Coille Beith Wind Farm

Technical Appendix 2.2: Carbon Balance Assessment

June 2025

Contents

1. Introduction and Methodology

1.1.1 This carbon balance assessment report has been prepared on behalf of the Applicant in support of an application for consent to construct and operate the Proposed Development.

1.1.2 The carbon balance assessment has been undertaken using an offline version of the Scottish Government's online calculation tool, version 2.14.1[1] (as advised by the Energy Consents Unit on 15th April 2025) which has been developed to assess the carbon impact of wind farm development. The carbon assessment tool calculates the CO_2 emissions from the Proposed Development and compares these against the CO_2 emissions estimated from other electricity generation sources.

1.1.3 This carbon calculator results are shown in **Annex 1: Carbon Calculator Results and Charts**.

1.1.4 The carbon calculator tool uses the methodology and approach developed by Nayak *et al*[2].

2. Input Parameters

2.1.1 This assessment should be read in conjunction with the carbon calculator inputs which are detailed in the EIA Report and Technical Appendices, including **Chapter 2** (EIA Report Volume 2). Information to inform the carbon calculator tool has been derived from either specific parameters of the Proposed Development itself or has been based on industry standard information.

2.2 Characteristics of the Proposed Development

2.2.1 The Proposed Development would comprise up to 11 turbines with an operational life of 50 years, and a total installed capacity of 79.2 MW. The net capacity factor for the Proposed Development is estimated to be approximately 35 %, which has been based on a technical estimate from wind data analysis.

2.2.2 The CO_2 emissions generated during the life of the wind turbines themselves, including those from created during manufacture and removal are calculated using default values within the carbon calculator.

2.3 Peatland and Environmental Characteristics of the Site

2.3.1 The Proposed Development is located on land ('the Site') which covers an area of approximately 1,306 hectares (ha) and is located approximately 18 km southwest of Lairg and 20 km northwest of Bonar Bridge, the Highlands, Scotland.

2.3.2 The Site is located on the southern slopes of Strath Oykel. The Site is located within an area of commercial forestry, typical of the valley sides along Strath Oykel, while more open hills rise to the north and south. The River Oykel and singletrack A837 pass through the strath, around 2 km north of the Site, and there is another minor road around 2 km to the northeast that runs along the southern side of the river linking up areas of dispersed settlement.

2.3.3 The Site is centred at approximate Ordnance Survey National Grid NH415986). The Site location and setting are described in more detail within **Chapter 2** (EIA Report Volume 2).

2.3.4 Digital solid and drift geological maps sourced from the British Geological Survey (BGS) Digimap (1:50,000 scale) website[3] show that there are superficial deposits across much of the Site, shown by BGS mapping to be peat and till. There are significant deposits of alluvium along the River Oykel in the north of the Site, and significant areas where no superficial deposits are displayed on BGS mapping. There are small areas of hummocky glacial deposits in the centre of the Site.

2.3.5 The majority of the Site is underlain by Altnaharra Psammite Formation metamorphic bedrock. A small area is underlain by Glen Achall Psammite and Semipelite Member in the southwestern part of the Site. There are six faults on-site, four run southwest to northeast, with only one that entirely transects the Site, two run northwest to southeast but neither transect the Site.

2.3.6 There are no known borehole records available online within the Site, however borehole records are available for Oykel Bridge Hotel, 2.4 km west of the Site. The records suggest that here psammite rock

[1] https://informatics.sepa.org.uk/CarbonCalculator/index.jsp
[2] Nayak D.R., Miller D., Nolan A., Smith P., Smith J.U. (2011). Calculating Carbon Savings from Windfarms on Scottish Peat Lands: A New Approach.
[3] BGS Geology Viewer - British Geological Survey [accessed February 2025]

is present from 9-170 m deep, with sand and gravel for the first two meters before hitting the unspecified rock head.

2.3.7 A review of the National Soil Map of Scotland[4] shows the majority of the Site to be underlain by peaty gleys with dystrophic blanket peat with peaty gleyed podzols, alluvial soils in the north of the Site and deep blanket peat on the southern boundary in an area of approximately 3 km².

2.3.8 The SNH Carbon and Peatland 2016 map[5] shows the majority of the Site to have Class 5 peat soil (carbon-rich soils and deep peat, no peatland vegetation), with areas of Class 2 peatland in the centre and north of the Site. There are smaller areas of Class 1 peatland (carbon-rich soils and deep peat, priority peatland vegetation) along the southern Site boundary, and Class 3 peatland in the west of the Site. The north of the Site, in the vicinity of the River Oykel, has mineral soils.

