estimated peat excavation volumes being over-stated, given that numbers reflected in the assessment are based on cumulative figures for both access routes (including borrow pits and gatehouse compound on the access tracks). It therefore follows that the emissions resulting from the Proposed Development will be slightly lower than those calculated when the final selection of one of the two access routes is confirmed. Even when considering both access routes, the assessment has identified a positive beneficial impact on climate.

17.1.3 The results of the Carbon Calculator for the Proposed Development show that the Proposed Development is estimated to produce annual carbon savings in the region of 36,000 tonnes of CO_2e per year, and lifetime savings of over 1.0 Mt of CO_2e through the displacement of grid electricity, based on the current average grid mix.

17.1.4 The assessment of the carbon losses and gains has estimated an overall loss of just over 100,000 tonnes of CO_2e, mainly due to embodied losses from the manufacture of the turbines and provision of backup power to the grid, which should be minimised through the provision of on-site energy storage. Ecological carbon losses account for only 11 % of the total emissions resulting from the Proposed Development construction and operation.

17.1.5 The estimated payback time of the Proposed Development, using the Scottish Government Carbon Calculator, is estimated at 2.9 years, with a minimum/maximum range of 2.5 to 3.5 years. The carbon intensity of the electricity produced by the Proposed Development is estimated at 0.024 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) and therefore the Proposed Development is evaluated to have an overall beneficial effect on climate change mitigation.

17.2 Introduction

17.2.1 The Carbon Balance Assessment has been undertaken by Clare Wharmby on behalf of Fluid Environmental Consulting. Clare is a Chartered Environmentalist with 10 years of experience undertaking climate change assessments for wind farms on peat across the UK.

17.2.2 Increasing atmospheric concentrations of greenhouse gases (GHGs), including carbon dioxide (CO_2) – also referred to as carbon emissions – are 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.

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

17.2.4 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 also 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.

17.2.5 The aim of this Chapter is to provide clear information about the whole life carbon balance of the Proposed Development. All applications that are over 50 MW are dealt with through the Scottish Government’s Energy Consents Unit in accordance with Section 36 of the Electricity Act 1989 and require a carbon balance assessment using the Scottish Government’s web-based Carbon Calculator. This Chapter 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 net carbon savings over the lifetime of the Proposed Development, once carbon losses from materials and ecological disturbance have been taken into account, including a sensitivity analysis for key parameters. The inputs into the Carbon Calculator assess the carbon balance of the full red line boundary as shown in Figure 1.1, given the specific access route has not been selected (northern or western). Therefore, it is important to note that the emissions resulting from some aspects such as access tracks, borrow pits and gatehouse compounds are overestimated.

17.3 Legislation, Policy and Guidelines

17.3.1 In the preparation of this Chapter, reference has been made to the following key pieces of legislation, policy and guidance:

Legislation

17.3.2 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

17.3.3 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

17.3.4 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. All new applications to the Energy Consents Unit are required to submit a completed Carbon Calculator. 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.

17.3.5 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.

17.3.6 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 for Scottish Ministers. It is one important consideration among many, and currently there are no official guidelines about what constitutes an acceptable or unacceptable payback time.

17.4 Consultation

17.4.1 A request for pre-application advice and EIA Scoping Opinion was submitted to the Energy Consents Unit (ECU), statutory and non-statutory consultees in December 2020. The Scoping Opinion issued on behalf of Scottish Ministers under the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 for Knockcronal Wind farm (Scottish Government, March 2021) has been searched for references to carbon, greenhouse gases and carbon calculator. However, none of the responding consultees raised any specific issues with respect to using the carbon calculator methodology to assess carbon emissions and savings from the Proposed Development.

17.5 Assessment Methodology and Significance Criteria

17.5.1 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.

17.5.2 The temporal scope for savings is set as the same period as the lifespan of the planning consent for the operation of the Proposed Development, i.e. 30 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.

17.5.3 The climate change assessment will cover the following potential sources, and savings, of carbon emissions from the three key project stages (Table 17.1):

Table 17.1 – 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, including for forestry felling. This element is only included in the Scottish Government Carbon Calculator if the detailed forestry felling calculations are used (larger scale). therefore the simple

		data was used for this site due to small areas of felling.
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 savings resulting from the displacement of grid electricity generated by fossil fuels.	-
	Carbon emissions resulting from the loss of active carbon-absorbing habitat, including forestry.	-
	Carbon uptake 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.

