Torfichen Wind Farm

Appendix 14.1

Carbon Calculator Input and Output

Author	ITPEnergised
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Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	18	18	18	Chapter 3, Project Description.
Duration of consent (years)	50	50	50	Chapter 3, Project Description.
Performance				
Power rating of 1 turbine (MW)	6	6	6	Chapter 3, Project Description.
Capacity factor	43.5	41.3	45.7	Information provided by RES October 2023 from energy yield assessment.
Backup				
Fraction of output to backup (%)	5	0	5	Following guidance provided by Nayak et al., (2008).
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life ($tCO2\ MW^{-1}$) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 8, Ecology and Technical Appendix 8.1: NVC & Habitat Survey Report.
Average annual air temperature at site (°C)	12.96	1.57	15	Met Office data, Royal Botanic Garden Edinburgh (Location: 55.9661, -3.2116).
Average depth of peat at site (m)	0.2	0	4	Technical Appendix 10.1: Peat Landslide Hazard Risk Assessment and SLR peat calculations.
C Content of dry peat (% by weight)	55	49	62	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance".
Average extent of drainage around drainage features at site (m)	10	5	50	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance".
Average water table depth at site (m)	0.1	0.05	0.3	1.3.10 Site specific values are not available, so the values for ‘intact peat’ from ‘Windfarm Carbon Calculator Web Tool, User Guidance’ have been used as a worst-case scenario.

Input data	Expected value	Minimum value	Maximum value	Source of data
Dry soil bulk density (g cm^{-3})	0.132	0.072	0.293	Scottish generic values from 'Windfarm Carbon Calculator Web Tool, User Guidance' have been used.
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	5	2	30	Values informed by Rochefort et al., (2003).
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.12	0.31	Calculating Potential Carbon Losses & Savings from Wind Farms on Scottish Peatlands, Technical Note, Version 2.10.0.
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	9.8	8.82	10.78	Chapter 3, Project Description.
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.6	3.4	3.8	Expected value from Cannell (1999).
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh^{-1})	0.19338	0.19338	0.19338	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.432	0.432	0.432	
Borrow pits				
Number of borrow pits	2	2	2	Chapter 3, Project Description.
Average length of pits (m)	251	238	264	GIS information - borrow pit shapefile.
Average width of pits (m)	251	238	264	GIS information - borrow pit shapefile.
Average depth of peat removed from pit (m)	0.11	0.1	0.12	SLR peat calculations.
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	27	25	30	Based on information provided in Chapter 3, Project Description and input from the Project Engineer.
Average width of turbine foundations (m)	27	25	30	Based on information provided in Chapter 3, Project Description and input from the Project Engineer.
Average depth of peat removed from turbine foundations(m)	0.26	0.1	1	SLR peat calculations.
Average length of hard-standing (m)	55	45	57	Based on information provided in Chapter 3, Project Description and input from the Project Engineer.
Average width of hard-standing (m)	35	30	37	Based on information provided in Chapter 3, Project Description and input from the Project Engineer.

Input data	Expected value	Minimum value	Maximum value	Source of data
Average depth of peat removed from hard-standing (m)	0.2	0.09	0.44	SLR peat calculations.
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	9750	8775	10725	Chapter 3, Project Description. Based on turbine number and associated infrastructure.
Access tracks				
Total length of access track (m)	17034	17000	17035	Chapter 3, Project Description and GIS infrastructure shapefiles for the Proposed Development.
Existing track length (m)	0	0	0	There is no existing track within the Proposed Development's site boundary.
Length of access track that is floating road (m)	0	0	0	No floating road is proposed.
Floating road width (m)	0	0	0	
Floating road depth (m)	0	0	0	
Length of floating road that is drained (m)	0	0	0	
Average depth of drains associated with floating roads (m)	0	0	0	
Length of access track that is excavated road (m)	17034	17000	17035	Chapter 3, Project Description and GIS infrastructure shapefiles for the Proposed Development.
Excavated road width (m)	5	5	6	Chapter 3, Project Description.
Average depth of peat excavated for road (m)	0.22	0.21	0.23	SLR peat calculations.
Length of access track that is rock filled road (m)	0	0	0	No rock filled roads are proposed.
Rock filled road width (m)	0	0	0	
Rock filled road depth (m)	0	0	0	
Length of rock filled road that is drained (m)	0	0	0	
Average depth of drains associated with rock filled roads (m)	0	0	0	
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	200	Chapter 3, Project Description.
Average depth of peat cut for cable trenches (m)	0.22	0.21	0.23	SLR peat calculations.
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	3413	3400	3500	SLR peat calculations for additional infrastructure.
Area of additional peat excavated (m^2)	20788	20700	20800	SLR peat calculations for additional infrastructure.

