18 Climate Change and Carbon Balance

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18. Climate Change and Carbon Balance

18.1. Summary

18.1.1. This assessment uses the Scottish Government's Carbon Calculator for wind farms on peat to assess the benefit of displacing electricity from fossil fuels with renewable generated electricity, compared to the emissions of carbon required for the construction and operation of Shepherds' Rig Wind Farm (the Proposed Varied Development) over its 40-year lifetime, including losses of stored carbon from disturbed peatland and reduction of forest cover. The Carbon Calculator provides an estimate of the carbon payback time for the Proposed Varied Development.

18.1.2. The results of the Carbon Calculator show that the Proposed Varied Development is estimated to save over 100,000 tonnes of CO_2e per year, through the displacement of grid electricity, based on the current fossil fuel grid mix. Displacement of existing sources of generating capacity depends on the time of day and how the grid needs to be balanced. Although it depends on the rate of electrification of transport and heat in buildings, it is reasonable to anticipate that over the lifetime of the Proposed Varied Development that generated electricity will displace existing fossil fuel usage.

18.1.3. The assessment of the Proposed Varied Development estimates losses of nearly 180,000 tonnes of CO_2e. The largest proportion of these is from the future lost sequestration potential of forestry that is felled for the construction of the wind farm. However, future gains from forestry restocking and compensatory planting are not included in the Carbon Calculator and therefore the total losses are likely to be overstated. The manufacture of the turbines and the Battery Energy Storage System (BESS) also contributes a significant proportion of the overall losses. Soil carbon losses account for around 6% of losses and it should be noted that the Carbon Calculator assumes that all extracted and drained peat is oxidised and does not include any reduction from peat that is reinstated. The baseline assessment demonstrated that around 1.4 % of the soil carbon within the site boundary could be affected by the Proposed Varied Development. Restoration of areas of forestry to bog are estimated to produce gains over the lifetime of the Proposed Varied Development through blocking of drains, re-wetting of peat and restoring surface vegetation; these gains are estimated at around 14,000 tonnes of CO_2e.

18.1.4. The estimated payback time of the Proposed Varied Development, using the Scottish Government Carbon Calculator, is 1.5 years, with a minimum/maximum range of 0.7 to 1.9 years, based on the fossil fuel mix of the electricity grid. There are no current guidelines about what payback time constitutes a significant impact, but 1.5 years is around 4% of the anticipated lifespan of the Proposed Varied Development. Compared to fossil fuel electricity generation projects, which also produce embodied emissions during the construction phase and then significant emissions during operation due to combustion of fossil fuels, the Proposed Varied Development has a low carbon footprint, and after 1.5 years the electricity generated is estimated to be carbon neutral and will displace grid electricity generated from fossil fuel sources or directly displace fossil fuel use for transport and heating. The carbon intensity of the electricity produced by the Proposed Varied Development is estimated at 0.016 $kgCO_2e/kWh$. This is well below the outcome indicator for maintaining the electricity grid carbon intensity below 0.04 $kgCO_2e/kWh$ required by the Scottish Government in the Climate Change Plan (Scottish Government, 2026), and

therefore; the Proposed Varied Development is evaluated to have an overall beneficial effect on carbon emissions associated with energy generation.

18.1.5. When compared to the Consented Development, the Proposed Varied Development is anticipated to save an additional 2,367,520 tonnes of CO_2e over its operational lifetime, as outlined in **Table 18.1**.

Table 18.1 – Summary of Conclusions – Proposed Varied Development and Consented Development

2018 Section 36 Application, supported by Additional Environmental Information I (2019) and Additional Environmental Information II (2021) - the Consented Development	2026 Section 36C Application - the Proposed Varied Development
The estimated payback time of the Consented Development is 1.4 years based on a fossil fuel mix of electricity generation. The Consented Development is expected to save 71,772 tonnes of CO_2e per year, through the displacement of grid electricity, based on the current fossil fuel grid mix. This equates to 2,153,160 tonnes of CO_2e over the Consented Development's 30-year operational lifetime.	The estimated payback time of the Proposed Varied Development is 1.5 years based on a fossil fuel mix of electricity generation. The Proposed Varied Development is expected to save 113,017 tonnes of CO_2e per year, through the displacement of grid electricity, based on the current fossil fuel grid mix. This equates to 4,520,680 tonnes of CO_2e over the Proposed Varied Development's 40-year operational lifetime.

18.2. Introduction

18.2.1. This Carbon Balance Assessment has been undertaken by Clare Wharmby on behalf of Fluid Environmental Consulting. Clare is a Full member of IEMA (now ISEP) and a Chartered Environmentalist with over 20 years of experience undertaking carbon balance assessments for wind farms on peat across the UK.

18.2.2. Increasing atmospheric concentrations of greenhouse gases (GHGs), also called carbon emissions, are resulting in global heating which will cause catastrophic changes to our climate. A major contributor to this increase in GHG emissions is the burning of fossil fuels for primary energy or electricity generation; in the UK, 34.9% of electricity was generated from fossil fuels in 2025 (Department for Energy Security and Net Zero, 2026). 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' delivery plans for climate targets (Carbon Budget and Growth Delivery Plan [Department for Energy Security and Net Zero, October 2025) and Scotland's Climate Change Plan: 2026–2040 [Scottish Government, 2026]).

18.2.3. However, no form of electricity generation is completely carbon free; for onshore wind farms (and any co-located technologies such as BESS), there will be emissions resulting from the manufacture of turbines and batteries, as well as emissions from both construction and decommissioning materials, transport and activities.

18.2.4. 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 can also decrease the area covered by carbon-fixing vegetation such as forestry. Conversely, restoration activities undertaken post-construction or post-decommissioning could have a beneficial effect on stored carbon 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 peatland and forestry on which they are sited, need to be evaluated to understand the consequences of permitting such developments.

