Foel Fach Wind Farm Limited.

Foel Fach Energy Wind Farm - Environmental Statement Volume III

Appendix 13.1: Carbon Balance Assessment

Project Reference: 664094

DECEMBER 2025

Energy for generations

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APPENDIX 13.1: CARBON BALANCE ASSESSMENT

13.1 Methodology

This carbon balance assessment uses The Scottish Government's Carbon Assessment Tool (version 2.14.1), which is based upon the work of Nayak *et al*., (2008[1], 2010[2]) and Smith *et al*., (2011)[3]. The latest online version of the Scottish Government Carbon Calculator Tool (version 1.8.1) was unavailable during the course of this assessment while undergoing maintenance and a server upgrade. Version 2.14.1 of the Calculator was provided as an Excel spreadsheet calculator by the relevant case officer as a suitable alternative. As there is no Welsh tool, while the tool is distributed by the Scottish Government, it is an industry recognised approach to determine the carbon emissions associated with wind farm developments.

The Carbon Assessment Tool adopts a lifecycle methodology approach to estimate the GHG emissions and savings associated with proposed renewable energy developments. It calculates the anticipated effects of the Proposed Development on peat and forestry habitats, and subsequent implications for greenhouse gas (GHG) emissions. The Carbon Assessment Tool also accounts for the emissions associated with the construction and decommissioning of the Proposed Development, as well as the emissions savings from operation.

Embodied Emissions

GHG emissions from turbine fabrication are based on a full lifecycle analysis of a typical turbine. This includes GHG emissions resulting from material production, transportation, erection, operation, dismantling and removal of turbines, and from foundations and transmission grid connection equipment to the existing electricity grid system. As the Scottish Government Carbon Assessment Tool does not account for the embodied emissions of a battery energy storage system (BESS) by standard, a supplementary analysis of these components was carried out and integrated into the outputs of the tool.

Losses Due to Back-up

Due to the inherent variability of wind generated electricity, it is recognised that conventional generation facilities are required to stabilise supply. Nayak *et al.,* (2008) refers to 'backup power generation' and identifies that the balancing capacity (as referred to henceforth) required is estimated as 5% of the rated capacity of the wind farm. It is also stated that balancing capacity is only necessary where wind power contributes more than 20% to the national grid.

It is assumed that the balancing capacity is from fossil fuels and that where such power is required, there will be additional emissions of 10% due to reduced thermal efficiency of the

[1] Nayak et al, (2008) Available at: http://www.scotland.gov.uk/Publications/2008/06/25114657/0

[2] Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., (2010), Calculating carbon budgets of wind farms on Scottish peatland. Mires and Peat 4: Art. 9. Available Online: http://www.mires-and-peat.net/map04/map_04_09.htm

[3] Smith, J.U., Graves, P., Nayak, D.R., Smith, P., Perks, M., Gardiner, B., Miller, D., Nolan, A., Morrice, J., Xenakis, G., Waldron, S., and Drew, S. (2011) Carbon implications of windfarms located on peatlands – Update of the Scottish Government Carbon Calculator tool. Final Report, RERAD Report CR/2010/05.

reserve generation. This value is the recommended default through the Carbon Assessment tool, sourced from Dale *et al.,* (2004).

The inclusion of BESS within the Proposed Development removes the need for backup power generation, allowing the input value for this Development to be 0%.

Input Data

A variety of data sources have been utilised to compile the input data needed for The Scottish Government's Carbon Assessment Tool. Wind farm design and site-specific data have been used wherever possible; however, where not available, standard (default) data or estimates have been applied. These are detailed below in **Table 13.1**. To reflect design and real-world uncertainty and range of +/- 10% has been applied to relevant categories.

