APPENDIX 13.1 CARBON CALCULATOR INPUT AND RESULTS

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
WINDFARM CHARACTERISTICS					
Dimensions					
1	Number of turbines	17	17	17	Chapter 2: Proposed Development
2	Duration of consent [years]	30	25	30	Chapter 2: Proposed Development
Performance					
3	Power rating of 1 No. turbine [MW]	4.8	3.8	5.3	Chapter 2: Proposed Development
4	Capacity factor [% estimated]	31	27	34	'Min'/'max' per Nayak et al (2008); 'expected' per central average Nayak, D.R.. *et al* (2008). *Calculating Carbon Savings from Windfarms on Scottish Peatlands – Revision of Guidelines. October 2007 to January 2008. Final Report*
Backup					
5	Fraction of output to backup [%]	5%	0%	5%	Per Nayak et al (2008)
6	Additional emissions from reduced thermal efficiency of reserve generation [%]	10%	10%	10%	Default
CO_2 emissions from turbine life					
7	CO_2 from turbine manufacture, construction, decommissioning etc	Calculated from installed capacity			
8	Type of peatland [acid bog / fen]	Acid Bog			
9	Average air temperature at site [°C]	7.0	3.3	10.7	Met Office (2018). Loch Glascarnoch climate. Available at: https://www.metoffice.gov.uk/public/weather/climate/gfk82sdb6 [Accessed 7th December 2018]

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
10	Average depth of peat at site [m]	0.67	0	4.69	Mean, minimum and maximum of all measured peat depths
11	Carbon content of dry peat [% by weight]	55	49	61	Figures have been derived from available data for peatland in the immediate vicinity of the site.
12	Average extent of drainage around drainage features at site [m]	0.75	0.5	1	Estimates based on observations of drainage around eroded peat areas and around excavated ditches in woodland area of development.
13	Average water table depth at site [m]	0.1	0	0.3	Estimate based on observed/measured ground conditions during dry summer of 2018, when peat surface remained wet despite prolonged dry weather, on standing water levels in drainage ditches in woodland area and on observations in eroded peatland area.
14	Dry soil bulk density [g cm^{-3}]	0.15	0.1	0.2	Figures have been derived from available data for peatland in the immediate vicinity of the site.
CHARACTERISTICS OF BOG PLANTS					
15	Time required for regeneration of bog plants after restoration [yrs]	10	5	15	Professional judgement based on areas and wind farms with similar characteristics.
16	C accumulation from fixation by bog plants in un-drained peats [tC ha^{-1} yr^{-1}]	0.25			Default value used on basis of professional judgement within the study area.
FORESTRY PLANTATION CHARACTERISTICS (simple data)					
17	Area of forestry plantation to be felled [ha]	16.6	14.94	18.26	The area of forestry plantation to be felled has been calculated and shown within the Forestry Appendix of the EIAR. Minimum and maximum values are plus and minus 10% to account for uncertainty.
18	Average rate of carbon sequestration in timber [tC ha^{-1} yr^{-1}]	3.6	2.4	4.4	Default value available if needed (3.6 tC ha^{-1} yr^{-1}) Fast growing Sitka Spruce used as highly conservative. Min/max per range for Sitka Spruce (YC 8 to 24) per Cannell (1999); expected per Sitka Spruce (YC 16) value from SNH technical guidance (2003), as calculated per Cannell (1999)

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
					Cannell M.G.R. (1999) *Growing trees to sequester carbon in the UK: answers to some common questions*. Forestry 72:238-247 Scottish Natural Heritage (2003). *Wind Farms and Carbon Savings. SNH Technical Guidance Note.* Available at: https://www2.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCguidance2-10-0 [Accessed 7th December 2018]
COUNTERFACTUAL EMISSION FACTORS					
19	Coal-fired plant emission factor [t CO_2 MWh^{-1}]	0.918	0.918	0.918	Default value.
20	Grid-mix emission factor [t CO_2 MWh^{-1}]	0.28088	0.28088	0.28088	Default value.
21	Fossil fuel- mix emission factor [t CO_2 MWh^{-1}]	0.46	0.46	0.46	Default value.
BORROW PITS (IF ANY)					
22	Number of borrow pits	2	2	2	2 Borrow pits – Confirmed in Project Description chapter 2.
23	Average length of pits [m]	102	82	122	The average is the average of the lengths of borrow pits 1 and 2, as follows: BP1: 82 m BP2: 122 m
24	Average width of pits [m]	108	86	130	The average is the average of the widths of borrow pits 1 and 2, as follows: BP1: 130 m BP2: 86 m
25	Average depth of peat removed from pit [m]	0.05	0	0.1	The average is the average of the depth of peat removed from borrow pits 1 and 2, as follows: BP1: 0 BP2: 0.1 m
FOUNDATIONS & HARD-STANDING AREA ASSOCIATED WITH EACH TURBINE (RECTANGULAR WITH VERTICAL WALLS)					

