APPENDIX 18.1: SCOTTISH GOVERNMENT'S CARBON CALCULATOR TOOL

18.1 Methodology

18.1.1 This assessment uses the Scottish Government's Carbon Calculator Tool (version 1.7.0), which is based upon the work of Nayak et al. (2008, 2010) and Smith et al. (2011)[1]. It adopts a lifecycle methodology approach to estimate the GHG emissions and savings associated with onshore windfarms.

Embodied Emissions

18.1.2 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.

Losses due to back-up

18.1.3 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 reserve generation.

18.2 Input data

18.2.1 A variety of data sources have been utilised to compile the input data needed for the Scottish Government's Carbon Calculator 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 18.2.1. To reflect design and real-world uncertainty and range of +/- 10% has been applied to many categories.

Table 18.2.1: Input parameter data for the Scottish Government's Carbon Calculator tool

[1] 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.

				Ref: 2UEM-CY9J-RWXX (v4)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Windfarm Characteristics				
Dimensions				
No. of turbines	11	11	11	Chapter 1: Introduction
Duration of consent (years)	35	35	35	Chapter 1: Introduction
Performance				
Power rating of 1 turbine (MW)	5.45	4.8	6	Chapter 1: Introduction
Capacity factor	35	31.5	38.5	All-Island Generation Capacity Statement 2021-2030
Backup				
Fraction of output to backup (%)	5	5	5	Chapter 1: Introduction
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO_2 emission from turbine life (tCO_2 MW^{-1}) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	Scottish Government Carbon Calculator
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 10. Land, Soils and Geology
Average annual air temperature at site (°C)	10.76	9.68	11.84	Weather and climate - Ardskeagh
Average depth of peat at site (m)	0.4	0	3.8	Chapter 10. Land, Soils and Geology
Content of dry peat (% by weight)	55	49	61	Chapter 10. Land, Soils and Geology
Average extent of drainage around drainage features at site (m)	63.5	2	244	Chapter 10. Land, Soils and Geology
Average water table depth at site (m)	0.2385	0.026	0.451	Chapter 10. Land, Soils and Geology
Dry soil bulk density (g cm^{-3})	0.2	0.18	0.22	Chapter 10. Land, Soils and Geology
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	18.5	2	35	Chapter 10. Land, Soils and Geology
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.12	0.31	SNH Guidance (NatureScot) (SNH, 2003) proposes an average value of 0.25 $tCha^{-1}yr^{-1}$. Minimum and maximum values are taken from estimated global averages of Botch et al. (1995) and Turunen et al. (2001) to be 0.12 to 0.31 $tCha^{-1}yr^{-1}$
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	54.18	48.76	59.60	Chapter 5: Project Description

				Ref: 2UEM-CY9J-RWXX (v4)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.6	2.4	4.4	Default value
Counterfactual emission factors				
Coal-fired plant emission factor (t CO_2 MWh^{-1})	1.002	1.002	1.002	Default value (Scottish Government Carbon Calculator)
Grid-mix emission factor (t CO_2 MWh^{-1})	0.19338	0.19338	0.19338	Default value (Scottish Government Carbon Calculator)
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.432	0.432	0.432	Default value (Scottish Government Carbon Calculator)
Borrow pits				
Number of borrow pits	0	0	0	Chapter 10. Land, Soils and Geology
Average length of pits (m)	0	0	0	Chapter 10. Land, Soils and Geology
Average width of pits (m)	0	0	0	Chapter 10. Land, Soils and Geology
Average depth of peat removed from pit (m)	0	0	0	Chapter 10. Land, Soils and Geology
Foundations and hard-standing area associated with each turbine				
Shape (circular/octagonal/hexagnal)	Circular			Infrastructure design and aggregate estimates
Diameter/side at surface (m)	12	10.8	13.2	Infrastructure design and aggregate estimates
Diameter/side at bottom (m)	12	10.8	13.2	Infrastructure design and aggregate estimates
Average depth of peat removed from turbine foundations [m]	0.34	0.1	1.38	Chapter 10. Land, Soils and Geology
Average length of hard-standing at surface [m]	127	114.3	139.7	Infrastructure design and aggregate estimates
Average length of hard-standing at bottom [m]	127	114.3	139.7	Infrastructure design and aggregate estimates
Average width of hard-standing at surface [m]	52	46.8	57.2	Infrastructure design and aggregate estimates
Average width of hard-standing at bottom [m]	52	46.8	57.2	Infrastructure design and aggregate estimates
Average depth of peat excavated when constructing hard-standing [m]	0.37	0.1	1.38	Chapter 10. Land, Soils and Geology
Is piling used? (Yes/No)	No			Infrastructure design and aggregate estimates
Volume of concrete (m^3)	18,000	16,200	19,800	Infrastructure design and aggregate estimates
Access tracks				
Total length of access track (m)	9,500	8,550	10,450	Infrastructure design and aggregate estimates
Existing track length (m)	3,500	3,150	3,850	Infrastructure design and aggregate estimates
Length of access track that is floating road (m)	0	0	0	Infrastructure design and aggregate estimates

