Technical Appendix 15.1: Carbon Calculator Input and Output

Table 1: Input parameter data for the Scottish Government's Carbon Assessment tool

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Windfarm Characteristics				
Dimensions				
No. of turbines	7	7	7	Chapter 1: Introduction
Duration of consent (years)	40	40	40	Chapter 1: Introduction
Performance				
Power rating of 1 turbine (MW)	4.6	4.2	5.0	Chapter 1: Introduction
Capacity factor (%)	39.6	35.6	42.0	Design Metric
Backup				
Fraction of output to backup (%)	0	0	0	Chapter 13: Other Issues: Climate Change. BESS Present
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Scottish Government Carbon Calculator, default value
Total CO_2 emission from turbine life (tCO_2 MW^{-1}) (eg. manufacture, construction, decommissioning)	Calculated from installed capacity	Calculated from installed capacity	Calculated from installed capacity	Scottish Government Carbon Calculator
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Average annual air temperature at site (°C)	9.44	5.63	13.25	Met office climate station - Falkirk Climate Station: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvqdmufu
Average depth of peat at site (m)	0.65	0.00	4.80	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Content of dry peat (% by weight)	41.5	19.0	65.0	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Average extent of drainage around drainage features at site (m)	0.75	0.5	1	Chapter 8: Geology, Hydrogeology, Hydrology and Peat

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Average water table depth at site (m)	0.10	0	0.75	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Dry soil bulk density (g cm^{-3})	0.15	0.05	0.30	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	30	10	40	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.225	0.275	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0.7	0.64	0.77	Chapter 15: Forestry
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.6	2.4	4.4	Default value for Sitka Spruce (highly conservative)
Counterfactual emission factors				
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.92	0.92	0.92	Scottish Government Carbon Calculator
Grid-mix emission factor (t CO_2 MWh^{-1})	0.25	0.25	0.25	Scottish Government Carbon Calculator
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.45	0.45	0.45	Scottish Government Carbon Calculator
Borrow pits				
Number of borrow pits	2	1	2	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Average length of pits (m)	87	73	110	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Average width of pits (m)	77	51	89	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Average depth of peat removed from pit (m)	0.37	0.01	1.43	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Foundations and hard-standing area associated with each turbine				
Shape (circular/octagonal/hexagonal)	Circular			Infrastructure design and aggregate estimates
Diameter/side at surface	22.5	20	25	Infrastructure design and aggregate estimates
Diameter/side at bottom	22.5	20	25	Infrastructure design and aggregate estimates
Average depth of peat removed from turbine foundations [m]	0.64	0.02	2.9	Chapter 8: Geology, Hydrogeology, Hydrology and Peat

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Average length of hard-standing at surface [m]	64.1	42	71.5	Infrastructure design and aggregate estimates
Average length of hard-standing at bottom [m]	64.1	42	71.5	Infrastructure design and aggregate estimates
Average width of hard-standing at surface [m]	32.5	15	50	Infrastructure design and aggregate estimates
Average width of hard-standing at bottom [m]	32.5	15	20	Infrastructure design and aggregate estimates
Average depth of peat excavated when constructing hard-standing [m]	0.64	0.02	2.9	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Is piling used? (Yes/No)	No			Infrastructure design and aggregate estimates
Volume of concrete used for ENTIRE WINDFARM [m3]	4,900	4,410	5,390	Infrastructure design and aggregate estimates
Access tracks				
Total length of access track (m)	9,800	8,820	10,780	Infrastructure design and aggregate estimates
Existing track length (m)	2,700	2,430	2,970	Infrastructure design and aggregate estimates
Length of access track that is floating road (m)	1,300	1,170	1,430	Infrastructure design and aggregate estimates
Width of access track that is floating road (m)	5.5	5.5	5.5	Infrastructure design and aggregate estimates
Floating road depth [m]	1.2	1.2	1.2	Infrastructure design and aggregate estimates
Length of floating road that is drained [m]	1,300	1,170	1,430	Conservative estimate
Average depth of drains associated with floating roads [m]	0.43	0.39	0.47	Benchmarked based on previous project experience
Length of access track that is excavated road (m)	5,800	5,220	6,380	Infrastructure design and aggregate estimates
Excavated road width (m)	5.5	5.5	5.5	Infrastructure design and aggregate estimates
Average depth of peat excavated for road (m)	0.49	0	2.79	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Length of access track that is rock filled road (m)	2,700	2,430	2,970	Infrastructure design and aggregate estimates
Rock filled road width (m)	0	0	0	Infrastructure design and aggregate estimates
Rock filled road depth (m)	0	0	0	Infrastructure design and aggregate estimates