Table 13.1 Input Parameter Data for The Scottish Government's Carbon Assessment Tool

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Wind farm characteristics				
Dimensions				
No. of turbines	10	10	10	Infrastructure design and aggregate estimate
Duration of consent (years)	40	40	40	Infrastructure design and aggregate estimates
Power rating of 1 turbine (MW)	7.2	7	7.2	Infrastructure design and aggregate estimates
Capacity factor	25.0	22.5	27.5	Dukes (2025)
Fraction of output to backup (%)	0	0	0	Default value of carbon calculator - (Nayak *et al*., 2008)
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Default value of carbon calculator - (Dale *et al*., 2004)
Total CO_2 emission from turbine life (tCO_2 MW^{-1}) (e.g.	Calculate wrt	Calculate wrt	Calculate wrt	Carbon calculator calculation methodology

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
manufacture, construction, decommissioning)	installed capacity	installed capacity	installed capacity	
Type of peatland	Acid Bog			Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average annual air temperature at site (°C)	9.14	5.27	13.0	Met Office weather station: Bala
Average depth of peat at site (m)	0.16	0.0	1.92	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Content of dry peat (% by weight)	55	49	61	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average extent of drainage around drainage features at site (m)	0.75	0.5	1.0	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average water table depth at site (m)	1.8	0.5	2.2	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Dry soil bulk density (g cm^{-3})	0.2	0.2	0.2	Default value of carbon calculator - (Turunen *et al.*, 2001; Botch *et al.*, 1995)
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	30	30	30	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.225	0.275	Default value of carbon calculator - (Lilly *et al.*, 2010)
Forestry Plantation Characteristics				

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Area of forestry plantation to be felled (ha)	0	0	0	Not Applicable
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.60	3.24	3.96	Default value of carbon calculator - (Cannell, 1999)
Counterfactual emission factors				
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.95	0.95	0.95	Default value
Grid-mix emission factor (t CO_2 MWh^{-1})	0.21	0.21	0.21	Default value
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.42	0.42	0.42	Default value
Borrow pits				
Number of borrow pits	1	1	1	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average length of pits (m)	42	42	42	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average width of pits (m)	60	60	60	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average depth of peat removed from pit (m)	0	0	0	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Foundations and hard-standing area associated with each turbine				
Shape (circular/octagonal/hexagonal)	Circular			Infrastructure design and aggregate estimates
Average length of turbine foundations [m]	6	5.4	6.6	Infrastructure design and aggregate estimates
Average width of turbine foundations [m]	28	25.2	30.8	Infrastructure design and aggregate estimates

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Average depth of peat removed from turbine foundations [m]	0.2	0.1	0.2	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Average length of hard-standing [m]	213	192	234	Infrastructure design and aggregate estimates
Average width of hard-standing [m]	70	63	77	Infrastructure design and aggregate estimates
Average depth of peat excavated when constructing hard-standing [m]	0.2	0.1	0.2	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Volume of concrete (m^3)	9,891	8902	10,881	Infrastructure design and aggregate estimates
Access tracks				
Total length of access track (m)	11,454	10,309	12,600	Infrastructure design and aggregate estimates
Existing track length (m)	830	747	913	Infrastructure design and aggregate estimates
Length of access track that is floating road (m)	0	0	0	Infrastructure design and aggregate estimates
Width of access track that is floating road (m)	0	0	0	Infrastructure design and aggregate estimates
Depth of floating road (m)	0	0	0	Infrastructure design and aggregate estimates
Length of floating road that is drained (m)	0	0	0	Infrastructure design and aggregate estimates
Average depth of drains associated with floating roads (m)	0	0	0	Infrastructure design and aggregate estimates

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Length of access track that is excavated road (m)	10,624	9,562	11,687	Infrastructure design and aggregate estimates
Excavated road width (m)	5	5	7.5	Infrastructure design and aggregate estimates
Average depth of peat excavated for road (m)	0.12	0.11	0.13	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Length of access track that is rock filled road (m)	0	0	0	Infrastructure design and aggregate estimates
Rock filled road width (m)	0	0	0	Infrastructure design and aggregate estimates
Rock filled road depth (m)	0	0	0	Infrastructure design and aggregate estimates
Length of rock filled road that is drained (m)	0	0	0	Infrastructure design and aggregate estimates
Average depth of drains associated with rock filled roads (m)	0	0	0	Infrastructure design and aggregate estimates
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (e.g. sand) (m)	0	0	0	Infrastructure design and aggregate estimates
Average depth of peat cut for cable trenches (m)	0	0	0	Not Applicable
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	1,175	1,058	1,293	Peat Specialist **(ES Volume II, Chapter 7: Land, Soils and Water**)
Area of additional peat excavated (m^2)	44,445	40,001	48,890	Peat Specialist (**ES Volume II, Chapter**