				Ref: 2UEM-CY9J-RWXX (v4)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Width of access track that is floating road (m)	0	0	0	Infrastructure design and aggregate estimates
Length of access track that is excavated road (m)	0	0	0	Infrastructure design and aggregate estimates
Excavated road width (m)	0	0	0	Infrastructure design and aggregate estimates
Average depth of peat excavated for road (m)	0	0	0	Chapter 10. Land, Soils and Geology
Length of access track that is rock filled road (m)	6,000	5,400	6,600	Infrastructure design and aggregate estimates
Rock filled road width (m)	5	5	5	Infrastructure design and aggregate estimates
Rock filled road depth (m)	0.45	0.405	0.495	Infrastructure design and aggregate estimates
Length of rock filled road that is drained (m)	6,000	5,400	6,600	Infrastructure design and aggregate estimates
Average depth of drains associated with rock filled roads (m)	0.6	0.54	0.66	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 (eg. sand) (m)	0	0	0	Infrastructure design and aggregate estimates
Average depth of peat cut for cable trenches (m)	0	0	0	Chapter 10. Land, Soils and Geology
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	17,248.4	15,523.5	18,973.2	Chapter 10. Land, Soils and Geology
Area of additional peat excavated (m^2)	53,690.5	48,321.5	59,059.6	Chapter 10. Land, Soils and Geology
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)	0	0	0	Chapter 10. Land, Soils and Geology
Water table depth in degraded bog before improvement (m)	0.2385	0.026	0.451	Chapter 10. Land, Soils and Geology
Water table depth in degraded bog after improvement (m)	0.11925	0	0.2385	Chapter 10. Land, Soils and Geology
Time required for hydrology and habitat of bog to return	18.5	2	35	Chapter 10. Land, Soils and Geology

				Ref: 2UEM-CY9J-RWXX (v4)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
to its previous state on improvement (years)				
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	18.5	2	35	Chapter 10. Land, Soils and Geology
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Species and Habitat Management Plan
Water table depth in felled area before improvement (m)	0.2385	0.026	0.451	Chapter 10. Land, Soils and Geology
Water table depth in felled area after improvement (m)	0.11925	0	0.2385	Chapter 10. Land, Soils and Geology
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	18.5	2	35	Species and Habitat Management Plan
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	18.5	2	35	Species and Habitat Management Plan
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	Chapter 10. Land, Soils and Geology
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.2385	0.026	0.451	Chapter 10. Land, Soils and Geology
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.11925	0	0.2385	Chapter 10. Land, Soils and Geology
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	18.5	2	35	Chapter 10. Land, Soils and Geology
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	18.5	2	35	Chapter 10. Land, Soils and Geology
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hard standing before restoration (m)	0.2385	0.026	0.451	Chapter 10. Land, Soils and Geology

				Ref: 2UEM-CY9J-RWXX (v4)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Water table depth around foundation and hard standing after restoration (m)	0.11925	0	0.2385	Chapter 10. Land, Soils and Geology
Time to completion of backfilling, removal of any surface drains, and full restoration of hydrology (years)	5	2	5	Chapter 9: Hydrology and Hydrogeology
Early removal of drainage from foundations and hardstanding				
Will you attempt to block any gullies that have formed due to the windfarm?	No	No	No	Client (Orsted)
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	Client (Orsted)
Will you control grazing on degraded areas?	No	No	No	Client (Orsted)
Will you manage areas to favour reintroduction of species	No	No	No	Client (Orsted)
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

18.3 Output data

Ref: 2UEM-CY9J-RWXX (v4)			
Output data	**Expected value**	**Minimum value**	**Maximum value**
1. Windfarm CO2 emission saving over...			
...coal-fired electricity generation (t CO2 / yr)	184,174	145,988	223,037
...grid-mix of electricity generation (t CO2 / yr)	35,545	28,175	43,045
...fossil fuel-mix of electricity generation (t CO2 / yr)	79,404	62,941	96,160
Energy output from windfarm over lifetime (MWh)	6,433,235	5,099,371	7,790,706
2. Total CO_2 losses due to wind farm (tCO_2e)			
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	56,559	49,310	62,781
3. Losses due to backup	39,702	34,967	43,709
4. Losses due to reduced carbon fixing potential	8,710	1,041	50,706
5. Losses from soil organic matter	19,663	-7,257	366,411
6. Losses due to DOC & POC leaching	56	0	3,755
7. Losses due to felling forestry	25,031	20,275	30,289
Total losses of carbon dioxide*	149,722	98,335	557,650

Ref: 2UEM-CY9J-RWXX (v4)			
Output data	**Expected value**	**Minimum value**	**Maximum value**
3. Total CO_2 changes due to improvement of site (tCO_2e)			
8a. Change in emissions due to improvement of degraded bogs	0	0	0
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	-5,589	0	-107,720
Total change in emissions due to improvements	-5,589	0	-107,720
Results			
Net emissions of carbon dioxide (tCO_2e)*	144,134	-9,385	557,650
...coal-fired electricity generation (years)*	0.8	0	3.8
...grid-mix of electricity generation (years)*	4.1	- 0.2	19.8
...fossil fuel-mix of electricity generation (years)*	1.8	- 0.1	8.9
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	3.53	-0.07	No gains