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

- the baseline assessment for the amount of 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 Peat Lands

17.5.5 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.

17.5.6 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.

17.5.7 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

17.5.8 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.

17.5.9 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

17.5.10 Table 17.2 details the site-based parameters and conversion factors used for the baseline assessment and 17.3 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 during site visits by Fluid Consulting (August 2020 and May 2021) and published equations in the literature. Detailed methodology describing the data and equations are provided below.

Methodology for Estimating Dry Soil Bulk Density

17.5.11 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 (dry soil bulk density) = 0.045 + 0.011 x, where x is the Von Post score for humification.

17.5.12 Cores were taken at 41 locations, however at ten of the core locations, no peat was recorded and these cores have not been included in the estimate of dry soil bulk density. For the locations where peat was present, 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 = 2.7, count 29 – 2 cores had no acrotelm);
- Calculate the average Von Post scores for catotelm layer (multiple measurements per core) (mean = 6.6, count 40);
- Calculate an average weighted Von Post score, using the average depth of acrotelm and catotelm to weight the score (weighted average score = 6.0)
- 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

17.5.13 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)

17.5.14 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).

17.5.15 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

17.5.16 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. 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 17.2 shows the parameters used for this estimate.

Table 17.2 Parameters used to estimate baseline stored carbon within red line boundary

Parameter	Expected	Minimum	Maximum
Size of site based on red line boundary (ha)	540	514	569
Average peat depth across site (m)	0.29	0.28	0.31
Carbon content of dry peat (% by weight)	56	49	62
Dry soil bulk density (g/cm^3)	0.11	0.08	0.14

17.5.17 The table below outlines the input parameters used in the Carbon Calculator (Table 17.3).

Table 17.3 Input parameters used in the Carbon Calculator

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Wind Farm Characteristics					
Dimensions					
No. of turbines	9	9	9	Chapter 3 of the EIA report states that the Proposed Development comprises of 9 turbines.	None
Life time of wind farm (years)	30	30	30	Chapter 3 states that the operational life of the Proposed Development will be 30 years.	None
Performance					
Turbine capacity (MW)	6.6	6.6	6.6	Chapter 3 states that the Proposed Development will comprise six wind turbines of up to 200 m maximum blade tip height and three turbines up to 180 m blade tip height when vertical, with an associated on-site energy storage system. The indicative combined generation capacity of the turbines is anticipated to be 59.4 MW.	None
Capacity factor – using direct input of capacity factor (percentage efficiency)	27.1	25.2	29.0	The estimated capacity factor for the windfarm is based on the 5 year average of wind load factors in Scotland (2016 to 2021) (BEIS, 2021).	A 95% confidence level has been calculated as the mean +/- 2 Standard Errors (SE) to estimate the likely minimum and maximum values of the average.

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
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 about 60% of gross electricity consumption via onshore wind (Scottish Renewables Statistics, 2021)	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.
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 referenced by the Carbon Calculator).
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					

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
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)	8.43	8.26	8.60	Based on average annual temperature data for west Scotland for the time period 2000 – 2020. The data is sourced from the Meteorological Office (2021). Mean: 8.43 Count: 21 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.
Average depth of peat at the site (m)	0.29	0.28	0.31	Based on peat probe data from within the red line boundary. Mean: 0.29 Count: 3,959 Standard Error: 0.01 m	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.

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Average extent of drainage around drainage features at site (m)	30	19	40	The average extent of drainage has been estimated using Von Post data from 31 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 Section 17.5	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)	0.11	0.10	0.12	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 0.11 m below the surface although this varied across the site and this was used as the average observed water table depth.	A range of +/- 10% has been used to calculate the likely minimum and maximum.
Dry soil bulk density (g/cm^3)	0.11	0.08	0.14	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 0.11 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					

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
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 30 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 30 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, referenced by the Carbon Calculator). 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					

