Technical Appendix

Drummarnock Wind Farm

Technical Appendix 13-1 Carbon Calculator Inputs

Drummarnock Wind Farm Limited

July 2024

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1 Introduction

This Appendix presents the findings of the Carbon Calculations prepared for the Proposed Development and should be read in conjunction with Chapter 13 Climate Change and Carbon Balance.

Therefore, the Scottish Government's Online Carbon Calculator v1.8.1 (updated in December 2023) was used to calculate the carbon cost and payback period of the Proposed Development.

The online Reference for the Carbon Calculator is CZS7-1TLY-VOE0 v3.

Table 1 and Table 2, presented below to summarise out the outputs and inputs respectively. These are presented with 'Expected' values – the best estimate of the anticipated value, based on the current understanding of the Proposed Development – along with 'minimum' and 'maximum' values to give a range of possible outputs, dependant on the variables within the model.

Table 1: Payback time and CO_2 emissions

	Expected	Minimum	Maximum
1: Wind farm CO2 Emission Saving over (tonnes CO_2 eq.):			
Coal Fired electricity Generation	86,921	78,229	95,613
Grid mix of electricity generation	19,040	17,136	20,944
Fossil fuel mix of electricity generation	39,000	35,100	42,899
Energy output from windfarm over lifetime (40 years) (MWh)	3,679,200	3,311,280	4,047,120
Total CO2 emissions due to wind farm (tCO_2 eq.)			
2. emissions due to turbine life (e.g. manufacture, construction, decommissioning)	27,161	27,161	27,161
3. emissions due to backup	22,285	22,285	22,285
4. emissions due to reduced carbon fixing potential	1,111	289	6,251
5. emissions from soil organic matter	13,131	998	99,499
6. emissions due to DOC & POC leaching	3	0	63
7. emissions due to felling forestry	0	0	0
Total emissions of Carbon dioxide	63,693	50,734	155,261
Total CO_2 gain due to improvement of site (tCO_2 eq.)			
8a. gains due to improvement of degraded bogs	-71	0	-212
8b. gains due to improvement of felled forestry	0	0	0
8c. gains due to restoration of peat form borrow pits	0	0	0
8 d. gains due to removal of drainage from foundations and hardstandings	-333	0	-4571
Total gains	-404	0	-4783
Results: Carbon Payback Time			
Net emissions of carbon dioxide (t CO_2 eq.)	63,288	45,951	155,261

	Expected	Minimum	Maximum
Coal Fired electricity Generation (years)	0.7	0.5	2
Grid mix of electricity generation (years)	3.3	2.2	9.1
Fossil fuel mix of electricity generation (years)	1.6	1.1	4.4
Carbon Intensity (gCO_2e/kWh)	17.20	11.35	46.89

Table 2: Inputs into the Scottish Government Carbon Calculator

Input date	Expected value	Minimum value	Maximum value	Source of Data
Windfarm characteristics				
No. of turbines	4	4	4	Chapter 3 - Description of Development
Duration of consent (years)	40	40	40	Chapter 3 - Description of Development
Performance				
Power rating of 1 turbine (MW)	7.5	7.5	7.5	Chapter 3 - Description of Development
Capacity factor	35	31.5	38.5	Chapter 13 Climate Change and Carbon Balance. Min and max +/-10%
Backup				
Fraction of output to backup (%)	5	5	5	The extra electricity generation capacity required to maintain electricity supply during times of low wind generation. The extra capacity needed for backup power generation, backup is currently estimated to be 5% of the rated capacity of the wind plant if wind power contributes more than 20% to the national grid (Dale et al., 2004).
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	Calculate wrt installed capacity
Characteristics of peatland before windfarm development				
Type of peatland	Acid Bog	Acid Bog	Acid Bog	Technical Appendix 8-3 Peat Hazard Landslide Risk Assessment
Average annual air temperature at site (°C)	9.52	5.79	13.26	Taken from nearest met office weather station Stirling S Wks Climate Station 1991 - 2000. (Met Office, 2023)
Average depth of peat at site (m)	0.77	0.693	0.847	Technical Appendix 8-4 OPMP. +/- 10% values used for maximum and minimum.
C Content of dry peat (% by weight)	55	49	62	Default value: An estimate of the range of %C in peat of between 49% and 62% is provided by Birnie et al. (1991).
Average extent of drainage around drainage features at site (m)	10	5	50	Generic precautionary values have been entered into the carbon calculator as follows: expected = 10m; minimum = 5m; and maximum = 50m as per Windfarm Carbon Calculator Web Tool User Guidance (SEPA, n.d)
Average water table	0.3	0.1	0.5	The Carbon Calculator notes that water

