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36405 R2

Environmental Impact Assessment

Sandy Knowe Wind Farm Extension

Appendix 3-1 Carbon Calculator

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Contents

Carbon Calculator Results

This Appendix presents the findings of the Carbon Calculations prepared for the Proposed Development and should be read in conjunction with Chapter 3 Description of Development.

Applicants are required to calculate potential carbon losses and savings from wind farms on Scottish peatlands as set out the ECU's online good practice guidance for applications under Section 36 and 37 of the Electricity Act 1989 (2022).

Therefore, the Scottish Government's Online Carbon Calculator v1.6.1 (updated in June 2020) was used to calculate the carbon cost and payback period of the Proposed Development. The online Reference for the Carbon Calculator is GFB5-9F1O-THPY 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.

The results of the Carbon Calculator (Table 1) show that the Proposed Development is estimated to produce annual carbon savings in the region of 66,000 tonnes of CO_2 eq., and lifetime savings of over 2.6 Mt of CO_2 eq. through the displacement of grid electricity. This is based on a counterfactual emission factor of 0. 25358 kgCO_2eq/kWh, which represents displacing grid electricity at the current average annual grid mix.

The estimated payback time of the Proposed Development, using the Scottish Government Carbon Calculator and grid mix of electricity generation, is estimated at 2.6 years, with a minimum/maximum range of 1.8 to 4.9 years. This payback time is the estimated time it will take for the carbon lost during wind farm construction (including through turbine manufacture, construction of foundations, and excavation of peat) to be 'paid back' by the carbon saved through generating electricity from a renewable energy resource and 2.6 years represents 6.5% of the operational life of the Proposed Development.

The Scottish Government's Climate Change Plan (2018) states that by 2030 Scotland will have a largely decarbonised electricity system with a grid carbon intensity of 50g CO_2/kWh of generation (0.05kg CO_2/kWh) (p. 66). As shown in Table 1, the carbon intensity of the Proposed Development is 16.77g CO_2/kWh (0.01677kg CO_2/kWh), which is below the 2030 carbon intensity target. The Proposed Development is anticipated to have an overall beneficial effect on climate change mitigation.

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	60,928	48,916	79,554
Grid mix of electricity generation	16,793	13,483	21,927
Fossil fuel mix of electricity generation	29,802	23,926	38,912
Energy output from windfarm over lifetime (40 years) (MWh)	2,649,024	2,126,788	3,458,868
Total CO2 losses due to wind farm (tCO_2 eq.)			
2. losses due to turbine life (e.g. manufacture, construction, decommissioning)	20,932	20,932	20,932
3. Losses due to backup	17,029	17,029	17,029
4.losses due to reduced carbon fixing potential	638	184	3,511
5. losses from soil organic matter	4,647	383	16,804
6.losses due to DOC & POC leaching	802	23	8,140
7. losses due to felling forestry	0	0	0
Total losses of Carbon dioxide	44,047	38,552	66,416
Total CO_2 gain due to improvement of site (tCO_2 eq.)			
8a. gains due to improvement of degraded bogs	0	0	0
8b. gains due to improvement of felled forestry	0	0	0
8c. gains due to restoration of peat form borrow pits	382	0	429
8 d. gains due to removal of drainage from foundations and hardstandings	0	0	0
Total gains	382	0	429
Results: Carbon Payback Time			
Net emissions of carbon dioxide (t CO_2 eq.)	44,429	38,980	66,416
Coal Fired electricity Generation (years)	0.7	0.5	1.4
Grid mix of electricity generation (years)	2.6	1.8	4.9
Fossil fuel mix of electricity generation (years)	1.5	1	2.8
Carbon Intensity ($kgCO_2e/kWh$)	**0.01677**	**0.01127**	**0.03123**