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Area of forestry plantation to be felled (ha)	3.65	3.29	4.02	There are four areas of forestry that could be felled on site; areas 1 & 2 would be felled if the northern access route is used, areas 3 & 4 would be felled if the western access route is used. Therefore, the slightly worse case scenario of the northern access route (3.65 ha in total) has been used for the assessment. Area 1 – Dalmorton 0.67 ha & Area 2 – Glenalla 2.67 ha Area 3 – Dyke 3.41 ha & Area 4 – Dalmorton Farm 0.24 ha	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	5.80	4.35	7.25	The areas to be felled are made up of a mixture of species and ages. The estimated average rate of carbon sequestration has been based on Sitka Spruce, using a spacing of 1.7 m and a yield class of 14. It has been assumed that the average age of trees at felling is between 15 and 20 years. The Woodland Carbon Calculation Spreadsheet (March 2021) provides an estimate of total carbon standing (in tCO_2e/ha/year) for each 5 year age period. The average rate of sequestration is the average of the 6 periods covering the planning consent of the windfarm. The CO_2e is converted to C by dividing by 3.67.	A range of +/- 25 % has been used to calculate the likely minimum and maximum.
Counterfactual emission factors					
Coal-fired plant emission factor (tCO_2 MWh^{-1})	0.920	0.920	0.920	Fixed counterfactual emission factors are provided in the Carbon Calculator. Values for both coal-fired and fossil fuel-mix emission factors are updated from DUKES data for the UK which is	

Online calculator reference: *CZOH-G7WS-WG42*					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Grid-mix emission factor ($tCO_2\ MWh^{-1}$)	0.25358	0.25358	0.25358	published annually. The source for the grid-mix emission factor is the list of emission factors used to report on greenhouse gas emissions by UK organisations published by BEIS	
Fossil fuel- mix emission factor ($tCO_2\ MWh^{-1}$)	0.450	0.450	0.450		
Borrow Pits					
Number of borrow pits	5	5	5	Chapter 3 states that five borrow pit search areas have been identified and it is proposed that the actual borrow pit(s) would be located within these search areas, however, would only require using a portion of the search area.	Only one of the options on either the northern and western access route options would be progressed, depending on the final route chosen, so only four borrow pits would be progressed. Therefore, this assessment is an overestimate of the actual area that would be required.
Average length of pits (m)	63	56.7	63	The five borrow pit search areas are of different sizes and shapes; in order to be able to enter an average value for length and width, the total area of the borrow pits was calculated from the GIS shapefile. This area was divided by the number of borrow pits and then the square root of this value was calculated to get an average length and width.	A range of -10 % has been used to calculate the likely minimum values of both length and width. No increase has been used for the maximum as the expected value is already the worst case scenario.
Average width of pits (m)	63	56.7	63		
Average depth of peat removed from pit (m)	0.14	0.13	0.16	The volume of peat in each borrow pit was calculated from the area of each borrow pit multiplied by the average peat depth for that location (averaged from all of the peat	A range of +/- 10 % has been used to calculate the likely minimum and maximum.

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
				probes within a 50 m buffer of the borrow pit infrastructure). The total volume of peat was divided by the total borrow pit area to provide an average overall peat depth across all nine locations.	
Foundations and hard-standing area associated with each turbine					
Method used to calculate CO_2 loss from foundations and hard-standing	The simple method of calculation for turbine foundations was used for this application.			Although Chapter 3 states that the turbine foundations would be circular, the only option for calculating foundation using the simple method is based rectangular with vertical walls. The dimensions for this assessment are based on the rectangular shape dimensions used in the GIS shape file for the turbine foundations.	None
Average length of turbine foundations (m)	24	22.8	25.2	The square root of the area of the turbine foundations from the shape file has been used to calculate an average length and width.	A range of +/- 5% has been used to calculate the minimum and maximum values of both length and width.
Average width of turbine foundations (m)	24	22.8	25.2		
Average depth of peat removed from turbine foundations (m)	0.34	0.29	0.40	The volume of peat at each turbine location was calculated from the turbine area multiplied by the average peat depth for 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 9 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 turbine foundation. The total maximum and minimum volumes were divided by the total area to get an estimate of