Input date	Expected value	Minimum value	Maximum value	Source of Data
depth at site (m)				table depth should be measured on site. However, where site-specific values are not available, for degraded peat, reasonable estimated minimum, expected and maximum values are: 0.1 m, 0.3 m and 0.5 m, respectively.
Dry soil bulk density (g cm-3)	0.132	0.072	0.293	The Windfarm Carbon Calculator Web Tool User Guidance (SEPA, n.d) notes that given the difficulty of collecting sufficient samples to derive a representative site-specific value for this parameter, Scottish generic values for peat may be used instead: expected = 0.132 g/cm3; minimum = 0.072 g/cm3; and maximum = 0.293 g/cm3.
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	10	5	15	Generic assumptions: "The physical and hydrological restoration of the site post construction, even if no wider site improvements and restoration are undertaken, should allow the vegetation to recover more rapidly than within 15 years. SEPA (n.d) Windfarm Carbon Calculator Web Tool User Guidance
Carbon accumulation due to C xation by bog plants in undrained peats (tC ha-1 yr-1)	0.25	0.12	0.31	Carbon Calculator default value: Apparent C accumulation rate in peatland is 0.12 to 0.31 tC ha-1 yr-1 (Turunen et al., 2001; Botch et al., 1995). The SNH guidance uses a value of 0.25 tC ha-1 yr-1 .
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	n/a - no felling will occur as a result of the Proposed Development
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	0	0	0	n/a - no felling will occur as a result of the Proposed Development
Counterfactual emission factors				
Coal-red plant emission factor (t CO2 MWh-1)	Fixed	Fixed	Fixed	Fixed
Grid-mix emission factor (t CO2 MWh-1)	Fixed	Fixed	Fixed	Fixed
Fossil fuel-mix emission factor (t CO2 MWh-1)	Fixed	Fixed	Fixed	Fixed
Borrow pits				
Number of borrow pits	4	4	4	Chapter 3 - Description of Development
Average length of	172	154.8	189.2	Chapter 3 - Description of Development.

Input date	Expected value	Minimum value	Maximum value	Source of Data
pits (m)				Average of 4 borrow pits used, +/- 10%
Average width of pits (m)	70	63	77	Chapter 3 - Description of Development. Average of 4 borrow pits used, +/- 10%
Average depth of peat removed from pit (m)	0.63	0.567	0.693	Technical Appendix 8-4 OPMP. +/- 10% values used for maximum and minimum.
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	27.4	27.4	27.4	Chapter 3 - Description of Development. Figure 3-5
Average width of turbine foundations (m)	27.4	27.4	27.4	Chapter 3 - Description of Development. Figure 3-5
Average depth of peat removed from turbine foundations(m)	0.68	0.612	0.748	Technical Appendix 8-4 OPMP. +/- 10% values used for maximum and minimum.
Average length of hard-standing (m)	36	36	36	Chapter 3 - Description of Development. Figure 3-5
Average width of hard-standing (m)	40	40	40	Chapter 3 - Description of Development. Figure 3-5
Average depth of peat removed from hard-standing (m)	0.78	0.702	0.858	Technical Appendix 8-4 OPMP. +/- 10% values used for maximum and minimum.
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m3)	3,168	3,168	3,168	Chapter 3 - Description of Development. This total only includes the turbines and does not include any other infrastructure
Access tracks				
Existing track length (m)	0	0	0	Chapter 3 Description of Development. No existing track will be used.
Total length of access track (m)	6590	5931	7249	Chapter 3 Description of Development. Sum of all tracks
Length of access track that is floating road (m)	5980	5382	6578	Chapter 3 Description of Development: 5.9 km new access track (not incl. floating track). Carbon Calculator requires that minimum is less than expected and maximum is more than expected therefore +/-10% used.
Floating road width (m)	5	5	5	Chapter 3 Description of Development. Tracks will have a total width of up to 5m (including verges).
Floating road depth (m)	0	0	0	Chapter 3 Description of Development. "Where the presence of peat has been identified to be greater than 0.5m in depth, floating tracks are proposed to be used." Detailed design will take place prior to construction.
Length of floating road that is drained (m)	0	0	0	Chapter 3 Description of Development. "Where the presence of peat has been identified to be greater than 0.5m in