2.3.9 Peat probing and peat coring investigations were undertaken and showed peat is not continuous across the Site. Significant areas of the Site have no peat or peat <1 m depth, with large areas of deeper peat in the east. The surveys also investigated peat characteristics and underlying geological conditions.

2.3.10 Full results of the peat surveys are described within **Technical Appendix 8.2, 8.3**, and **8.4** (EIA Report, Volume 4), and **Figures 8.9** and **8.10** (EIA Report Volume 3a) show the peat depth distribution across the Site based on the quantitative data collected from surveys.

2.3.11 The spatial occurrence and depth distribution of peat across the Site has been examined extensively based on the Developments on Peatland: Site Surveys guidance (SNH, SEPA, Scottish Government and The James Hutton Institute) and high-density probing has taken place at all infrastructure locations to determine peat depth and facilitate appropriate and accurate minimisation.

2.3.12 As outlined in **Technical Appendix 8.2** (EIA Report Volume 4) peat probing was undertaken on a 100 m grid across the Site, at 50 m intervals with 10 m offset probes along all proposed and existing access tracks and across the footprint of all infrastructure on a 10 m grid and probing within a 50 m buffer area on a 20 m grid.

2.3.13 Peat has been determined to be present up to a depth of 3.8 m based on 7,067 depth of penetration probes and 12 cores. A distinct acrotelm layer was identified in 10 of the 12 cores and averaged 0.16 m in thickness. Coring for peat depth verification and assessment of peat characteristics was completed at 12 locations.

2.3.14 No amorphous peat (Von Post value of H9 or above) was identified on-site.

2.3.15 The data indicates that peat >0.5 m depth is present across 49.2.5% of the Site; and no peat (0 - 0.5 m depth) is present across 26.5% of the Site. Peat >1.0 m depth is present at 24.3% of the Site.

2.3.16 The data collected has been used to produce an interpreted maximum depth of peat contour map, see **Figure 8.10** (EIA Report, Volume 3a).

2.3.17 Peat is present on the Site up to a depth of 3.8 m with the majority of peat in the south where an almost continuous, but variable depth, of peat has been identified. Peat is confined to pockets in all other parts of the Site, although some are quite large, with the number of pockets decreasing with proximity to the River Oykel in the north of the Site.

2.3.18 The deepest peat has been avoided as much as possible by the Proposed Development infrastructure.

2.3.19 The expected, minimum and maximum values relevant for the Site included within the carbon calculator are 1.12 m, 0 m and 3.8 m respectively although it should be noted that the assessment of peat/ soil depth assumes peat exists to the full depth of the probed depth value, with potential for an over estimation dependent on the underlying organic material/clay present.

2.3.20 The mean annual temperature was derived based on the mean annual air temperature for Rosehall over a five year period between 2020 to 2025 . The mean annual air temperature for Rosehall was found to be 7.8 °C, with minimum and maximum values of -3 °C and 20 °C respectively.

2.3.21 The carbon content of the peat has been derived using the carbon assessment tool default values in the absence of laboratory test analysis of peat cores taken at the Site, 65 %, 19 % and 65 % have been used respectively for the expected, minimum and maximum values.

2.3.22 Generic hydrological parameters have been used for average groundwater. A value of 0.3 m has been used as the expected value. A 'maximum' value of 0.5 m has been used to represent areas of intact peat (the higher the water table the longer the payback period), and a 'minimum' value of 0.1 m has been used to represent areas of eroded peat.

2.3.23 The extent of drawdown on drainage features due to excavations on-site is variable and can extend between 2 m and 50 m horizontally around the feature. Site specific values are not available, so the

[4] http://map.environment.gov.scot/Soil_maps/?layer=1 [accessed February 2025]
[5] https://www.environment.gov.scot/maps/scotlands-environment-map/ [accessed February 2025]

standard values from 'Windfarm Carbon Calculator Web Tool, User Guidance' have been used. Therefore, the expected value is 10 m, minimum is 5 m and maximum 50 m.

2.3.24 For dry soil bulk density a value of 0.2 g/cm^3 has been used in the absence of specific laboratory testing undertaken with a maximum of 0.3 g/cm^3 based on the tool parameters.

2.3.25 For vegetation restoration, a conservative estimate of five years has been assumed as a reasonable time period for regeneration of most bog plants based on the Site, with minimum and maximum values of 2 and 10 years. The carbon accumulation rate for peatland has been derived based on the carbon calculator guidance, 0.25 tC ha-1 yr-1, with the accumulation rates of 0.12 tC ha-1 yr-1 and 0.31 tC ha-1 yr-1 adopted as the minimum and maximum values respectively.