18.2.5. The aim of this Chapter is to provide clear information about the whole life carbon balance of the Proposed Varied 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, details the methodology and input parameters used and provides an estimate of the expected net carbon savings over the lifetime of the Proposed Varied Development, once carbon losses from materials and ecological disturbance have been considered.

18.3. Legislation, Policy and Guidelines

18.3.1. This assessment has been carried out in accordance with the principles contained within the following legislation and policy.

Legislation

18.3.2. 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.

Policy

18.3.3. The Clean Power 2030 Action Plan which was published at the end of 2024 emphasises that all routes to a Clean Power system by 2030 (defined as using clean sources to generate as much power as Great Britian consumes) will require mass deployment of offshore wind, onshore wind, and solar but also states that 'new energy infrastructure should be built in a way that protects the natural environment by following a "mitigation hierarchy" to do what is possible to avoid damage to nature, and then minimising, restoring and delivering compensation when damage is impossible to avoid'.

18.3.4. Scotland's Climate Change Plan (Scottish Government, 2026) recognises the need to continue to grow renewable energy capacity with a strong pipeline of future projects that will play a key role in decarbonising the GB power system. However, the CCP also recognises that the extensive area of peatland and forestry in Scotland, are critical to climate goals for the whole of the UK.

18.3.5. The Scottish Energy Strategy (Scottish Government, 2017) set a whole-system target to supply the equivalent of 50% of all the energy for Scotland's heat, transport, and electricity consumption from renewable sources by 2030. The new Draft Energy Strategy and Just Transition Plan was published 10 January 2023 and is currently undergoing post-consultation review. The draft strategy recognises that the peatland impacts of onshore wind farms can be significant, and Scotland needs to balance the benefits from onshore wind deployment and the impact on carbon rich habitats. The draft strategy commits to convening an expert group, including representatives from industry, agencies, and academia to provide advice to the Scottish Government on how guidance could be developed to support both peatland and onshore wind aims. Furthermore, the strategy states that the Scottish Government will ensure that adequate tools and guidance are available to inform the assessment of net carbon impacts of development proposals on peatlands and other carbon-rich soils.

18.3.6. National Planning Framework 4 (Scottish Government, 2023) sets the national spatial strategy for Scotland, including spatial principles, regional priorities, national developments, and national planning policy.

18.3.7. Policy 1 states:

When considering all development proposals significant weight will be given to the global climate and nature crises.

18.3.8. Policy 5 states that:

c) Development proposals on peatland, carbon rich soils and priority peatland habitat will only be supported for:

ii. The generation of energy from renewable sources that optimises the contribution of the area to greenhouse gas emissions reductions targets;

d) Where development on peatland, carbon-rich soils or priority peatland habitat is proposed, a detailed site specific assessment will be required to identify:

iii. the likely net effects of the development on climate emissions and loss of carbon.

18.3.9. 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

18.3.10. The Environmental Impact Assessment Guide to Assessing Greenhouse Gas Emissions and Evaluating their Significance (IEMA, 2022) provides guidance for assessing the baseline against which the impact of a new project can be compared against, how to set an appropriate study boundary and how to communicate the impacts. This guidance has been considered in the content of this Chapter.

18.4. Assessment Methodology

18.4.1. The assessment has used the following methodologies to estimate the overall impact of the Proposed Varied Development on the carbon balance at the site:

- the baseline assessment of carbon stored in soils at the site has been calculated using desk and field data and standard values for carbon content of peat; and
- the carbon payback of the wind turbine component of the Proposed Varied Development has been estimated using the Scottish Government's Carbon Calculator, (excel version 2.14.1).

18.4.2. 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 GHG, 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 GHGs emitted, or saved, at different project stages.

Baseline Assessment Methodology

18.4.3. The stored carbon within the Proposed Varied Development red line boundary (the 'site') was estimated from the estimated volume of peat, which was calculated from the average depth of peat at the site from the 100 m peat grid peat probes across the site to reduce the sampling bias from detailed peat probing for infrastructure multiplied by the total site area. This volume was multiplied by the estimated percentage of carbon content and dry soil bulk density. Tonnes of carbon were converted to carbon dioxide (tCO_2) by multiplying with the factor of 3.67, which converts from the atomic weight of carbon ('C') to the molecular weight of CO_2. **Table 18.2** shows the parameters used to estimate the baseline of stored carbon. The source and references for these parameters are provided in **Table 18.4** at the end of this section.

Table 18.2 – Parameters used to Estimate Baseline Stored Carbon within the Peat Study Area

Parameter	Expected	Minimum	Maximum
Size of site based on red line boundary (ha)	637	605	669
Average peat depth across peat study area (m)	0.50	0.45	0.56
Carbon content of dry peat (% by weight)	56%	49%	62%
Dry soil bulk density (g/cm^3)	0.12	0.09	0.15

The Scottish Government's Carbon Calculator for Wind Farms on Peat Lands

18.4.4. 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 GHG emissions arising from large scale wind farm developments on peat land. Accompanying this methodology was an excel spreadsheet tool called the 'Carbon Calculator for wind farms on peat' which estimates 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 Varied Development based on predicted emissions from construction materials and grid backup and losses and gains of stored carbon on site, but excludes minor sources such as result of traffic generated during construction or operation.

18.4.5. This method built further on the Technical Guidance note produced by Scottish Natural Heritage (SNH, now NatureScot) 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 peatlands. The current methodology provides a straightforward way to model the impacts of installation and operation of wind farms on peat soils, considering the wider potential impacts on peat land hydrology and decomposition of organic matter.

18.4.6. The most recent version of the Carbon Calculator (v1.8.1) 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. However, as of 01/10/24, the online version is not accessible and there is no published timeframe for when the online version will be available again. Therefore, this Chapter has used the Excel version of the tool (v2.15.0) which produces the same results as the online tool. **Table 18.4** at the end of this section outlines the input parameters used in the Carbon Calculator. Individual aspects of the methodology will be discussed further within this Chapter, in the context of actual inputs and outputs of the model.