Online calculator reference: ***CZOH-G7WS-WG42***

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
					the range of the maximum and minimum average depth.
Average length of hard-standing (m)	195	185	205	Chapter 3 states that a crane hardstanding area and turning area at each turbine location will be required to accommodate assembly cranes and construction vehicles. This will comprise a crushed stone hardstanding area measuring approximately 195 m long by 65 m wide, with a typical thickness of approximately 1000 mm. However, in order to enter more accurate dimensions, the irregular area of hardstanding has been measured using the shapefile for each of the nine turbine locations and the total area has been divided by the length of 195 m to get an average width.	A range of +/- 5% has been used to calculate the minimum and maximum values of both length and width.
Average width of hard-standing (m)	32	30.4	33.6		
Average depth of peat removed from hard-standing (m)	0.34	0.29	0.40	The volume of peat at each hardstanding location was calculated from the hardstanding area multiplied by the average peat depth for 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 hardstanding area to provide an average peat depth across all 9 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					

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Volume of concrete used (m^3) in the entire area	16,278	14,650	17,906	Chapter 3 states that each foundation will have a typical radius of 12 m and a depth of 4 m. The volume of concrete has been estimated by multiplying the volume of the turbine foundation by the number of turbines.	The carbon calculator allows for a volume of concrete to be entered in this instance, providing a more accurate value in comparison to the dimensions of the foundations and hardstandings. A range of +/- 10% has been used to calculate the likely minimum and maximum.
Access tracks					
Total length of access track (m)	12,688	11,419	12,713	This is total length of both new excavated and floating track and upgraded existing track. It includes both proposed western and northern access track routes as, but in reality only one of these routes would be used and therefore the actual length would be less. All types of access tracks are included in this category: • Excavated - new • Floating - new • Existing track – upgraded	Given the specific access route has not been selected (northern and western), the total access track length within the red line boundary has been included. Areas of overlap have been excluded to avoid double counting areas of loss.
Length of access track that is floating road (m)	240	216	264	The length of the floating access track has been calculated from the GIS shape files.	A range of +/- 10% has been used to calculate the likely minimum and maximum

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Floating road width (m)	5.0	5.0	5.5	This width is estimated from the shape file area divided by the length. Due to the short length of floating road, it requires no widening for bends/passing places	A range of + 10% has been used to calculate the likely maximum.
Floating road depth (m)	0	0	0.29	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 Proposed Development. If no sinking is expected, enter as zero. It is 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.	Zero value for expected and minimum values. The maximum is estimated at 50% of the average peat depth for all the floating road locations on-site.
Length of floating road that is drained (m)	240	216	264	Chapter 3 states that surface or sub-surface water flow within the vicinity of the access tracks and hardstanding areas will be routed into drainage channels which will be situated on the upstream side of the infrastructure and run in parallel with them. Therefore, it is assumed that 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 9.3 states that V drains will be installed either side of the track at 0.5 m length of each V, which gives an approximate depth of 0.43 m	A range of +/- 10% has been used to calculate the likely minimum and maximum

*Online calculator reference: **CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Length of access track that is excavated road (m)	12,448	11,203	12,448	This is total length of both new excavated track and upgraded existing track. It includes both proposed northern and western access track routes.	Given that the specific access route has not been selected (northern and western), all new excavated tracks within the red line boundary have been included. A range of - 10% has been used to calculate the likely minimum, but no increase has been used for the maximum value.
Excavated road width (m)	5.7	5.7	6.3	This width is estimated from the shape file area and includes both the normal running width of 5m and widening on bends and passing places.	A range of + 10% has been used to calculate the likely maximum.
Average depth of peat excavated for road (m)	0.14	0.13	0.15	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 = 1,692 Mean = 0.14 m	A range of +/- 10% has been used to calculate the likely minimum and maximum.
Cable Trenches					
Length of any cable trench on peat that does not follow access	0	0	0	Chapter 3 states that the wind farm array cables on site will be laid in trenches, typically approximately 0.5 m deep and 1 m wide, laid on a sand bed and backfilled using suitably	Assume all cable trenches follow access track routes.