2.4 Counterfactual Emission Factors

2.4.1 The most recent counterfactual emission factors for three methods of energy generation have been used as provided in the carbon calculator tool. These are 0.207 tCO2 MWh-1 CO2 emissions for grid mix, 0.945 tCO2 MWh-1 for coal, and 0.424 tCO2 MWh-1 for fossil fuel mix.

2.5 Proposed Development

2.5.1 For the purposes of this assessment, the turbine foundations are assumed to remain unchanged regardless of their location within the Site and the calculation was based on a central excavation of approximately 22 m diameter and an approximate depth of 3 m to 5 m subject to prevailing ground conditions. Based on the peat probing survey results, the average peat depth at the turbine footprint is estimated to be 0.6 m. The minimum and maximum expected peat depths are 0.22 m and 1.61 m respectively.

2.5.2 The proposed turbine permanent area of the hardstandings and laydowns total 42,405 m^2, with the same excavation footprint. Based on the peat probing survey results, the average peat depth at the turbine hardstandings is calculated as 0.22 m. For the purposes of the carbon calculator, minimum and maximum depths recorded around hardstandings of 0.22 m and 1.61 m respectively are used.

2.5.3 A total of 9,540 m of new access tracks are outlined as part of the Proposed Development with an additional 3,180 m for the West Access Track option. A total of 1,800 m are upgrades to existing tracks and 1,600 m are floating tracks. The proposed width of the excavated access track is 5 m with 0.5 m shoulders on both sides. Expected peat depths used are 0.81 m for excavated tracks.

2.5.4 A total of 52.16 ha of forestry is to be cleared as part of the Proposed Development. An area of 52.16 ha of compensatory planting is proposed to be replanted.

2.5.5 Peat excavated for other permanent excavations include substations, with a total area of 10,500 m^2 and peat excavation volume of 5,400m^3 has also been considered in the carbon balance assessment.

2.5.6 The potential peat excavation volumes associated with the proposed borrow pit has also been considered, covering 1.68 ha in area.

2.5.7 Temporary infrastructure such as construction compounds, and cable trenches are not expected to result in a permanent displacement of peat.

2.5.8 Peat excavation volumes have been estimated based on the interpolated peat depth survey information, as outlined in **Technical Appendix 8.3** (EIA Report Volume 4).

2.5.9 The peat landslide hazard is fixed as 'negligible' in the online carbon calculator.

2.6 Opportunities for Carbon Sequestration

2.6.1 Any local improvements to carbon sequestration, such as areas of peatland habitat restoration, would result in a reduction in the net carbon emissions from the Proposed Development.

2.6.2 Opportunities for potential habitat and peatland improvement are summarised in **Technical Appendix 2.3** and **8.2** (EIA Report Volume 4)and Chapter 6 (EIA Report Volume 2) which includes up 95 ha of peatland restoration.

2.6.3 Drainage implemented during the construction phase of the Proposed Development would be removed prior to operation and has been assumed to be temporary in duration. For the purposes of the carbon calculator the expected value for completion of backfilling, removal of any surface drains, and restoration of the hydrology is 0.25 years, and the minimum and maximum are assumed to be 0.1 year and 3 years respectively.

2.6.4 It has been assumed that at the end of the operational phase of the Proposed Development, the Site would either be re-powered or decommissioned. In the event of decommissioning, it has been assumed

that access tracks constructed would remain in situ, drainage channels and gullies in peat would be blocked, and turbine infrastructure removed.

3. Results

3.1.1 The estimated total carbon losses as calculated by the carbon calculator tool is shown in **Table 3.1**.

Table 3.1 – Total Carbon Losses

Source	Expected CO_2 Losses (tCO_2)	Minimum Value CO_2 Losses (tCO_2)	Maximum Value CO_2 Losses (tCO_2)
Losses due to turbine life	68,857	68,857	68,857
Losses due to backup	73,542	0	73,542
Losses due to reduced carbon fixing potential	2,177	670	11,150
Losses from soil organic matter	33293	-2,207	135,386
Losses from Dissolved Organic Carbon and Particulate Organic Carbon Leaching	824	0	33,455
Losses due to forestry felling	105,199	95,342	106,893
Total losses of carbon dioxide	283,891	162,663	429,283

3.1.2 The carbon losses calculated are independent of the generation mix used to calculate the overall carbon balance. It is assumed that back up capacity is derived from conventional fossil fuel generation.

3.1.3 The predicted payback time for the Proposed Development, as determined from the online carbon calculator, is shown in **Table 3.2**.