18.5. Scope of Carbon Calculator

18.5.1. **Table 18.3** shows the following potential sources, and savings, of carbon emissions from the three key project stages that are covered by the Carbon Balance Assessment.

Table 18.3 – Carbon Emissions and Savings Included in the Assessment

Project Phase	Included in Assessment	Excluded from Assessment
Construction	Carbon emissions resulting from the extraction, production and manufacture of turbine components and concrete required for foundations. The turbine Lifecycle Carbon Assessment (LCA) values are taken from the literature and put into the carbon calculator as direct input of values. The carbon emissions resulting from the manufacture of the BESS has also been taken from the literature and added to the turbine LCA estimate.	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 direct excavation of peat on-site for building tracks, hardstanding, turbine foundations and other infrastructure.	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 from the use of plant and equipment for construction of the Proposed Varied Development. This element is not included in the Scottish Government Carbon Calculator for wind farms on peat.
		Carbon emissions from the use of plant, equipment and materials from the forestry restocking and compensatory planting. This element is not included in the basic forestry calculations of the Scottish Government Carbon Calculator for wind farms on peat.
Operation	Carbon emissions from the indirect impact of drainage on peat surrounding the Proposed Varied Development infrastructure.	Carbon emissions resulting from transport of labour required throughout the lifetime of the Proposed *Varied* Development. These elements are not explicitly included in the Scottish Government Carbon Calculator for wind farms on peat and are also not included within the boundary of the LCA.
	Carbon savings resulting from the generation of electricity by wind turbines and displacement of grid electricity generated by fossil fuels.	

Project Phase	Included in Assessment	Excluded from Assessment
	Carbon emissions from the manufacture and supply of materials for maintenance and repair are included within the boundary of the LCA.	Emissions from use of diesel in generators used to restart turbines following shutdown. This is likely to be a very small emission source.
	Carbon emissions during the lifetime of the Proposed *Varied* Development resulting from the loss of active carbon-absorbing habitat, including forestry and bog habitat.	Carbon removals resulting from the creation or restoration of active carbon-absorbing habitat such as peatland or restocked woodland. The Scottish Government Carbon Calculator does not estimate future sequestration from restored vegetation, only the change to the existing carbon balance of soils in restored areas.
	Changes to the methane/CO_2 balance resulting from the restoration of forestry and degraded bog habitat.	
Decommissioning	Carbon emissions from the dismantling and disposal of turbine and associated infrastructure are included within the boundary of the LCA but these are not separated from the overall embodied emissions of the turbines in the Carbon Calculator.	-

Temporal Scope

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

Study Area

18.5.3. The baseline assessment looks at the estimated stored soil carbon within the site boundary under existing conditions, as this will enable the percentage loss of this carbon through the Proposed Varied Development to be estimated.

18.5.4. 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 site. Land-based emissions from peat and habitat losses are based on the Proposed Varied Development footprint, but other activities, for example, emissions resulting from the extraction and production of steel for turbines, are still attributable to the Proposed Varied Development even though they are likely to occur in other parts of the world.

18.6. Significance Criteria

18.6.1. 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, therefore this assessment looks at a range of metrics, including the payback, the carbon intensity of electricity produced and the ratio of soil carbon losses to gain, to evaluate the impact of the Proposed Varied Development on carbon emissions.

Table 18.4 – Input Parameters used in Carbon Calculator

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Wind Farm Characteristics					
Dimensions					
No. of turbines	11	11	11	**Chapter 4**: Description of Proposed Varied Development states that the Proposed Varied Development would comprise eleven wind turbines at a maximum tip height of 220 m.	None
Lifetime of wind farm (years)	40	40	40	**Chapter 4** states that the lifetime of the Proposed Varied Development is envisaged to be 40 years operational lifetime.	None
Performance					
Turbine capacity (MW) – this represents increase in site capacity due to repowering	7.0	7.0	7.0	**Chapter 4** states that the indicative combined generation capacity of the turbines is anticipated to be in the region of 77 MW. This is an average of 7.0 MW per turbine.	None

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Capacity factor – using direct input of capacity factor (percentage efficiency)	37.4%	35.5%	39.3%	A site-based capacity factor of 37.4% has been provided by the Applicant based on wind modelling.	A range of +/- 5% has been used to calculate the likely minimum and maximum.
Backup					
Extra capacity required for backup (%)	0%	0%	0%	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 2024, Scotland generated 58% via wind (Scottish Government, 2025). However, **Chapter 4** states it is proposed that a battery energy storage system (BESS) with a capacity of up to approximately 50 MW in total will be	None.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				constructed to enable co-location of battery storage with the proposed wind turbines. This represents over 50% of the total site energy output, therefore, this parameter has been reduced by 100%, from 5% to 0% to represent this onsite balancing.	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed value within the Carbon Calculator for scenario where extra capacity for backup is required, therefore not applicable for this site.	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)	Direct input of total emissions			**Chapter 4** states that turbine parameters for the Proposed Varied Development will be based on the Nordex N163 with a maximum overall height (to blade tip) of 220 m and an indicative hub height of 138.5 m. There is an Environmental Product Declaration available for this turbine model (Nordex, 2024) and this has been used to estimate the turbine lifecycle emissions. Given this committed maximum tip height, and the range of	

