APPENDIX 15.1: SCOTTISH GOVERNMENT'S CARBON CALCULATOR TOOL

15.1 Methodology

15.1.1 This assessment utilises 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. The Calculator Tool assesses the impact of the Proposed Development on peat and forestry habitats and the implications for GHG emissions; however, this is not applicable for this Site as explained in Chapter 11: Soils, Geology, and Hydrology, and the scoping assessment. The Calculator Tool also accounts for the emissions associated with the construction and decommissioning of the Development, as well as the emissions savings from operation. As the site held carbon rich, organic soils, these were treated within the 'peat' section of the Carbon Calculator Tool. Further information regarding soil on the Site is available in Chapter 11: Soils, Geology, and Hydrology.

Embodied Emissions

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

15.1.2 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.

The inclusion of a battery energy storage system (BESS) within the Proposed Development removes the need for backup power generation. The Scottish Government's Carbon Calculator Tool includes embodied emissions from turbines and their foundations, but not for Battery Energy Storage System (BESS). As such, a

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.

supplementary life cycle analysis of BESS has been conducted and integrated within the calculator outputs.

15.2 Input data

15.2.1 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 15.1.1. To reflect design and real-world uncertainty and range of +/- 10% has been applied to many categories.

Table 15.1.1: Input parameter data for the Scottish Government's Carbon Calculator tool

CARBON CALCULATOR TOOL v1.7.0				Ref: JOJR-QDFN-I89P (v3)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Windfarm Characteristics				
Dimensions				
No. of turbines	17	17	17	Chapter 1: Introduction
Duration of consent (years)	40	40	40	Chapter 1: Introduction
Performance				
Power rating of 1 turbine (MW)	6.6	6.0	8.0	Chapter 1: Introduction (Belltown Power)
Capacity factor	45.60	41.04	50.16	Belltown Power
Backup				
Fraction of output to backup (%)	0	0	0	BESS Present (224.4 MWh)
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 11: Soils, Geology, and Hydrology
Average annual air temperature at site (°C)	9.66	8.69	10.62	Met Office – Dunbar climate station
Average depth of peat at site (m)	0.29	0.0	2.8	Chapter 11: Soils, Geology, and Hydrology
Content of dry peat (% by weight)	55	49	61	Chapter 11: Soils, Geology, and Hydrology
Average extent of drainage around drainage features at site (m)	10	2	30	Chapter 11: Soils, Geology, and Hydrology
Average water table depth at site (m)	0.1	0.0	0.3	Chapter 11: Soils, Geology, and Hydrology

CARBON CALCULATOR TOOL v1.7.0				Ref: JOJR-QDFN-I89P (v3)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Dry soil bulk density (g cm^{-3})	0.2	0.18	0.22	Chapter 11: Soils, Geology, and Hydrology
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	5	2	10	Chapter 11: Soils, Geology, and Hydrology
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.23	0.28	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)	0	0	0	No forestry
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	0	0	0	No forestry
Counterfactual emission factors				
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.92	0.92	0.92	Default value (Scottish Government Carbon Calculator)
Grid-mix emission factor (t CO_2 MWh^{-1})	0.25358	0.25358	0.25358	Default value (Scottish Government Carbon Calculator)
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.45	0.45	0.45	Default value (Scottish Government Carbon Calculator)
Borrow pits				
Number of borrow pits	2	2	2	Chapter 11: Soils, Geology, and Hydrology
Average length of pits (m)	140	115	255	Chapter 11: Soils, Geology, and Hydrology
Average width of pits (m)	140	115	255	Chapter 11: Soils, Geology, and Hydrology
Average depth of peat removed from pit (m)	0.25	0.21	0.27	Chapter 11: Soils, Geology, and Hydrology Based on average depths within each borrow pit search area - note that ALL excavation depths reported are organic soils, not peat (this is the case for all figures documented below).
Foundations and hard-standing area associated with each turbine				
Shape (circular/octagonal/hexagnal)	Circular			Infrastructure design and aggregate estimates
Diameter/side at surface (m)	18	16.20	19.80	Infrastructure design and aggregate estimates
Diameter/side at bottom (m)	18	16.20	19.80	Infrastructure design and aggregate estimates
Average depth of peat removed from turbine foundations [m]	0.27	0.24	0.30	Chapter 11: Soils, Geology, and Hydrology
Average length of hard-standing at surface [m]	90	70	200	Infrastructure design and aggregate estimates
Average length of hard-standing at bottom [m]	90	70	200	Infrastructure design and aggregate estimates

