Hill of Fare Wind Farm

Technical Appendix 14.1

Carbon Calculator

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1 Carbon Calculator Input and Results

1.1 Input Data

Carbon Calculator v1.7.0
Hill of Fare Wind Farm Location: 57.114419 -2.495947
Renewable Energy Systems Ltd (RES)

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	16	16	16	Chp 2 Proposed Development Description
Duration of consent (years)	50	50	50	Chp 2 Proposed Development Description
Performance				
Power rating of 1 turbine (MW)	6.6	6.6	6.6	Chp 2 Proposed Development Description
Capacity factor	38.59	38	39	Chp 2 Proposed Development Description
Backup				
Fraction of output to backup (%)	5	5	5	RES
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	Chp 10
Average annual air temperature at site (°C)	8.01	3.56	12.45	Aboyne No.2 Met Station
Average depth of peat at site (m)	2.75	0.5	5	Appendix 10.2 PLRA
C Content of dry peat (% by weight)	42.3	19.57	64.28	Appendix 10.2 PLRA standard guidance values
Average extent of drainage around drainage features at site (m)	10	5	50	Site specific values are not available. Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance".
Average water table depth at site (m)	0.1	0.05	0.3	Site specific values are not available. Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance" for intact peat.
Dry soil bulk density (g cm^{-3})	0.15	0.072	0.293	Appendix 10.1 PLR and standard guidance values
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	5	5	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	Carbon Tool Guidence doc
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	0	0	0	
Counterfactual emission factors				

Input data	Expected value	Minimum value	Maximum value	Source of data
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	5	5	6	Chp 2
Average length of pits (m)	50	50	50	Chp 2
Average width of pits (m)	80	80	80	Chp 2
Average depth of peat removed from pit (m)	0.2	0.19	0.21	Chp 2
Access tracks				
Total length of access track (m)	27900	27899	27901	RES Existing + new
Existing track length (m)	10300	10300	10300	Chp 2 Proposed Development Description
Length of access track that is floating road (m)	17600	17599	17601	Chp 2 Proposed Development Description
Floating road width (m)	5	5	5	Chp 2 Proposed Development Description
Floating road depth (m)	0	0	0	n/a
Length of floating road that is drained (m)	0	0	0	n/a
Average depth of drains associated with floating roads (m)	0	0	0	n/a
Length of access track that is excavated road (m)	0	0	0	RES
Excavated road width (m)	5	5	6	RES
Average depth of peat excavated for road (m)	0.27	0.26	0.28	TA10.2 PMP
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	0	
Average depth of peat cut for cable trenches (m)	0	0	0	
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	No peat elsewhere, just soils present
Area of additional peat excavated (m^2)	0	0	0	No peat elsewhere, just soils present
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				

Input data	Expected value	Minimum value	Maximum value	Source of data
Improvement of degraded bog				
Area of degraded bog to be improved (ha)	51.03	29.16	72.9	Chp 8 BEMP
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	0.3	Standard values from "Standard values are from "Windfarm Carbon Calculator Web Tool, User Guidance". Values for 'intactpeat'.0.05
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)	12.56	0	12.57	Chp 14
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)	1.45	1.45	1.45	Subject to GI. total area anticipated to be 14,500m2 split across up to 6 borrow pits.
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	50	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				

Input data	Expected value	Minimum value	Maximum value	Source of data
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	This will form part of a decommissioning and restoration plan for the site in the future.
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	This will form part of a decommissioning and restoration plan for the site in the future.
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	This will form part of a decommissioning and restoration plan for the site in the future.
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	This will form part of a decommissioning and restoration plan for the site in the future.
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

Input data	Expected value	Minimum value	Maximum value	Source of data
1				
Number of turbines in this area	16	16	16	Chp2 Proposed Development Description
Turbine foundations				
Depth of hole dug when constructing foundations (m)	0.2	0.2	0.2	m
Aproximate geometric shape of whole dug when constructing foundations	Circular	Circular	Circular	assumes subformation at 3m bgl with a 1V1H banking
Diameter at bottom	22.5	20	25	
Diameter at surface	27.5	26	29	
Hardstanding				
Depth of hole dug when constructing hardstanding (m)	0.2	0.2	0.2	No peat elsewhere, just soils
Aproximate geometric shape of whole dug when constructing hardstanding	Rectangular	Rectangular	Rectangular	rectangualr
Length at surface	35	35	35	
Width at surface	35	35	35	
Length at bottom	55	55	55	
Width at bottom	55	55	55	
Piling				
Is piling used?	No	No	No	no
Volume of Concrete				
Volume of concrete used (m^3) in the entire area	9600	6900	9600	m3

1.2 Payback Time

Payback Time and CO_2 emissions • GYPU-K6X2-14MT v2

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	357,693	352,224	361,493
...grid-mix of electricity generation (t CO2 / yr)	69,033	67,977	69,766
...fossil fuel-mix of electricity generation (t CO2 / yr)	154,215	151,857	155,853
Energy output from windfarm over lifetime (MWh)	17,848,956	17,576,064	18,038,592

Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	94,220	93,367	94,220
3. Losses due to backup	99,906	99,906	99,906
4. Lossess due to reduced carbon fixing potential	1,100	434	6,356
5. Losses from soil organic matter	-2,571	-12,211	-2,294
6. Losses due to DOC & POC leaching	148	0	3,079
7. Losses due to felling forestry	17,833	7,829	18,831
Total losses of carbon dioxide	210,637	189,326	220,098

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	-15,880	0	-36,500
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	-208	0	-199
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-2,072	0	-28,368
Total change in emissions due to improvements	-18,160	0	-65,067

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	192,477	124,259	220,098
Carbon Payback Time			
...coal-fired electricity generation (years)	0.5	0.3	0.6
...grid-mix of electricity generation (years)	2.8	1.8	3.2
...fossil fuel-mix of electricity generation (years)	1.2	0.8	1.4
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	-0.13	-0.19	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	10.78	6.89	12.52