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				turbine models likely to be available and suitable for the local wind conditions, there is considered to be negligible potential for the significance of environmental effects to be different than as assessed based on the candidate turbine model.	
Total CO_2 emission from turbine life (tCO_2 MW^{-1})	749.8	674.8	824.8	The LCA assessment is in units of gCO_2e per kWh generated of electricity over the assessment time period of 25 year design life. Units have been converted to tCO_2e per MWh and scaled to electricity generation over 40 years in order to not overestimate the emissions for the longer lifetime of the site. The embodied carbon of the BESS has been estimated using data from a published LCA of a Lithium-ion BESS (Parlikar, et al. 2021). The value for the net emissions from production and end of life phase per MW have been calculated for the whole site and then added to the embodied turbine emissions.	A range of +/- 10% has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				The whole life emissions for turbines and BESS have been divided by the installed capacity to get an estimate of tCO_2e per MW installed.	
Characteristics of peat land before wind farm development					
Type of peat land	Acid Bog	Acid Bog	Acid Bog	There are only two options, of which one has to be selected within the Carbon Calculator: acid bog and fen. Based on **Chapter 9: Ecology**, within the site, habitats are overwhelmingly dominated by coniferous plantation of various ages, which makes up approximately 67% of the habitat recorded. Wetland habitats recorded within the site were limited to streams running throughout the site, marshy grassland in forestry rides and the remnant degraded modified bog which underlies the coniferous plantation. Therefore, acid bog has been chosen as the more representative option.	None

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Average air temperature at site (°C)	8.5	8.3	8.7	Based on average annual temperature data for West Scotland for the time period 2006 – 2025. The data is sourced from the Meteorological Office (2026). Mean: 8.5 Count: 20 Standard Error: 0.10	A 95% confidence level has been calculated as the mean +/- 2 SE to estimate the likely minimum and maximum values of the range. Although, 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)	0.5	0.45	0.55	The peat depth distribution data from the Outline Peat Management Plan (**Appendix 12.2**) was used to estimate the average peat depth across the study area, using the mid-point of the peat depth ranges and the areas of peat depth distribution across the survey area. This methodology provides a high-level estimate of average peat depth.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
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 used as expected value.
Average extent of drainage around drainage features at site (m)	27	17	39	The average extent of drainage has been estimated using Von Post data from 22 cores on-site. Von Post scores were recorded at intervals throughout 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 18.7.	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)	0.15	0.0	0.30	The minimum annual water table depth can be estimated as the average mid-depth of the acrotelm/catotelm boundary, assuming that this boundary represents the maximum, however many of the core samples taken lacked an acrotelmic layer. The Von Post B scores taken throughout the core depth did not vary between significantly by depth. Therefore,	The range has been set between 0 minimum and 0.3m maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				a reasonably wide range of water table values from 0 as a minimum to 0.3m as a maximum has been used as the range. The expected value is the midpoint of the minimum and maximum.	
Dry soil bulk density (g/cm^3)	0.12	0.09	0.15	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) and detailed in Section 18.7. The estimated bulk density of $0.12g/cm^3$ 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	The overall Proposed Varied 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.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				functional ecosystem that accumulates peat in perhaps 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}.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Forestry Plantation Characteristics					
Area of forestry plantation to be felled (ha)	226.1	214.8	237.4	Data as outlined in **Chapter 7: Forestry** has been used to estimate the area of forestry plantation to be felled. The areas coded as: 1 – Infrastructure felling (permanent loss for Wind Farm infrastructure 2 – Advanced felling (felling required because the stand would be liable to wind blow, this area can be restocked). Although areas coded as 2 can be restocked, the worst-case scenario has been modelled.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.34	3.01	3.67	The age class structure of the forest has been used to create a future carbon sequestration profile from the Woodland Carbon Code (v3.0 August 2025) based on average annual sequestration rate for the next 40 years for each age group, using the model of Sitka Spruce, spacing 2.0m, Yield Class 16-18 and no thin management. This was converted to an	A range of +/- 10 % has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				average annual sequestration rate per hectare based on the percentage of age classes across the site. The sequestration rate in tCO_2e per year was converted from tCO_2 to tC.	
Counterfactual Emission Factors					
Coal-fired plant emission factor **(tCO_2 MWh^{-1})**	0.919	0.919	0.919	Fixed counterfactual emission factors are provided in the Carbon Calculator and cannot be altered. These factors were last updated by the Scottish Government in June 2026. Values for both coal-fired and fossil fuel-mix emission factors are updated from DUKES data for the UK which is 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.	
Grid-mix emission factor **(tCO_2 MWh^{-1})**	0.177	0.177	0.177		
Fossil fuel- mix emission factor **(tCO_2 MWh^{-1})**	0.448	0.448	0.448		
Borrow Pits					
Number of borrow pits	1	1	1	Chapter 4 states that there will be two borrow pits. However, according to the Outline Peat Management Plan (**Appendix 12.2**) excavations, there is	None

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				only a very small volume of peat to be excavated for the north borrow pit location, indicating that there is little peat at this location. Therefore, only the south borrow pit has been included in this section.	
Average length of pits (m)	150	142	157	The average length and width of the south borrow pit has been taken from the Peat Management Plan excavation calculations and is based on the square root of the average area, including earthworks.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Average width of pits (m)	150	142	157		
Average depth of peat removed from pit (m)	0.12	0.10	0.13	The average peat depth excavated from the south borrow pit is calculated from Peat Management Plan excavation data using the total volume of peat excavated, including earthworks, divided by the total area, also including the earthworks.	A range of +/- 10 % has been used to calculate the likely minimum and maximum.
Foundations and hard-standing area associated with each turbine					
Method used to calculate CO_2 loss	Rectangular, with vertical sides			The simple method of calculation for turbine foundations was used for this application.	None