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
tracks and is lined with a permeable membrane (e.g. sand) (m)				graded material and cables would be laid in trenches along the edges of tracks 0.5 m will mainly be located adjacent to the access tracks within the wind farm itself	
Additional peat excavated (not accounted for above)					
Volume of additional peat excavated (m^3)	18,312	16,480	20,143	The volume of additional peat excavated has been calculated from the average peat depth (area of component +50 m buffer) at each component, multiplied by the area. The six components included are: Gatehouse – Compound North (zero peat depth) Gatehouse – Compound West Compound Energy Storage Substation Meteorological Mast	Given that the specific access route has not been selected (northern and western), both gatehouse compound within the red line boundary have been included. A range of +/- 10% has been used to calculate the likely minimum and maximum
Area of additional peat covered by infrastructure (m^2)	71,023	63,921	78,125	The area of additional peat covered by infrastructure includes all the infrastructure components above, calculated from the GIS shapefile.	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.					
Improvement of degraded bog				Appendix 8.6 outlines the objective of the OHMP to deliver native riparian tree species planting within the site boundary. The aim of this planting would be to improve	

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
				areas of shelter for wildlife using the watercourses, including invertebrates and any fish, and improve connectivity in the north-west of the site, for species, such as foraging/commuting bats. However, it does not fit into the activities listed under the improvement of degraded bog or improvement of felled plantation land within the Carbon Calculator tool and therefore this area of planned restoration has not been entered in the Carbon Calculator tool. An initial assessment indicated that the area in question (under 1 ha in area) would not have a significant impact on the carbon payback even if it was counted as restoration of degraded bog.	
Restoration of peat removed from borrow pits					
Area of borrow pits to be restored (ha)	1.96	1.59	1.96	Chapter 3 states that following construction, the borrow pit(s) will be restored and reinstated to agreed profiles. The area is the total of the five borrow pit search areas that have been identified. For the purposes of the assessment above, it has been assumed that all five areas would be excavated, therefore it is assumed here that all five areas would be restored.	However, to note only four borrow pits would be excavated as only one access route will be progressed. A range of - 10% has been used to calculate the likely minimum.
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.14	0.13	0.16	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 bottom before restoration with respect to the restored surface – therefore	A range of – 10% has been used to calculate the likely minimum.

Online calculator reference: ***CZOH-G7WS-WG42***					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
				the water table depth would be the expected average depth of peat extracted.	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.11	0.10	0.12	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. The average annual water table depth is set as the site average as measured from the cores.	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	7.5	12.5	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 +/- 25% 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)	30	30	30	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 (30 years), the period of time when the improvement can be guaranteed should be entered as 30 years.	
Removal of drainage from foundations and hardstanding				Chapter 3 states the crane hardstandings will remain in place during the lifetime of the Proposed Development to facilitate maintenance works. There it is also assumed that drainage around foundations and hardstandings will be maintained. It should be noted that there is no significant improvement to the payback by completing this section.	

Online calculator reference: **CZOH-G7WS-WG42**					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Restoration of Application Site after decommissioning					
Will hydrology of the Proposed Development site be restored on decommissioning?	No	No	No	At this point there is insufficient information available about the restoration activities following decommissioning, and therefore the response to this question has been marked as 'no' as a worst case scenario. However, it should be noted, this response has no impact on the overall carbon payback at this site.	
Will habitat of the Proposed Development site be restored on decommissioning?	No	No	No	See above.	
Choice of methodology for calculating emission factors	Site specific			As required for planning applications.	

17.6 Assessment of Potential Effect Significance

Baseline Conditions

17.6.1 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.

17.6.2 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.

17.6.3 Table 17.4 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 17.4 – 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)	1,595,000	1,432,000	1,767,000
Estimated amount of carbon in soils (tC)	97,000	56,000	153,000
Estimated equivalent emissions of CO_2 (tCO_2)	357,000	206,000	563,000

17.6.4 Table 17.4 shows that there is approximately 97,000 tonnes of stored carbon on-site and if this was fully oxidised, this would equate to approximately 357,000 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

17.6.5 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.

17.6.6 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 177.5 – 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	56,436	55,922	56,951	54.8 %

CO_2 loss from excavated peat	3,861	382	9,939	3.8 %
Subtotal of emissions during construction	60,297	56,304	66,890	**58.6 %**

17.6.7 Table 17.5 shows that 59 % 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 only contributes 4 % to overall losses.