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
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)	0	0	0	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 8: Geology, Hydrogeology, Hydrology and Peat
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	2,748	2,473	3,023	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Area of additional peat excavated (m^2)	8,615	7,753	9,476	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	Low			Chapter 8: Geology, Hydrogeology, Hydrology and Peat
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)	148.0	133.2	162.8	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Water table depth in degraded bog before improvement (m)	0.6	0.3	1	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Water table depth in degraded bog after improvement (m)	0.1	0	0.3	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	15	10	20	Chapter 7: Ecology
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	20	15	30	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0.7	0.63	0.77	Chapter 15: Other Issues, Forestry
Water table depth in felled area before improvement (m)	1.5	0.75	3	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Water table depth in felled area after improvement (m)	0.5	0	1	Chapter 8: Geology, Hydrogeology, Hydrology and Peat

CARBON ASSESSMENT TOOL v2.14.1				
Input data	**Expected value**	**Minimum value**	**Maximum value**	**Source of data**
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	40	Chapter 7: Ecology
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	20	2	40	Chapter 15: Other Issues, Forestry
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	1.1	0.99	1.21	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	2	1.8	2.5	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.8	0.5	1.5	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	20	15	30	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	20	15	30	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hard standing before restoration (m)	0.2	0.1	0.4	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Water table depth around foundation and hard standing after restoration (m)	0.05	0	0.1	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
Time to completion of backfilling, removal of any surface drains, and full restoration of hydrology (years)	5	2	5	Chapter 8: Geology, Hydrogeology, Hydrology and Peat
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	FEI Chapter 7
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	FEI Chapter 7
Will you control grazing on degraded areas?	Yes	Yes	Yes	FEI Chapter 7
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	FEI Chapter 7
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Table 2: Output data from the Scottish Government's Carbon Assessment tool

Output data	Expected value	Minimum value	Maximum value
1. Windfarm CO_2 emission saving over...			
...coal-fired electricity generation (t CO_2 / yr)	102,764	84,446	118,470
...grid-mix of electricity generation (t CO_2 / yr)	28,325	23,276	32,654
...fossil fuel-mix of electricity generation (t CO_2 / yr)	50,265	41,305	57,947
Energy output from windfarm over lifetime (MWh)	4,468,020	3,671,547	5,150,880
Total CO_2 losses due to wind farm (tCO_2 eq.)			
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	28,362	25,591	31,133
3. Losses due to backup	0	0	0
4. Losses due to reduced carbon fixing potential	637	279	1,036
5. Losses from soil organic matter	6,042	- 5,269	143,089
6. Losses due to DOC & POC leaching	34	0	2037
7. Losses due to felling forestry	370	225	497
8. Losses due to BESS*	3,200	2,400	3,200
Total losses of carbon dioxide	38,644	23,226	180,992
9. Total CO_2 gains due to improvement of site (tCO_2 eq.)			
9a. Change in emissions due to improvement of degraded bogs	0	0	- 39,891
9b. Change in emissions due to improvement of felled forestry	- 150	0	- 492
9c. Change in emissions due to restoration of peat from borrow pits	0	0	- 271
9d. Change in emissions due to removal of drainage from foundations & hardstanding	- 11	0	- 75
Total change in emissions due to improvements	- 162	0	- 40,730
RESULTS			
Net emissions of carbon dioxide (t CO_2 eq.)	38,483	-17,504	180,992
Carbon Payback Time			
...coal-fired electricity generation (years)	0.4	- 0.1	2.1
...grid-mix of electricity generation (years)	1.4	- 0.5	7.8
...fossil fuel-mix of electricity generation (years)	0.8	- 0.3	4.4
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	**No Gains!**	**No Gains!**	**No Gains!**

Output data	Expected value	Minimum value	Maximum value
?* Blue shaded cells denote those that have been modified from the carbon calculator output due to the inclusion of embodied emissions from BESS			