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
from foundations and hard-standing					
Average length of turbine foundations (m)	22.2	21.0	23.3	**Chapter 4** states that for the purposes of this EIA Report, the following approximate dimensions have been used: • A round reinforced concrete slab approximately 1440 m^3; • approximate slab diameter up to 25 m; and • depth of the foundations approximately 3.5 m. This diameter equates to a square of 22.2 m length and width.	A range of + 5% has been used to calculate the likely expected and maximum values of both length and width.
Average width of turbine foundations (m)	22.2	21.0	23.3		
Average depth of peat removed from turbine foundations (m)	0.26	0.23	0.28	The sum of the volume of peat at each turbine/hardstanding location was calculated from the Outline Peat Management Plan excavation data (total volume of peat excavated, including temporary and permanent hardstanding, clearance areas and earthworks). The total volume of peat was divided by the	A range of +/- 10 % has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				total infrastructure area of these categories.	
Average length of hard-standing (m)	133	126	139	The hardstanding area is made up of both permanent and temporary excavated areas, the turbine foundations and additional excavated area for clearance and earthworks. The total excavated area was calculated from the Outline Peat Management Plan (**Appendix 12.2**) excavation data, minus the turbine foundation area. An average length and width were calculated using the square root of the average hardstanding area, although in reality the shapes are irregular and vary slightly depending on the location.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Average width of hard-standing (m)	133	126	139		
Average depth of peat removed from hard-standing (m)	0.26	0.23	0.28	The sum of the volume of peat at each turbine/hardstanding location was calculated from the Outline Peat Management Plan (**Appendix 12.2**) excavation data (total volume of peat excavated, including temporary and permanent hardstanding, clearance areas and earthworks). The total volume of peat	A range of +/- 10 % has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				was divided by the total infrastructure area of these categories.	
Volume of concrete used in entire area	15,840	15,048	16,632	**Chapter 4** states that the foundations would have a round reinforced concrete slab approximately 1440 m^3. This was multiplied by the number of turbines to estimate the total concrete volume.	A range of +/- 5% has been used to calculate the minimum and maximum.
Access tracks					
Total length of access track (m)	10,300	9,785	10,815	**Chapter 4** states that the Proposed Varied Development will include approximately 7.7 km of new access tracks and 2.6 km of existing tracks which will be upgraded.	A range of +/- 5% has been used to calculate the minimum and maximum.
Existing track length (m)	2,600	2,470	2,730	There is approximately 2.6 km of upgraded existing track which only requires a small amount of peat to be excavated. The excavated area and peat volume have been added to the excavated track below.	A range of +/- 5% has been used to calculate the minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Length of access track that is floating road (m)	200	190	210	**Chapter 4** states that where proposed access tracks cross areas of deep peat, floated track construction is proposed, to avoid the requirement for excavation of peat. It is proposed that approximately 0.2 km of the new access track would be floated over deep peat if, following detailed site investigations, deep peat cannot be avoided by micro-siting.	A range of +/- 5% has been used to calculate the minimum and maximum.
Floating road width (m)	6.4	6.1	6.7	The total width of the track has been estimated from the length of track in Chapter 4 and the infrastructure area for floating tracks stated in the Outline Peat Management Plan (**Appendix 12.2**).	A range of +/- 5% has been used to calculate the minimum and maximum.
Floating road depth (m)	0	0	0.81	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 Varied 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	Zero value for expected and minimum values. The maximum is estimated at 50% of the average peat depth for all the floating track locations on-site.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				values. The average peat depth for the floating track has been taken from the Peat Management Plan excavation calculations.	
Length of floating road that is drained (m)	200	190	210	**Chapter 4** states the need for drainage on the access track network would be considered for all parts of the track network separately, since slope and wetness vary considerably across the site. Drainage methods will adapt to different track construction types, ensuring minimal environmental impact and maintaining natural drainage paths. In flat areas, drainage is generally unnecessary as rainfall can infiltrate the ground. On slopes, lateral drainage is installed on the upslope side to prevent pooling and rapid runoff, with cross-drains allowing water to pass across the track and re-infiltrate downslope. It is assumed therefore that all floating road will be drained.	A range of +/- 5% has been used to calculate the minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Average depth of drains associated with floating roads (m)	0.43	0.39	0.47	It is assumed that the drainage would be a V shape of around 0.5 m which equates to a depth of around 0.43 m.	A range of +/- 10% has been used to calculate the minimum and maximum.
Length of access track that is excavated road (m)	7,500	7,125	7,875	**Chapter 4** states there will be approximately 7.5 km of new cut track.	A range of +/- 5% has been used to calculate the likely minimum and maximum
Excavated road width (m)	11.3	10.7	11.9	The average width of the track has been estimated from the length of track in **Chapter 4** and the total infrastructure area for new excavated track in the Outline Peat Management Plan (**Appendix 12.2**), and a small area of excavation required to widen the existing track. This is wider than the running width stated in Chapter 4 because it includes turning heads, earthworks and drains, as well as the earthworks and widened area of the existing track.	A range of +/- 5% has been used to calculate the likely minimum and maximum
Average depth of peat excavated for road (m)	0.26	0.23	0.28	The average peat depth across the new track was calculated from the Outline Peat Management Plan (**Appendix 12.2**) as the total volume of peat excavated for	A range of +/- 10% has been used to calculate the likely minimum and maximum

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				cut tracks, including earthworks + a small volume of peat excavated to widen the existing track, divided by the area.	
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 4** states that cabling will mainly be located adjacent to the access tracks within the wind farm itself.	Assume all cable trenches follow access track routes.
Additional peat excavated (not accounted for above)					
Volume of additional peat excavated (m^3)	4,265	4,052	4,478	The volume of additional excavated peat has been calculated from the Outline Peat Management Plan (**Appendix 12.2**) excavation calculations for the additional infrastructure components listed below: • Substation • Construction compound	A range of +/- 5% has been used to calculate the likely minimum and maximum