Input data	Expected value	Minimum value	Maximum value	Source of data
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed
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)	36.96	36.96	36.96	Technical Appendix 8.6: Outline Biodiversity Enhancement Management Plan.
Water table depth in degraded bog before improvement (m)	0.3	0.1	0.5	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'degraded peat'.
Water table depth in degraded bog after improvement (m)	0.1	0.05	0.3	Standard values from "Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'intactpeat'.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10	5	15	Based on professional judgement of the project team.
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	50	50	50	The duration of consent for the Proposed Development is 50 years.
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Technical Appendix 8.6: Outline Biodiversity Enhancement and Management Plan. The felled area will not be designated for restoration to bog habitat.
Water table depth in felled area before improvement (m)	0	0	0	n/a
Water table depth in felled area after improvement (m)	0	0	0	n/a
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	A minimum value of two is required.
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	A minimum value of two is required.
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	12.57	12.57	12.57	GIS Infrastructure shapefiles.

Input data	Expected value	Minimum value	Maximum value	Source of data
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.3	0.1	0.5	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'degraded peat'.
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.1	0.05	0.3	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'intact peat'.
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	5	2	30	Same values as used for 'Time required for regeneration of bog plants after restoration'.
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	50	50	50	The duration of consent for the Proposed Development is 50 years.
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.3	0.1	0.5	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'degraded peat'.
Water table depth around foundations and hardstanding after restoration (m)	0.1	0.05	0.3	Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'intact peat'.
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	1	0.5	3	Expected values based on professional judgment.
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	Technical Appendix 8.6: Outline Biodiversity Management Plan.
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	Technical Appendix 8.6: Outline Biodiversity Management Plan.
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	Technical Appendix 8.6: Outline Biodiversity Management Plan.
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	Technical Appendix 8.6: Outline Biodiversity Management Plan.
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

Payback Time and CO_2 Emissions

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	412,368	391,513	433,223
...grid-mix of electricity generation (t CO2 / yr)	79,585	75,560	83,609
...fossil fuel-mix of electricity generation (t CO2 / yr)	177,787	168,796	186,779
Energy output from windfarm over lifetime (MWh)	20,577,240	19,536,552	21,617,928

Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	95,575	95,267	95,883
3. Losses due to backup	102,177	0	102,177
4. Lossess due to reduced carbon fixing potential	3,558	1,055	24,155
5. Losses from soil organic matter	-727	-23,405	24,051
6. Losses due to DOC & POC leaching	309	0	23,531
7. Losses due to felling forestry	6,468	5,498	7,510
Total losses of carbon dioxide	207,360	78,414	277,307

8. Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-5,267	0	-23,752
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	90	0	459
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-1,031	0	-32,319
Total change in emissions due to improvements	-6,207	0	-55,611

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	201,153	22,803	277,307
Carbon Payback Time			
...coal-fired electricity generation (years)	0.5	0.1	0.7
...grid-mix of electricity generation (years)	2.5	0.3	3.7
...fossil fuel-mix of electricity generation (years)	1.1	0.1	1.6
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	-0.07	-0.42	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	9.78	1.05	14.19