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
				7: Land, Soils and Water)
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	Low	Low	Low	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
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)	4.8	4.3	5.3	Ecology Specialist (**ES Volume II, Chapter 5: Terrestrial Ecology**)
Water table depth in degraded bog before improvement (m)	0.3	0.2	0.5	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Water table depth in degraded bog after improvement (m)	0.1	0	0.3	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	5	2	10	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	20	15	30	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Not Applicable
Water table depth in felled area before improvement (m)	N/A	N/A	N/A	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Water table depth in felled area after improvement (m)	N/A	N/A	N/A	Peat Specialist (**ES Volume II, Chapter**

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
				7: Land, Soils and Water)
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	N/A	N/A	N/A	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	N/A	N/A	N/A	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	No restoration of peat planned at the borrow pit
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	N/A	N/A	N/A	No restoration of peat planned at the borrow pit
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	N/A	N/A	N/A	No restoration of peat planned at the borrow pit
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	N/A	N/A	N/A	No restoration of peat planned at the borrow pit
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	N/A	N/A	N/A	No restoration of peat planned at the borrow pit
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hard standing before restoration (m)	1.6	1.2	2.2	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Water table depth around foundation and hard standing after restoration (m)	15	15	15	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Time to completion of backfilling, removal of any surface drains,	5	5	5	Peat Specialist (**ES Volume II, Chapter**

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
and full restoration of hydrology (years)				**7: Land, Soils and Water**)
Early removal of drainage from foundations and hardstanding				
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Will you control grazing on degraded areas?	No	No	No	Peat Specialist (**ES Volume II, Chapter 7: Land, Soils and Water**)
Will you manage areas to favour reintroduction of species	N/A	N/A	N/A	HMP Specialist
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Output data

CARBON ASSESSMENT TOOL v2.14.1			
Output data	**Expected value**	**Minimum value**	**Maximum value**
1. Wind farm CO_2 emission saving over...			
...coal-fired electricity generation (t CO_2 / yr)	149,008	130,382	163,908
...grid-mix of electricity generation (t CO_2 / yr)	32,640	28,560	35,904
...fossil fuel-mix of electricity generation (t CO_2 / yr)	66,856	58,499	73,542
Energy output from windfarm over lifetime (MWh)	6,307,200	5,518,800	6,937,920
2. Total CO_2 losses due to wind farm (tCO_2e)			

CARBON ASSESSMENT TOOL v2.14.1			
Output data	**Expected value**	**Minimum value**	**Maximum value**
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	65,723	63,542	66,036
3. Losses due to backup	0	0	0
4. Losses due to reduced carbon fixing potential	1,747	1,301	2,491
5. Losses from soil organic matter	-29,843	-25,300	-25,275
6. Losses due to DOC & POC leaching	5	0	50
7. Losses due to felling forestry	0	0	0
8. Losses due to BESS	3,760	3,384	4,136
Total losses of carbon dioxide	41,393	42,928	47,438
8. Total CO_2 changes due to improvement of site (tCO_2e)			
8a. Change in emissions due to improvement of degraded bogs	-107	0	-1,645
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	-107	0	-1,645
Results			
Net emissions of carbon dioxide (tCO_2e)	41,285	41,283	47,438
Carbon Payback Time			

CARBON ASSESSMENT TOOL v2.14.1			
Output data	**Expected value**	**Minimum value**	**Maximum value**
...coal-fired electricity generation (years)	0.3	0.3	0.4
...grid-mix of electricity generation (years)	1.3	1.1	1.7
...fossil fuel-mix of electricity generation (years)	0.6	0.6	0.8
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	7	6	9
?* Blue shaded cells denote those that have been modified from the carbon calculator output due to the inclusion of embodied emissions from BESS			