Table 2: Inputs into the Scottish Government Carbon Calculator

Input data	Expected value	Minimum value	Maximum value	Source of Data
Windfarm characteristics				
No. of turbines	6	6	6	Figure 1-2: Layout TL01n
Duration of consent (years)	40	40	40	Chapter 3: Description of Development
Performance				
Power rating of 1 turbine (MW)	3.6	3.6	3.6	Chapter 3: Description of Development
Capacity factor	35	28.1	45.7	As set out in BEIS Digest of UK Energy Statistics (DUKES) Load factors for renewable electricity generation for 2020 (BEIS, 2021)),
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). Taken from Scottish Government Technical Note Version 2.10.0.
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	Appendix 8-1 PLHRA and 8-2 PMP; the peat on site is likely to be blanket bog
Average annual air temperature at site (°C)	9.6	6.08	13.08	Taken from nearest met office weather station 1991-2020 (Dumfries)

Input data	Expected value	Minimum value	Maximum value	Source of Data
Average depth of peat at site (m)	0.79	0.79	0.79	Appendix 8-1 and 8-2: The mean peat depth was 0.79m across the Proposed Development Footprint
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 depth at site (m)	0.1	0.05	0.3	The Windfarm Carbon Calculator Web Tool User Guidance (SEPA, n.d) 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. As noted in Appendix 8-1 and 8-2, review of site conditions indicated that much of the Proposed Development Footprint comprises relatively intact planar peat.
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." Windfarm Carbon Calculator Web Tool User Guidance (SEPA, n.d.)
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.

Input data	Expected value	Minimum value	Maximum value	Source of Data
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	No felling is proposed. See Chapter 3 Description of Development.
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	0	0	0	No felling is proposed. See Chapter 3 Description of Development.
Counterfactual emission factors				
Coal-red plant emission factor (t CO2 MWh-1)	0.92	0.92	0.92	Fixed
Grid-mix emission factor (t CO2 MWh-1)	0.25358	0.25358	0.25358	Fixed
Fossil fuel-mix emission factor (t CO2 MWh-1)	0.45	0.45	0.45	Fixed
Borrow pits				
Number of borrow pits	1	1	1	No new borrow pits are proposed. Use of an existing borrow pit for the excavation of on-site aggregate to be used in the construction of the Proposed Development and for peat reinstatement. Any extraction of aggregate will be within the existing boundaries of the Borrow pit (See Chapter 3 Project Description)
Average length of pits (m)	100	100	100	No new borrow pits are proposed. Use of an existing borrow pit for the excavation of on-site aggregate to be used in the construction of the Proposed Development and for peat reinstatement. Any extraction of aggregate will be within the existing boundaries of the Borrow pit (See Chapter 3 Project Description). 17,599m^2 area is available for the Proposed Development Peat reinstatement. This value is an indicative length of the reinstatement area to reach 17,599m^2
Average width of pits (m)	175.99	175.99	175.99	No new borrow pits are proposed. Use of an existing borrow pit for the excavation of on-site aggregate to be used in the construction of the Proposed Development and for peat reinstatement. Any extraction of aggregate will be within the existing boundaries of the Borrow pit (See Chapter 3 Project Description). 17,599m^2 area is available for the Proposed Development Peat reinstatement. This value is an indicative length of the reinstatement

Input data	Expected value	Minimum value	Maximum value	Source of Data
				area to reach 17,599m^2
Average depth of peat removed from pit (m)	0	0	0	No new borrow pits are proposed. Use of an existing borrow pit for the excavation of on-site aggregate to be used in the construction of the Proposed Development and for peat reinstatement. Any extraction of aggregate will be within the existing boundaries of the Borrow pit (See Chapter 3 Project Description). As no peat/surface material is to be removed for the Proposed Development, this value is set to 0
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	25	25	25	Chapter 3: Description of Development Table 3-3
Average width of turbine foundations (m)	25	25	25	Chapter 3: Description of Development Table 3-3
Average depth of peat removed from turbine foundations(m)	0.512357	0.512357	0.512357	Taken as an average from interpolated peat depth across the turbine foundation areas
Average length of hard-standing (m)	62.5	62.5	62.5	Chapter 3: Description of Development Table 3-3
Average width of hard-standing (m)	25	25	25	Chapter 3: Description of Development Table 3-3
Average depth of peat removed from hard-standing (m)	0.512867	0.512867	0.512867	Taken as an average from interpolated peat depth across the turbine hardstanding areas
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m3)	11250	11250	11250	Chapter 3: Description of Development Table 3-3
Access tracks				
Existing track length (m)	6500	6500	6500	Chapter 3: Description of Development
Total length of access track (m)	3000	2900	3100	Approximately 3,000m of track is proposed. See Chapter 3 Description of Development. + / - 10% of values presented