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				The sum of total volume of peat excavated includes earthworks.	
Area of additional peat covered by infrastructure (m^2)	22,020	20,919	23,121	The area of additional infrastructure has been calculated from the Outline Peat Management Plan (**Appendix 12.2**) excavation calculations for the above additional infrastructure components and includes earthworks.	A range of +/- 5% 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					
Area of degraded bog to be improved (ha)	0	0	0	All of the restoration has been included in the category below of felled forestry to bog.	No variance
Improvement of felled plantation land					
Area of felled plantation to be improved (ha)	66.8	60.1	73.5	**Chapter 4** states that the Proposed Varied Development Restocking Plan (Figure 7.5) shows which woodlands would be restocked and with which species. No replanting would be carried out on the areas to be felled for the Proposed Varied Development's	A range of +/- 10% has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				permanent infrastructure or for habitat management (refer to Appendix 9.8), forest management or forest design purposes. As a result, there would be a net loss of woodland area of 119.9 ha (66.6 ha of this loss comprising forest to bog restoration).	
Water table depth in felled area before improvement (m)	0.30	0.23	0.38	This parameter has not been directly measured but from experience in other similar environments, in peat that is degraded, the water table to be down between 30-40 cm. A value of 0.3 m has been used as the average in order to not overestimate the gains from restoration.	A range of +/- 25% has been used to calculate the likely minimum and maximum.
Water table depth in felled area after improvement (m)	0.10	0.09	0.11	Target optimum water table depth for restoring peat is around 0.1 m. The Habitat Enhancement and Management Plan (**Appendix 9.8**) states that one of the target characteristics of the restored area is a high water table within 10 cm of the surface most of the year with small pools formed when the water table is high	A range of +/- 10% has been used to calculate the likely minimum and maximum

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	12.5	10	15	The Habitat Enhancement and Management Plan (**Appendix 9.8**) states that the restoration is coming from a combination of tree harvesting, furrow re-wetting and ground smoothing. It is estimated that the time for restoration of hydrology and habitat would be a minimum of 10 years.	The minimum has been set at 10 years and a range of + 25% & +50% has been used to calculate the likely expected and maximum.
Period of time when effectiveness of the improvement in felled plantation 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 Varied 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					
Area of borrow pits to be restored (ha)	2.18	2.07	2.29	Outline Peat Management Plan (**Appendix 12.2**) states that the south borrow pit will be restored with up to 1.0	A range of +/- 5 % has been used to calculate the likely minimum and maximum.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
				m depth of peat. The area to be restored is from the reuse calculations.	
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.50	0.11	0.18	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 around halfway up the depth of peat to be restored (maximum depth of 1 m stated in the OPMP).	A range of +/- 25% has been used to calculate the likely minimum and maximum.
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.10	0.09	0.11	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	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.

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
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 Varied Development (40 years), the period of time when the improvement can be guaranteed should be entered as 40 years.	None
Removal of drainage from foundations and hardstanding	0	0	0	**Chapter 4** states that the permanent crane hardstanding areas will remain in place during the lifetime of the Proposed Varied Development to facilitate maintenance work. The worst-case scenario is assumed that all 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.	None
Restoration of Application Site after decommissioning					
Will hydrology of the Proposed Development site be	No	No	No	**Chapter 4** states that consent is being sought for an operational lifespan of 40 years from the date of commissioning the	None

Parameter	Expected	Minimum	Maximum	Data Source	Key Assumptions
restored on decommissioning?				turbines. Prior to decommissioning, a Decommissioning Environmental Management Plan (DEMP) will be produced to reflect then current legislation and policy and will be agreed with the relevant statutory authorities. Due to the lack of detailed information, the response to these questions 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		
Choice of methodology for calculating emission factors	Site specific			As required for planning applications.	

18.7. Detailed Methodology Statements

18.7.1. **Table 18.2** details the site-based parameters and conversion factors used for the baseline assessment and **Table 18.4** 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 and published equations in the literature. Detailed methodology describing the data and equations are provided below.

Methodology for Estimating Dry Soil Bulk Density

18.7.2. 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.

18.7.3. Cores were taken at 22 locations and the range of Von Post score for humification (H score) was recorded in the acrotelm and then at metre intervals down the peat column. The coverage of Von Post data across the 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 = 4.4, count 8)

Calculate the average Von Post scores for catotelm layer (mean = 6.6, count 26)

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

18.7.4. 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 (Lindsay, 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/cm^3, the equation is y = 7683.3(exp(-74.981*x))*

If the bulk density is greater than 0.13 g/cm^3, the equation is y = 10^-8(x^-8.643)*

18.7.5. 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).

18.7.6. 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.

18.8. Results of Carbon Balance Assessment

Baseline Conditions

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

18.8.2. However, the key carbon balance impact of constructing a wind farm on peatland 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 Varied Development to be estimated.

18.8.3. **Table 18.5** shows the estimate of stored carbon in peat within the site, based on the peat study area that was probed and excluding the area that was assessed to not contain peat. Estimated volume and emissions have been rounded up to the nearest thousand cubic metres/tonnes.

Table 18.5 – Estimated Stored Carbon in Peat at the Proposed Varied Development Site (Based on Peat Study Area)

Parameter	Expected	Minimum	Maximum
Estimated volume of peat (m^3) (based on peat study area of 637 ha, multiplied by average peat depth of 0.5 m)	3,217,000	2,751,000	3,716,000
Estimated amount of carbon in soils (tC)	209,000	118,000	337,000
Estimated equivalent emissions of CO_2 (tCO_2)	766,000	434,000	1,236,000

18.8.4. **Table 18.5** shows that there are approximately 0.2 million tonnes of stored carbon onsite and if this were fully oxidised, this would equate to approximately 0.75 million tonnes of CO_2 emissions. It is hard to assess the future of this stored carbon onsite in the absence of the Proposed Varied Development, but it is probable that future climate change impacts will negatively affect this store of carbon, even in the absence of development.

Carbon Balance Assessment - Emissions

18.8.5. 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.

18.8.6. This section looks at the two key project stages of construction and operation (specific decommissioning activities are not included in the Carbon Calculator) and allocates emissions to those two 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 Varied Development life cycle.

Table 18.6 – Estimated Carbon Emissions during the Construction Phase

Emission source	Estimated emissions (tCO_2e)			% of overall emissions (expected scenario)
	Expected	Minimum	Maximum	
Losses due to production of turbines, BESS and construction materials	57,735	51,961	63,508	32.2%
CO_2 loss from excavated peat	5,907	-7,946	5,641	3.3%
Subtotal of emissions during construction	63,642	44,015	69,149	35.5%

18.8.7. **Table 18.6** shows that around a third of the total losses occur during the Proposed Varied Development construction phase. The majority of these are from the manufacture of the turbines and the BESS with a small proportion due to other materials used in construction (for example concrete for foundations). The emissions from the oxidation of peat excavated for infrastructure construction contributes only around 3% to the overall losses and the Carbon Calculator assumes that all the peat excavated is fully oxidised whereas the Outline Peat Management Plan *(*refer to **Appendix 12.2**) is designed to reduce these losses by reusing and restoring this peat around the site. As a result, it is expected that these losses will be less through good peat management techniques.