Table 3.2 – Carbon Payback Period

Source	Counterfactual Emission Factors (tCO_2 MWh^{-1})	Carbon Payback Period (years)		
		Expected Value	Minimum Value 0% Balancing Capacity	Maximum Value 5% Balancing Capacity
Coal fired generation	0.945	1.2	0.5	1.9
Grid mix generation	0.207	5.6	2.3	8.8
Fossil fuel mix generation	0.424	2.7	1.1	4.3

4. Summary

4.1.1 The carbon assessment indicates that the carbon emission payback time for the Proposed Development would be between 0.8 and 4.3 years, with an expected value of 2.7 years. This is when compared against a fossil fuel mix generation.

Annex 1: Carbon Calculator Results and Charts

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Results

PAYBACK TIME AND CO_2 EMISSIONS

Note: The carbon payback time of the windfarm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or grid-mix.

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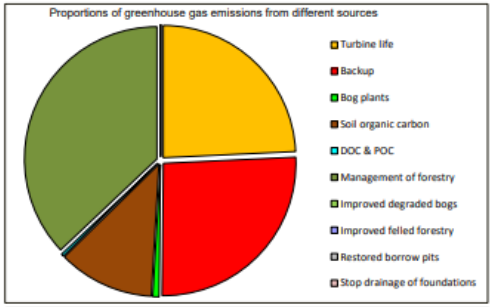
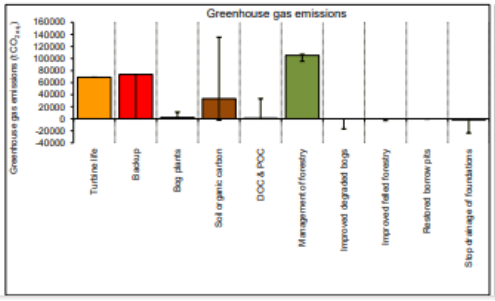
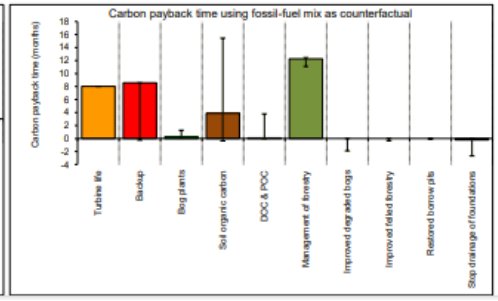
	Exp.	Min.	Max.
1. Windfarm CO_2 emission saving over...			
...coal-fired electricity generation (tCO_2 yr^{-1})	229472	222915	236028
...grid-mix of electricity generation (tCO_2 yr^{-1})	50265	48829	51701
...fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	102959	100017	105900
Energy output from windfarm over lifetime (MWh)	12141360	11794464	12488256
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	68857	68857	68857
3. Losses due to backup	73542	0	73542
4. Losses due to reduced carbon fixing potential	2177	670	11150
5. Losses from soil organic matter	33293	-2207	135386
6. Losses due to DOC & POC leaching	824	0	33455
7. Losses due to felling forestry	105199	95342	106893
Total losses of carbon dioxide	283891	162663	429283
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	0	0	-16688
8b. Change in emissions due to improvement of felled forestry	0	0	-2979
8c. Change in emissions due to restoration of peat from borrow pits	0	0	-351
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-1818	0	-23674
Total change in emissions due to improvements	-1818	0	-43693

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t $CO_{2\ eq}$)	**282073**	**118970**	**429283**
Carbon Payback Time			
...coal-fired electricity generation (years)	1.2	0.5	1.9
...grid-mix of electricity generation (years)	5.6	2.3	8.8
...fossil fuel - mix of electricity generation (years)	**2.7**	**1.1**	**4.3**
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	No gains!	No gains!	No gains!
Ratio of CO_2 eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	**23**	**10**	**36**







Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions

	Exp.	Min	Max
Turbine life	68857	0	0
Backup	73542	73542	0
Bog plants	2177	1507	8973
Soil organic carbon	33293	35499	102093
DOC & POC	824	824	32632
Management of forestry	105199	9857	1694
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	0
Stop drainage of foundations	0	0	0

Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions				Carbon payback time (months)		
	Exp.	Min.	Max.	Exp.	Min.	Max.
Turbine life	68857	0	0	8	0	0
Backup	73542	73542	0	9	9	0
Bog plants	2177	1507	8973	0	0	1
Soil organic carbon	33293	35499	102093	4	4	12
DOC & POC	824	824	32632	0	0	4
Management of forestry	105199	9857	1694	12	1	0
Improved degraded bogs	0	0	-16688	0	0	-2
Improved felled forestry	0	0	-2979	0	0	0
Restored borrow pits	0	0	-351	0	0	0
Stop drainage of foundations	-1818	-1818	-21856	0	0	-2
	282073			33		