Input data	Expected value	Minimum value	Maximum value	Source of Data
Total width of access track (m)	5.5	5.5	5.5	Chapter 3: Description of Development
Length of access track that is floating road (m)	100	90	110	See Appendix 8-1 and 8-2 PLHRA and PMP. +/ - 10% provided for minimum and maximum value presented
Average depth of peat on proposed track	0.818376	0.818376	0.818376	Taken as an average from interpolated peat depth across the proposed access track
Floating road width (m)	5.5	5.5	5.5	See Chapter 3 Description of Development; Appendix 8-1 & 8-2; and Figure 3-7
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	All cable trenches follow access tracks
Average depth of peat cut for cable trenches (m)	0	0	0	All cable trenches follow access tracks
Additional peat excavated (not already accounted above)				
Volume of additional peat excavated (m3)	2218	2218	2218	This value is taken from Appendix 8-2 PMP which includes peat excavated from the following temporary infrastructure: Blade laydowns; Turning heads; and Boom assemblies
Area of additional peat excavated (m2)	4028	4028	4028	This value is taken from Chapter 3 Description of Development which includes the footprint of the following temporary infrastructure: Blade laydowns; Turning heads; and Boom assemblies
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	0	0	n/a
Water table depth in degraded bog before	0	0	0	n/a

Input data	Expected value	Minimum value	Maximum value	Source of Data
improvement (m)				
Water table depth in degraded bog after improvement (m)	0	0	0	n/a
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	0	0	0	n/a
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	0	0	0	n/a
Area of felled plantation to be improved (ha)	0	0	0	n/a
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)	0	0	0	n/a
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	0	0	0	n/a

Input data	Expected value	Minimum value	Maximum value	Source of Data
Area of borrow pits to be restored (ha)	1.7599	1.7599	1.7599	No new borrow pits are proposed. Use of an existing borrow pit for the excavation of on-site aggregate to be used in the construction of the Proposed Development and for peat reinstatement. 17,599m^2 area is available for the Proposed Development Peat reinstatement.
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.11	0.051	0.31	The Windfarm Carbon Calculator Web Tool User Guidance (SEPA, n.d) notes that water table depth should be measured on site. However, where site-specific values are not available, for intact peat, reasonable estimated can be used. As noted in Appendix 8-1 and 8-2, review of site conditions indicated that much of the Proposed Development Footprint comprises relatively intact planar peat. Note that 0.01 has been added to the values as the depth of water table in borrow pit after restoration needed to be less than the value before restoration
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.1	0.05	0.3	The Windfarm Carbon Calculator Web Tool User Guidance (SEPA, n.d) 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. As noted in Appendix 8-1 and 8-2, review of site conditions indicated that much of the Proposed Development Footprint comprises relatively intact planar peat. As noted in Chapter 8, Mitigation, there is a commitment to maintain the natural pre-existing shallow groundwater flow.
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	10	5	15	Assumption from the Windfarm Carbon Calculator Web Tool user guidance: 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.
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	40	40	40	The Carbon Calculator states that if the time required for hydrology and habitat to return to its previous state is 15 years and the restoration can be guaranteed over the lifetime of the Proposed Development (40 years), the period of time when the improvement can be guaranteed should be entered as 40 years.
Water table depth around foundations and hardstanding before	0	0	0	n/a

Input data	Expected value	Minimum value	Maximum value	Source of Data
restoration (m)				
Water table depth around foundations and hardstanding after restoration (m)	0	0	0	n/a
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	2	1	5	Assumption provided between 1 and 5 years

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