Table 18.7 – Estimated Carbon Emissions during the Operational Phase

Emission source	Estimated emissions (tCO_2e)			% of overall emissions (expected scenario)
	Expected	Minimum	Maximum	
Losses due to reduced carbon fixing potential	4,921	1,674	11,117	2.7%
Losses due to Dissolved Organic Carbon (DOC) & Particulate Organic Carbon (POC) leaching	120	28	243	0.1%
CO_2 loss from drained peat	-	-32,353	-0	0.0%
Losses due to reduced carbon sequestration potential of felled forestry	110,769	94,707	127,938	61.7%
Subtotal of emissions during operation	**115,810**	**64,057**	**139,298**	**64.5%**

18.8.8. **Table 18.7** shows that nearly two thirds of the emissions occur during the operational phase of the Proposed Varied Development. The most significant of these is due to the reduced future carbon sequestration potential over the lifetime of the wind farm from the reduction in area of stocked woodland in the forestry which contributes nearly 62%% of losses in total. It should be noted that gains from restocking following temporary felling or compensatory woodland planting are not included in the Carbon Calculator. The other sources of losses from peat, including reduced carbon fixing potential, peat drainage and carbon leaching from peat contribute minimal losses.

18.8.9. Emissions produced during the decommissioning phase are not included separately in the Carbon Calculator assessment, although an estimate of these are included within the 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.

Carbon Balance Assessment – Gains

18.8.10. **Table 18.8** shows the estimated carbon gains over the lifetime of the Proposed Varied Development from restoration of forest to bog, and restoration of the borrow pit areas with peat. The gains from restoration of felled forest to bog are negative because they represent avoided emissions resulting from the predicted increase in the water table in these areas. 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 re-wetting of peat. The restoration of the borrow pits produces a very small estimate of emissions rather than gains due to the uncertainty of restoring shallow peat deposits.

Table 18.8 – Estimated Carbon Gains

Source of gains	Estimated gains (tCO_2e)			% of overall gains (expected scenario)
	Expected	Minimum	Maximum	
Change in emissions due to improvement of felled forestry	-14,360	-6,657	-23,881	100.2%
Change in emissions due to restoration of peat from borrow pits	21	41	0	-0.1%
Total estimated gains	**-14,339**	**-6,616**	**-23,881**	**100%**

Comparison with the Baseline

18.8.11. The soil carbon losses from the Proposed Varied Development are estimated at 11,000 tonnes of CO_2e. This represents 1.4% of the estimated total stored carbon onsite (as set out in Table 18.4) and includes anticipated losses from excavated peat, losses due to leaching and losses from reduced carbon fixing potential. 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.

Comparison of Soil Carbon Losses with Carbon Gains from Restoration

18.8.12. **Table 18.9** shows a comparison of soil carbon losses with the estimated carbon gains from restoration. The estimated carbon is shown for the expected value within the carbon calculator.

Table 18.9 – Comparison of Soil Carbon Losses with Restoration Gains

Soil carbon loss category	Expected tCO_2e	Restoration gain category	Expected tCO_2e
CO_2 loss from removed peat	5,907	Change in emissions due to improvement of felled forestry	-14,360

Soil carbon loss category	Expected tCO_2e	Restoration gain category	Expected tCO_2e
Losses due to reduced carbon fixing potential	4,921	Change in emissions due to restoration of peat from borrow pits	21
Losses due to Dissolved Organic Carbon (DOC) & Particulate Organic Carbon (POC) leaching	120		
Total soil carbon losses	**10,948**	**Total restoration gains**	**-14,339**

18.8.13. **Table 18.9** shows that the ratio between soil carbon loss and restoration gains is around 1:1.3; there are 1.3 times more restoration gains than soil carbon losses.

Carbon Balance Assessment – Savings

18.8.14. **Table 18.10** 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 from September 2024 when the UK's last coal power station closed, there is no more coal-fired generation remaining in the UK to be displaced. The average 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. The fossil fuel mix represents displacement of existing fossil fuel electricity generation plant, the majority of which uses natural gas which is planned to be removed over the lifetime of the Proposed Varied Development. However, to meet Net Zero targets, renewable electricity will be required to displace existing transport (diesel and petrol) and heating (natural gas and burning oil) fuels and therefore, the fossil fuel mix is probably the closest representation of the energy that the Proposed Varied Development's generated electricity would be displacing.

Table 18.10 – Estimated Annual and Lifetime Carbon Savings from the Operation of the Proposed Varied Development from the Displacement of Grid Electricity

Counterfactual emission factor – annual savings	Estimated savings (tCO_2e per year)		
	Expected	Minimum	Maximum
Coal-fired electricity generation	231,837	220,245	243,428
Grid-mix of electricity generation	44,652	42,419	46,884
Fossil fuel - mix of electricity generation	**113,017**	**107,366**	**118,668**

Counterfactual emission factor – lifetime savings	Estimated savings (tCO_2e over lifetime)		
Coal-fired electricity generation	9,273,463	8,809,790	9,737,136
Grid-mix of electricity generation	1,786,075	1,696,771	1,875,379
Fossil fuel - mix of electricity generation	**4,520,687**	**4,294,653**	**4,746,721**

Payback Time and Carbon Intensity

18.8.15. 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 generated units of electricity. This calculation divides the net emissions by the total units of electricity expected to be produced over the lifetime of the Proposed Varied Development. This calculation is useful as it is independent of the emission factor used for displaced electricity.