Input date	Expected value	Minimum value	Maximum value	Source of Data
				depth, floating tracks are proposed to be used." Detailed design will take place prior to construction.
Average depth of drains associated with floating roads (m)	0	0	0	Chapter 3 Description of Development. "Where the presence of peat has been identified to be greater than 0.5m in depth, floating tracks are proposed to be used." Detailed design will take place prior to construction.
Length of access track that is excavated road (m)	5980	5382	6578	Chapter 3 Description of Development: 5.9 km new access track. Carbon Calculator requires that minimum is less than expected and maximum is more than expected therefore +/-10% used.
Excavated road width (m)	5	5	5	Chapter 3 Description of Development. Tracks will have a total width of up to 5m (including verges).
Average depth of peat excavated for road (m)	0.68	0.612	0.748	Technical Appendix 8-4 OPMP. +/- 10% values used for maximum and minimum.
Length of access track that is rock filled road (m)	0	0	0	n/a All roads have been accounted for in previous sections
Rock filled road width (m)	5	5	5	Carbon calculator requires a value of greater than 5 therefore 5 was used.
Rock filled road depth (m)	0	0	0	n/a All roads have been accounted for in previous sections
Length of rock filled road that is drained (m)	0	0	0	n/a All roads have been accounted for in previous sections
Average depth of drains associated with rock filled roads (m)	0	0	0	n/a All roads have been accounted for in previous sections
Cable Trench				
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	Chapter 3 Description of Development. It is anticipated these cables will be sited within the footprint of the existing and proposed access track and will be suitably marked on the surface.
Average depth of peat cut for cable trenches (m)	0.68	0.612	0.758	Technical Appendix 8-4 OPMP. +/- 10% values used for maximum and minimum.
Additional peat excavated (not already accounted above)				
Volume of additional peat excavated (m3)	10,290	9,261	11,319	Technical Appendix 8-4 OPMP. Minimum and maximum values are minus and plus 10% of that value. Includes infrastructure not previously listed above including peat permanently excavated from the following infrastructure: Blade storage