Table 177.6 – 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	35,123	35,123	35,123	34 %
Losses due to reduced carbon fixing potential	5,193	1,553	11,248	5 %
Losses due to Dissolved Organic Carbon (DOC) & Particulate Organic Carbon (POC) leaching	2	-	4	<1 %
Losses due to felling forestry	2,329	1,574	3,206	2 %
CO_2 loss from drained peat	-	-573	-	<1 %
Subtotal of emissions during operation	**42,647**	**37,677**	**49,581**	**41.4 %**

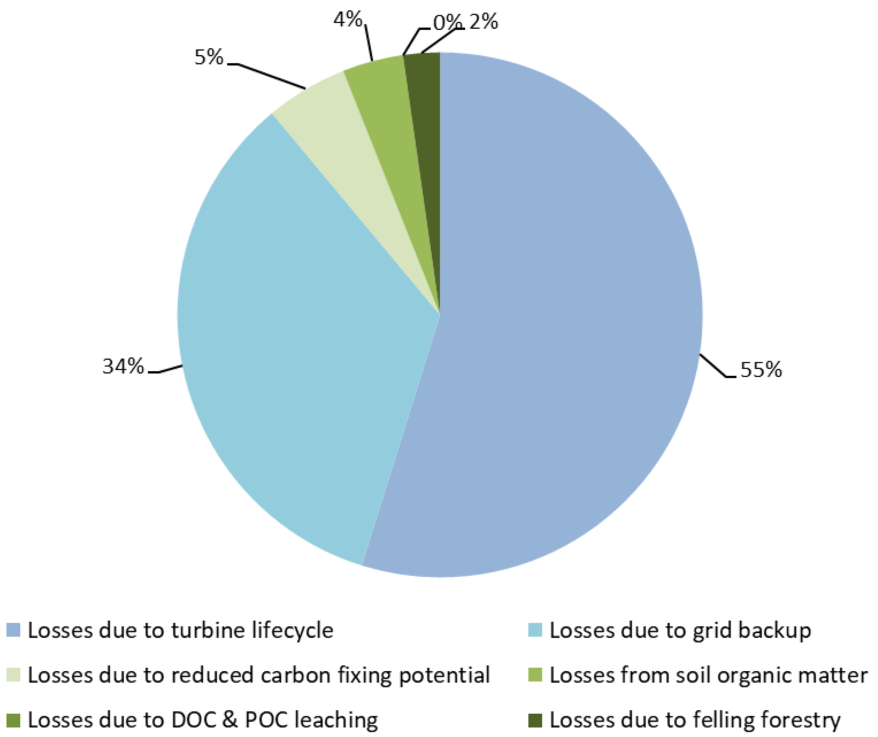
17.6.8 Table 17.6 shows that a further 41% of the emissions occur during the operational phase of the Proposed Development. The most significant of these is the requirement for back-up power in the grid, which is assumed to come from a fossil fuel source. Losses of carbon fixing potential of bog plants and felled forestry account for 7% whereas losses of carbon due to leaching and oxidation of drained peat are minimal.

17.6.9 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.

17.6.10 Graph 17.1 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 power and this depends on both the grid mix and future grid management policies and is not under the control of the Applicant.

17.6.11 Emissions under the control of the Applicant are shown in green. These include the losses of carbon due to the forestry felling, loss of carbon fixing potential in bog plants and extraction 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 177.1 – Breakdown of Emission Sources for the Proposed Development



Carbon Balance Assessment – Gains

17.6.12 Table 17.7 shows the estimated carbon gains over the lifetime of the Proposed Development from improvements through restoration of peat in borrow pits. 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 areas, such as tree planting.

Table 17.7 – 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 restoration of peat from borrow pits	-27	-9	-64	100 %

Comparison with the Baseline

17.6.13 The soil carbon losses from the Proposed Development are estimated at around 4,000 tonnes of CO_2e. This represents just over 1 % of the total stored carbon on-site (the estimated stored carbon is set out in Table 17.4) and includes anticipated losses from excavated and drained peat and losses due to leaching. 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

17.6.14 Table 17.8 shows the estimated annual and lifetime 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 177.8 – Estimated Annual and Lifetime 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	129,732	120,637	138,828
Grid-mix of electricity generation	35,758	33,251	38,265
Fossil fuel - mix of electricity generation	63,456	59,007	67,905
	Estimated savings (tCO_2 over lifetime of the Proposed Development)		
Coal-fired electricity generation	3,891,960	3,619,110	4,164,840
Grid-mix of electricity generation	1,072,740	997,530	1,147,950
Fossil fuel - mix of electricity generation	1,903,680	1,770,210	2,037,150

Payback Time and Carbon Intensity

17.6.15 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.

