APPENDIX 10.1: SCOTTISH GOVERNMENT'S CARBON CALCULATOR TOOL

10.1 Methodology

10.1.1 This assessment uses the Scottish Government's Carbon Calculator Tool (version 2.14.1), which is based upon the work of Nayak et al. (2008, 2010) and Smith et al. (2011). It adopts a lifecycle methodology approach to estimate the GHG emissions and savings associated with onshore windfarms.

Embodied Emissions

10.1.2 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

10.1.3 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.

10.2 Input data

10.2.1 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 10.2**. To reflect design and real-world uncertainty and range of +/- 10 % has been applied to many categories.

Table 10.1: Input parameter data for the Scottish Government's Carbon Calculator tool

Input Data	Expected Value	Minimum Value	Maximum Value	Source of Data
Windfarm Characteristics				
Dimensions				
No. of Turbines	18	18	18	Chapter 2: Development Description
Duration of consent (years)	35	35	35	Chapter 2: Development Description
Performance				
Power Rating of 1 turbines (MW)	4.3	4.3	4.3	Chapter 2: Development Description
Capacity factor	35	31.5	38.5	All-Island Generation Capacity Statement 2021-2030
Backup				
Extra capacity required for backup (%)	5	5	5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Extra emissions due to reduced thermal efficiency of the reserve power generation ≈ 10% (Dale et al 2004).
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	Scottish Government Carbon Calculator
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	
Average annual air temperature at site (°C)	10.5	6.6	15	Chapter 10: Air & Climate (Belmullet Monitoring Station, Table 10.3)
Average depth of peat at site (m)	0.22	0	4	Chapter 8: Soils and Geology
Content of dry peat (% by weight)	55	50	60	Default
Average extent of drainage around drainage features at site (m)	10	5	15	Chapter 9: Hydrology and Hydrogeology
Average water table depth at site (m)	0.25	0	0.5	Chapter 9: Hydrology & Hydrogeology (Worst Case based on average water table of bog lands)
Dry soil bulk density (g cm-3)	0.1	0.09	0.11	Default
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	10	5	15	Best Practice for Bog Restoration

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-1yr-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-1yr-1
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	40.24	40.24	40.24	Chapter 2: Development Description
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.6	3.5	3.7	Default
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh-1)	0.945	0.945	0.945	
Grid-mix emission factor (t CO2 MWh-1)	0.207	0.207	0.207	
Fossil fuel-mix emission factor (t CO2 MWh-1)	0.424	0.424	0.424	
Borrow pits				
Number of borrow pits	0	0	0	Chapter 2: Development Description
Average length of pits (m)	0	0	0	Chapter 2: Development Description
Average width of pits (m)	0	0	0	Chapter 2: Development Description
Average depth of peat removed from pit (m)	0	0	0	Chapter 2: Development Description
Foundations and hard-standing area associated with each turbine				
Method used to calculate CO_2 loss from foundations and hard-standing	Rectangular with vertical walls	Rectangular with vertical walls	Rectangular with vertical walls	
Average length of turbine foundations (m)	21.6	21.6	21.6	Chapter 2: Development Description
Average width of turbine foundations (m)	21.6	21.6	21.6	Chapter 2: Development Description
Average depth of peat removed from turbine foundations (m)	0.86	0.2	0.3	Chapter 8 Soils and Geology, Spoil Calcs
Average length of hard-standing (m)	65	65	65	Chapter 2: Development Description
Average width of hard-standing (m)	25	25	25	Chapter 2: Development Description)
Average depth of peat removed from hard-standing (m)	0.86	0.2	0.3	Chapter 8 Soils and Geology, Spoil Calcs
Access tracks				