Input date	Expected value	Minimum value	Maximum value	Source of Data
				area, working areas, earthworks - cut, earthworks - fill, turning head.
Area of additional peat excavated (m2)	0	0	0	Chapter 3 Description of Development, Table 3-3 None of the following infrastructure will result in permanent land take therefore total entered is 0 (Blade storage area, working areas, earthworks - cut, earthworks - fill, turning head.)
Peat Landslide Hazard and Risk Assessments	negligible	negligible	negligible	Fixed
Improvement of C sequestration at site by blocking drains, restoration of habitat, etc				
Area of degraded bog to be improved (ha)	0.6	0.6	0.6	Technical Appendix 6-5 Habitat Management Plan
Water table depth in degraded bog before improvement (m)	0.3	0.1	0.5	The Carbon Calculator notes that water table depth should be measured on site. However, where site-specific values are not available, for degraded peat, reasonable estimated minimum, expected and maximum values are: 0.1 m, 0.3 m and 0.5 m, respectively.
Water table depth in degraded bog after improvement (m)	0.1	0.05	0.3	The Carbon Calculator notes that water table depth should be measured on site. However, where site-specific values are not available, for intact peat, reasonable estimated minimum, expected and maximum values are: 0.05m, 0.1m, 0.3m respectively.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	15	5	30	Carbon Calculator requires that a value between 2 and 30 is input. Values of 5, 15 and 30 used for min, max and expected to show worst case scenario.
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	30	30	30	Due to uncertainty this value has been set the maximum that the carbon calculator requires a value between 2 and 30 years. 30 years chosen for worst case
Area of felled plantation to be improved (ha)	0	0	0	n/a no felling will take place
Water table depth in felled area before improvement (m)	0.3	0.1	0.5	The Carbon Calculator requires a value and notes that water table depth should be measured on site. However, where site-specific values are not available, for degraded peat, reasonable estimated minimum, expected and maximum values are: 0.1 m, 0.3 m and 0.5 m, respectively.

Input date	Expected value	Minimum value	Maximum value	Source of Data
Water table depth in felled area after improvement (m)	0.1	0.05	0.3	The Carbon Calculator requires a value and notes that water table depth should be measured on site. However, where site-specific values are not available, for intact peat, reasonable estimated minimum, expected and maximum values are: 0.05m, 0.1m, 0.3m respectively.
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	30	30	30	Carbon calculator requires a value between 2 and 30 years. 30 years chosen for min, expected and max, to illustrate worst case scenario.
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	30	30	30	Carbon calculator requires a value between 2 and 30 years. 30 years chosen for min, expected and max, to illustrate worst case scenario.
Area of borrow pits to be restored (ha)	3.27	3.27	3.27	Chapter 3 Description of Development
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	This will be dependent upon water table levels and borrow pit design. Due to this, it is assumed on a highly conservative basis for the purpose of the carbon calculator that there will be no change in the water table depth and therefore no "gain". This value is therefore presented as "0".
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	This will be dependent upon water table levels and borrow pit design. Due to this, it is assumed on a highly conservative basis for the purpose of the carbon calculator that there will be no change in the water table depth and therefore no "gain". This value is therefore presented as "0".
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	30	30	30	Carbon calculator requires a value between 1 and 30 years. 30 years chosen for worst case scenario.
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	30	30	30	Carbon calculator requires a value between 1 and 30 years. 30 years chosen for worst case scenario.
Water table depth around foundations and	0.3	0.1	0.5	The Carbon Calculator notes that water table depth should be measured on site. However, where site-specific values are

Input date	Expected value	Minimum value	Maximum value	Source of Data
hardstanding before restoration (m)				not available, for degraded peat, reasonable estimated minimum, expected and maximum values are: 0.1 m, 0.3 m and 0.5 m, respectively.
Water table depth around foundations and hardstanding after restoration (m)	0.1	0.05	0.3	The Carbon Calculator notes that water table depth should be measured on site. However, where site-specific values are not available, for intact peat, reasonable estimated minimum, expected and maximum values are: 0.05 m, 0.1 m and 0.3 m, respectively.
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	5	5	5	Carbon calculator requires a value between 0.1 and 5 years. 5 years chosen for worst case.
Restoration of site after decommissioning				
Will you attempt to block any gullies that have formed due to the windfarm?	No	No	No	Technical Appendix 8-4 OPMP
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	Technical Appendix 6-5 Habitat Management Plan
Will you control grazing on degraded areas?	Yes	Yes	Yes	Technical Appendix 6-5 Habitat Management Plan
Will you manage areas to favour reintroduction of species?	Yes	Yes	Yes	Technical Appendix 6-5 Habitat Management Plan