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
26	Average length of turbine foundations [m]	25	25	26.25	25m expected/min (per Chapter 2: Proposed Development); max including a 5% variation
27	Average width of turbine foundations [m]	25	25	26.25	As above
28	Average depth of peat removed from turbine foundations [m]	0.52 m	0.24	1.51	Exp' is mean of the mean volume for each turbine foundation footprint. 'Max' is max of the mean volume for each turbine. 'Min' is min of the mean volume for each turbine.
29	Average length of hard-standing [m]	62.5	62.5	65.63	62.5m exp/min (per Chapter 2: Proposed Development); max including a 5% variation
30	Average width of hard-standing [m]	25	25	26.25	TH: as above
31	Average depth of peat removed from hard-standing [m]	0.58 m	0.26	1.45	As above, but for hardstandings
32	Volume of concrete used for ENTIRE WINDFARM [m^3]	11020 (for all foundation)	9918	12122	Volume of concrete calculated to be used for the wind farm. Plus and minus 10% to account for uncertainty and discrepancies.
ACCESS TRACKS					
33	Existing track length [m]	600 (requires upgrading)	570	630	600m, as per Chapter 2: Project description. Plus and minus 5% to account for potential discrepancy.
34	Length of floating road access tracks [m]	0			No floating road.
35	Width of floating road access tracks [m]	0			No floating road.
36	Floating road depth [m]	0			No floating road.
37	Length of floating road that is drained [m]	0			No floating road.
38	Average depth of drains associated with floating roads [m]	0			No floating road.
39	Length of access track that is excavated road [m]	10,230	9,719	10,742	Figure from Project Description chapter 2, +/- 5% variation

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
40	Excavated road width [m]	7	6.65	7.35	Coriolis: "*it is considered unlikely that the total track width (averaged at 7m width) will vary on average by more than +/- 0.5m"*
41	Average depth of peat associated with excavated roads [m]	0.58 m	0	3.1	Mean, minimum and maximum of all measured peat depths associated with tracks,
42	Length of access track that is rock filled road [m]	0			No rock filled road
43	Rock filled road width [m]	0			No rock filled road
44	Rock filled road depth [m]	0			No rock filled road
45	Length of rock-filled road that is drained [m]	0			No rock filled road
46	Average depth of drains associated with rock filled roads [m]	0			No rock filled road
47	Total length of access tracks [m]	10,830	10,288.5	11,371.5	10,830 m, as per Chapter 2: Project description. Plus and minus 5% to account for any potential discrepancy.
CABLE TRENCHES					
48	Length of any cable trench on peat that doesn't follow access tracks and is lined with a permeable medium (e.g. sand) [m]	0	0	0	Coriolis: "it is intended that all cable trenches will follow the route of access tracks and that there will be zero impact for the purpose of the calculator, and the value used is zero"
49	Average depth of peat cut for cable trenches [m]	0	0	0	
ADDITIONAL PEAT EXCAVATED (NOT ALREADY ACCOUNTED ABOVE)					
50	Volume of additional peat excavated [m^3]	3,977	3436	4519	Expected is calculated peat volume for all other infrastructure that would require excavation, not previously covered. Min and max are +/- 1 SD from the calculated volume.
51	Area of additional peat excavated [m^2]	17,125	15413	18838	Expected is based on provided footprints of infrastructure. +/- 10% to account for any discrepancy.
52	Peat landslide hazard	Negligible			Fixed
IMPROVEMENT OF C SEQUESTRATION AT SITE BY BLOCKING DRAINS, RESTORATION OF HABITAT ETC					
Improvement of degraded bog					