Total length of access track (m)	10406	10406	10406	Chapter 2: Development Description
Existing track length (m)	2275	2275	2275	Chapter 2: Development Description
Length of access track that is floating road (m)	0	0	0	Chapter 2: Development Description
Width of access track that is floating road (m)	0	0	0	Chapter 2: Development Description
Length of access track that is excavated road (m)	10406	10406	10406	Chapter 2: Development Description
Excavated road width (m)	4.5	4.5	4.5	Chapter 2: Development Description
Average depth of peat excavated for road (m)	0.5	0.5	0.5	Chapter 2: Development Description
Length of access track that is rock filled road (m)	0	0	0	Chapter 2: Development Description
Rock filled road width (m)	0	0	0	Chapter 2: Development Description
Rock filled road depth (m)	0	0	0	Chapter 2: Development Description
Length of rock filled road that is drained (m)	0	0	0	Chapter 2: Development Description
Average depth of drains associated with rock filled roads (m)	0	0	0	Chapter 2: Development Description
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)	857	857	857	Chapter 8: Soils and Geology
Average depth of peat cut for cable trenches (m)	0.5	0.5	0.5	Chapter 8: Soils and Geology
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m_3)	41477	41477	41477	Chapter 8: Soils and Geology
Area of additional peat excavated (m_2)				
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	Neglible	Neglible	Neglible	Chapter 7: Soils and Geology

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 6: Biodiversity 1.09ha of degraded bog for the HMP drains will not have its drained blocked so is omitted from this calculation
Water table depth in degraded bog before improvement (m)	0	0	0	Chapter 6: Biodiversity 1.09ha of degraded bog for the HMP drains will not have its drained blocked so is omitted from this calculation
Water table depth in degraded bog after improvement (m)	0	0	0	Chapter 6: Biodiversity 1.09ha of degraded bog for the HMP drains will not have its drained blocked so is omitted from this calculation
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	2	2	2	
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	2	2	2	
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Chapter 2: Project Description
Water table depth in felled area before improvement (m)	0	0	0	Chapter 2: Project Description
Water table depth in felled area after improvement (m)	0	0	0	Chapter 2: Project Description
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	Chapter 2: Project Description
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	Chapter 2: Project Description

Depth of water table in borrow pit after restoration with respect to the restored surface (m	0	0	0	Chapter 2: Project Description
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	1	1	1	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2	2	2	
Early removal of drainage from foundations and hardstanding	-	-	-	-
Water table depth around foundations and hard standing before restoration (m)	0	0	0	Chapter 2: Project Description
Water table depth around foundation and hard standing after restoration (m)	0	0	0	Chapter 2: Project Description
Time to completion of backfilling, removal of any surface drains, and full restoration of hydrology (years)	0	0	0	Chapter 2: Project Description
Early removal of drainage from foundations and hardstanding	-	-	-	-
Will you attempt to block any gullies that have formed due to the windfarm?	Not Applicable	Not Applicable	Not Applicable	
Will you attempt to block all artificial ditches and facilitate rewetting?	Not Applicable	Not Applicable	Not Applicable	
Will you control grazing on degraded areas?	Not Applicable	Not Applicable	Not Applicable	
Will you manage areas to favour reintroduction of species	Not Applicable	Not Applicable	Not Applicable	
Methodology calculating emission factors	IPPC Default			

10.2 Output data

Table 10.2: Output data for the Scottish Government's Carbon Calculator tool

Output data	Expected Value	Minimum Value	Maximum Value
1. Windfarm CO2 emission saving over...	-	-	-
...coal-fired electricity generation (tCO2 yr-1)	224,256	201,831	246,682
...grid-mix of electricity generation (tCO2 yr-1)	49,123	44,211	54,035
...fossil fuel-mix of electricity generation (tCO2 yr-1)	100,619	90,557	110,681
Energy output from windfarm over lifetime (MWh)	8,305,794	7,475,215	9,136,373
2. Total CO2 losses due to wind farm (tCO2e)	-	-	-
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	63,903	63,903	63,903
3. Losses due to backup	50,309	50,309	50,309
4. Losses due to reduced carbon fixing potential	1,509	392	2,902
5. Losses from soil organic matter	33,437	14,825	45,854
6. Losses due to DOC & POC leaching	7,365	1,045	18,283
7. Losses due to felling forestry	18,593	18,076	19,109
Total losses of carbon dioxide*	175,112	148,551	200,359
3. Total CO2 changes due to improvement of site (tCO2e)	-	-	-
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	0	0	0
Total change in emissions due to improvements	0	0	0
Results	-	-	-
Net emissions of carbon dioxide (tCO2e)*	175,112	148,551	200,359
-	-	-	-
...coal-fired electricity generation (years)*	0.8	0.6	1
...grid-mix of electricity generation (years)*	3.6	2.7	4.5
...fossil fuel-mix of electricity generation (years)*	1.7	1.3	2.2