CARBON CALCULATOR TOOL v1.7.0				Ref: JOJR-QDFN-I89P (v3)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Average width of hard-standing at surface [m]	30	27	60	Infrastructure design and aggregate estimates
Average width of hard-standing at bottom [m]	30	27	60	Infrastructure design and aggregate estimates
Average depth of peat excavated when constructing hard-standing [m]	0.25	0.23	0.28	Chapter 11: Soils, Geology, and Hydrology
Is piling used? (Yes/No)		Yes		Infrastructure design and aggregate estimates
Volume of concrete (m^3)	20,050	18,045	22,055	Infrastructure design and aggregate estimates
Access tracks				
Total length of access track (m)	10,410	9,369	11,451	Infrastructure design and aggregate estimates
Existing track length (m)	0	0	0	Infrastructure design and aggregate estimates
Length of access track that is floating road (m)	0	0	0	Infrastructure design and aggregate estimates
Width of access track that is floating road (m)	5	5	5	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	Infrastructure design and aggregate estimates
Length of access track that is rock filled road (m)	10,410	9,369	11,451	Infrastructure design and aggregate estimates
Rock filled road width (m)	5	5	5	Infrastructure design and aggregate estimates
Rock filled road depth (m)	0.26	0.23	0.29	Chapter 11: Soils, Geology, and Hydrology
Length of rock filled road that is drained (m)	0	0	0	Infrastructure design and aggregate estimates
Average depth of drains associated with rock filled roads (m)	5	5	5	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)	0.26	0.23	0.29	Chapter 11: Soils, Geology, and Hydrology
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	Chapter 11: Soils, Geology, and Hydrology
Area of additional peat excavated (m^2)	0	0	0	Chapter 11: Soils, Geology, and Hydrology
Peat Landslide Hazard				

CARBON CALCULATOR TOOL v1.7.0				Ref: JOJR-QDFN-I89P (v3)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
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 11: Soils, Geology, and Hydrology
Water table depth in degraded bog before improvement (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology No water table raising works to be undertaken
Water table depth in degraded bog after improvement (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology No water table raising works to be undertaken
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	2	2	2	Minimum applicable values applied due to lack of peat
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	2	2	2	Minimum applicable values applied due to lack of peat
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	No forestry
Water table depth in felled area before improvement (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology No water table raising works to be undertaken
Water table depth in felled area after improvement (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology No water table raising works to be undertaken
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	Minimum applicable values applied due to lack of forestry
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	Minimum applicable values applied due to lack of forestry
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	Chapter 11: Soils, Geology, and Hydrology
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology

CARBON CALCULATOR TOOL v1.7.0				Ref: JOJR-QDFN-I89P (v3)
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	1	1	1	Minimum applicable values applied due to lack of peat
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2	2	2	Minimum applicable values applied due to lack of peat
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hard standing before restoration (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology No water table raising works to be undertaken
Water table depth around foundation and hard standing after restoration (m)	0	0	0	Chapter 11: Soils, Geology, and Hydrology No water table raising works to be undertaken
Time to completion of backfilling, removal of any surface drains, and full restoration of hydrology (years)	0.1	0.1	0.1	Chapter 11: Soils, Geology, and Hydrology n/a to the Development so minimum accepted values applied
Early removal of drainage from foundations and hardstanding				
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	Chapter 11: Soils, Geology, and Hydrology
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	Chapter 11: Soils, Geology, and Hydrology
Will you control grazing on degraded areas?	Yes	Yes	Yes	Chapter 11: Soils, Geology, and Hydrology
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	Chapter 11: Soils, Geology, and Hydrology
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

15.3 Output data

Ref: JOJR-QDFN-I89P (v3)			
Output data	**Expected value**	**Minimum value**	**Maximum value**
1. Windfarm CO2 emission saving over...			

Ref: JOJR-QDFN-I89P (v3)			
Output data	**Expected value**	**Minimum value**	**Maximum value**
...coal-fired electricity generation (t CO2 / yr)	449,086	367,434	598,781
...grid-mix of electricity generation (t CO2 / yr)	86,671	70,913	115,561
...fossil fuel-mix of electricity generation (t CO2 / yr)	193,618	158,415	258,157
Energy output from windfarm over lifetime (MWh)	17,927,585	14,668,024	23,903,447
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	103,222	93,058	126,093
3. Losses due to backup	0	0	0
4. Losses due to reduced carbon fixing potential	1,733	583	7,610
5. Losses from soil organic matter	11,137	-37,281	40,194
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	0	0	0
8. Losses due to embodied emissions of BESS*	44,880	33,660	49,368
Total losses of carbon dioxide*	160,972	90,020	223,265
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
Net emissions of carbon dioxide (t CO2 eq)*	160,972	90,020	223,265
...coal-fired electricity generation (years)*	0.4	0.2	0.6
...grid-mix of electricity generation (years)*	1.9	0.8	3.1
...fossil fuel-mix of electricity generation (years)*	0.8	0.3	1.4
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	**No Gains**	**No Gains**	**No Gains**
* Blue shaded cells denote those that have been modified from the carbon calculator output due to the inclusion of embodied emissions from BESS			