18.8.16. **Table 18.11** shows the estimated payback time, if the electricity generated by the Proposed Varied Development is assumed to displace electricity generated by the grid for a range of different displaced fuels, and the carbon intensity of the units produced.

Table 18.11 – 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	0.7	0.3	0.9
Grid-mix of electricity generation	3.7	1.8	4.8
Fossil fuel - mix of electricity generation	**1.5**	**0.7**	**1.9**
Carbon intensity of electricity generated	**Carbon intensity ($kgCO_2e/kWh$)**		
Carbon intensity of units generated	0.016	0.008	0.021

18.8.17. **Table 18.11** shows that the Proposed Varied Development is estimated to have a payback of 1.5 years based on the fossil fuel mix, and the carbon intensity of units produced would be significantly lower than the current grid mix (the value of 0.177 $kgCO_2e/kWh$ 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 Varied 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 Varied Development would be shown to be even more beneficial.

Sensitivity Analysis

18.8.18. The assessment of the payback of the Proposed Varied 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 significant 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 site parameters on the payback time under a fossil mix counterfactual emission factor, whilst holding all other parameters constant, as shown in **Table 18.12**.

Table 18.12 – Impact of Changing Individual Parameters on Expected Payback in Years

Sensitivity analysis	Estimated time to payback (years) (based on expected scenario, fossil fuel mix electricity factor)		
	As assessed: Expected	Reduce parameter	Increase parameter
Average extent of drainage around drainage features at site (m) – 28 m, impact of decreasing and increasing by 50%	1.5	1.4	1.5
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1}) – 3.51 tC ha^{-1} yr^{-1}, impact of decreasing and increasing by 50%	1.5	1.0	2.0
Average water table depth at site (m) – 0.04 m, impact of decreasing and increasing by 50%	1.5	1.4	1.4
Water table depth in felled plantation (m) before improvement – 0.30 m,	1.5	1.6	1.4

Sensitivity analysis	Estimated time to payback (years) (based on expected scenario, fossil fuel mix electricity factor)		
	As assessed: Expected	Reduce parameter	Increase parameter
impact of decreasing and increasing by 50%			

18.8.19. **Table 18.12** shows that increasing or decreasing key site-based parameters by 50% has minimal impact on the overall expected payback, which improves the confidence around the payback range. The parameter with the highest impact is the estimated average rate of carbon sequestration in timber. However, since the losses from felling forestry do not take into account the gains from restocking or compensatory planting, it is reasonable to assume the losses from forestry sequestration are overestimated within the Carbon Calculator.

18.9. Summary

18.9.1. The results of the Carbon Calculator show that the Proposed Varied Development is estimated to save over 100,000 tonnes of CO_2e per year, through the displacement of grid electricity, based on the current fossil fuel grid mix. Displacement of existing sources of generating capacity depends on the time of day and how the grid needs to be balanced. Although it depends on the rate of electrification of transport and heat in buildings, it is reasonable to anticipate that over the lifetime of the Proposed Varied Development that generated electricity will displace existing fossil fuel usage.

18.9.2. The assessment of the Proposed Varied Development estimates losses of nearly 180,000 tonnes of CO_2e. The largest proportion of these is from the future lost sequestration potential of forestry that is felled for the construction of the windfarm However, future gains from forestry restocking and compensatory planting are not included in the Carbon Calculator and therefore the total losses are likely to be overstated. The manufacture of the turbines and the BESS also contributes a significant proportion of the overall losses. Soil carbon losses account for around 6% of losses and it should be noted that the Carbon Calculator assumes that all extracted and drained peat is oxidised and does not include any reduction from peat that is reinstated. The baseline assessment demonstrated that around 1.4 % of the soil carbon within the site boundary could be affected by the Proposed Varied Development. Restoration of areas of forestry to bog are estimated to produce gains over the lifetime of the Proposed Varied Development through blocking of drains, re-wetting of peat and restoring surface vegetation; these gains are estimated at around 14,000 tonnes of CO_2e.

18.9.3. The estimated payback time of the Proposed Varied Development, using the Scottish Government Carbon Calculator, is 1.5 years, with a minimum/maximum range of 0.7 to 1.9 years, based on the fossil fuel mix of the electricity grid. There are no current guidelines about what payback time constitutes a significant impact, but 1.5 years is around 4% of the anticipated lifespan of the Proposed Varied Development. Compared to fossil fuel electricity generation projects, which also produce embodied emissions during the construction phase and then significant emissions during operation due to combustion of fossil fuels, the Proposed Varied Development has a low carbon footprint, and after 1.5 years the electricity generated is estimated to be carbon neutral and will displace grid electricity generated from fossil fuel sources or directly displace fossil fuel use for transport and heating. The carbon intensity of the electricity produced by the Proposed Varied Development is estimated at 0.016 kgCO_2e/kWh. This is well below the outcome indicator for maintaining the electricity grid carbon intensity below 0.04 kgCO_2e/kWh required by the Scottish Government in the Climate Change Plan (Scottish Government, 2026), and therefore; the Proposed Varied Development is evaluated to have an overall beneficial effect on carbon emissions associated with energy generation.

18.9.4. When compared to the Consented Development, the Proposed Varied Development is anticipated to save an additional 2,367,520 tonnes of CO_2e over its operational lifetime.

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Abbreviations

Abbreviations	Definition
BESS	Battery Energy Storage System
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DOC	Dissolved Organic Carbon
EIA	Environmental Impact Assessment
EIA-R	Environmental Impact Assessment Report
GHG	Greenhouse Gas
GWP	Global Warming Potential
ha	Hectare
IEMA	Institute of Environmental Assessment and Management
kWh	Kilowatt-hour
LCA	Life Cycle Assessment
m	Metre
MW	Megawatt
MWh	Megawatt-hour
NPF4	National Planning Framework 4
POC	Particulate Organic Carbon
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage (now NatureScot)
tC	Tonnes of carbon
tCO_2	Tonnes of carbon dioxide
tCO_2e	Tonnes of carbon dioxide equivalent