17.6.16 Table 17.9 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 17.9 – 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	0.8	0.7	1.0
Grid-mix of electricity generation	2.9	2.5	3.5
Fossil fuel - mix of electricity generation	1.6	1.4	2.0
Carbon intensity ($kgCO_2e/kWh$)	0.024	0.021	0.030

17.6.17 Table 17.9 shows that the Proposed Development is estimated to have a payback of 2.9 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.

Limitations to Assessment

17.6.18 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. In order 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 17.10.

17.6.19 Additionally, it is important to note that the estimate of turbine lifecycle emissions due to extraction, production, manufacture and transport of components and construction materials is likely to be overestimated in the carbon calculator due to out of date information about turbine output and size.

Table 17.10 – 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) – 30 m – impact of decreasing and increasing by 50%	2.9	2.8	3.0
Average water table depth at site (m) – 0.05 m – impact of decreasing and increasing by 50%	2.9	2.9	2.8
Carbon (C) Content of dry peat (% by weight) – 56% - impact of decreasing and increasing by 50%	2.9	2.7	3.0
Dry soil bulk density (g/cm^3) – 0.11 g/cm^3– impact of decreasing and increasing by 50%	2.9	2.7	3.0

17.6.20 Table 17.10 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 30 m to 60 m only increases the payback time by 0.1 years. Decreasing or increasing the water table depth has a very little impact, due partly to the low average depth of peat at the site.

17.6.21 Increasing either the dry soil bulk density or carbon content parameters by 50% adds about 0.1 years to the overall payback

17.6.22 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 2.9 years.

17.7 Standard Mitigation

17.7.1 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 2.9 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) to avoid areas of deeper peat where possible.

Construction phase

17.7.2 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. Chapter 9, Technical Appendix 9.3 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.

17.8 Additional Mitigation and Enhancement

17.8.1 A large proportion of overall emissions are due to the lifecycle assessment of the turbines themselves and other construction materials, and due to provision of back up power in the grid. Although there is no facility to add energy storage within the carbon calculator, it is anticipated that the energy storage will provide the back up service, thereby reducing or eliminating the need for provision of grid backup, which was estimated to contribute 34 % of the overall site losses.

17.9 Cumulative Assessment

17.9.1 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.

17.9.2 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 (2024 to 2053) of approximately 0.058 $kgCO_2e/kWh$ (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 2.9 years to 12.6 years. However, this would not affect the carbon intensity of the project, estimated at 0.024 $kgCO_2e/kWh$, 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.

17.10 Summary

17.10.1 The results of the Carbon Calculator for the Proposed Development show that the Proposed Development is estimated to produce annual carbon savings of approximately 36,000 tonnes of CO_2e per year, and lifetime savings of over 1.0 Mt of CO_2e 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.

17.10.2 The assessment of the carbon losses and gains has estimated an overall loss of just over 100,000 tonnes of CO_2e, mainly due to embodied losses from the manufacture of the turbines and provision of backup power to the grid, which should be minimised through the provision of onsite energy storage. Ecological carbon losses account for only 11 % of the total emissions resulting from the Proposed Development construction and operation and the baseline assessment demonstrated that just over 1 % of the soil carbon within the site boundary would be lost.

The estimated payback time of the Proposed Development, using the Scottish Government Carbon Calculator, is estimated at 2.9 years, with a minimum/maximum range of 2.5 to 3.5 years. There are no current guidelines about what payback time constitutes a significant impact, but 2.9 years is around 10% 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 2.9 years, the electricity generated is estimated to be carbon neutral and will displace grid electricity generated from fossil fuel sources. The carbon intensity of the electricity produced by the Proposed Development is estimated at 0.0245 $kgCO_2e/kWh$. 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. As previously mentioned, two potential access routes (northern and western) have been identified, although only one route to site will be selected and utilised. Given that it is not certain at this stage which route will be used, the potential effects associated with construction and operation of both options have been assessed. This results in some parameters such as development footprint area and estimated peat excavation volumes being over-stated, given that numbers reflected in the assessment are based on cumulative figures for both access routes (including borrow pits and gatehouse compound on the access tracks). It therefore follows that the emissions resulting from the Proposed Development will be slightly lower than those calculated when the final selection of one of the two access routes is confirmed. Even when considering both access routes, the assessment has identified a positive beneficial impact on climate.

17.11 References

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