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
53	Area of degraded bog to be improved [ha]	15.8	4.9	122.6	See Habitat Management Plan. Maximum, minimum and expected areas of peat restoration possible within the red line boundary.
54	Water table depth in degraded bog before improvement [m]	0.2	0.1	0.4	Estimate based on water levels in drainage ditches and eroded peat areas.
55	Water table depth in degraded bog after improvement [m]	0.05	0	0.1	Estimate assuming peatland is restored, so water table is back to normal good quality peatland levels.
56	Time required for hydrology and habitat of bog to return to its previous state on improvement [years]	10	5	15	Based on professional judgement from ecologist and hydrologist. Estimated as hydrology recovery is dependent on habitat.
57	Period of time when effectiveness of the improvement in degraded bog can be guaranteed [years]	20	15	25	Based on years provided in the line above.
Improvement of felled plantation land					
58	Area of felled plantation to be improved [ha]	4	4	16.6	Calculated from the area of felled woodland on site (see Forestry appendix). All felled areas not used for operational area will be improved (4 ha)
59	Water table depth in felled area before improvement [m]	0.2	0.1	0.4	Estimate based on water levels in drainage ditches and eroded peat areas.
60	Water table depth in felled area after improvement [m]	0.05	0	0.1	Estimate assuming peatland is restored, so water table is back to normal good quality peatland levels.
61	Time required for hydrology and habitat of felled plantation to return to its previous state on improvement [years]	8	5	12	Based on professional judgement from ecologist and hydrologist.
62	Period of time when effectiveness of the improvement in felled plantation can be guaranteed [years]	22	15	27	Based upon years entered above.
Restoration of peat removed from borrow pits					
63	Area of borrow pits to be restored [ha]	2.06	2.06	2.06	The total borrow pit area would be restored.

Data No°	Input data	Data			Notes & Reference to relevant submission documents [Volume, Chapter, Page]
		Expected	Minimum	Maximum	
64	Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	There should not be any water in either borrow pit, except rainfall. The bedrock is impermeable.
65	Water table depth in borrow pit after restoration [m]	0	0	0	There should not be any water in either borrow pit, except rainfall. The bedrock is impermeable.
66	Time required for hydrology and habitat of borrow pit to return to its previous state on restoration [years]	10	5	15	Based upon professional judgement.
67	Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed [years]	20	15	25	Based on 30-year operational lifespan of wind farm and estimated time to recovery provided in Line 66.
Early removal of drainage from foundations and hardstanding					
68	Water table depth around foundations and hardstanding before restoration [m]	0.2	0.1	0.4	Estimate based on water levels in drainage ditches and eroded peat areas.
69	Water table depth around foundations and hardstanding after restoration [m]	0.05	0	0.1	Estimate assuming peatland is restored, so water table is back to normal good quality peatland levels.
70	Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology [years]	5	2	5	Professional judgement based on similar projects and previous work.
Restoration of site after decommissioning					
71	Will you attempt to block any gullies that have formed due to the windfarm? [Yes / No / Not Applicable]	Yes	Yes	Yes	Confirmed by Coriolis.
72	Will you attempt to block all artificial ditches and facilitate rewetting? [Yes / No / Not Applicable]	No	No	No	Confirmed by Coriolis.
73	Will you control grazing on degraded areas? [Yes / No / Not Applicable]	No	No	No	Confirmed by Coriolis.
74	Will you manage areas to favour reintroduction of species? [Yes / No / Not Applicable]	Yes	Yes	Yes	Confirmed by Coriolis.

Payback Time and CO_2 emissions • 1A9L-8ZAS-PFAV v21

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	203,422	140,263	246,349
...grid-mix of electricity generation (t CO2 / yr)	62,241	42,916	75,375
...fossil fuel-mix of electricity generation (t CO2 / yr)	101,933	70,284	123,443
Energy output from windfarm over lifetime (MWh)	6,647,789	3,819,798	8,050,615

Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	71,777	55,545	80,067
3. Losses due to backup	49,322	0	54,460
4. Lossess due to reduced carbon fixing potential	769	370	1,201
5. Losses from soil organic matter	14,701	4,772	36,202
6. Losses due to DOC & POC leaching	26	0	950
7. Losses due to felling forestry	6,574	3,287	8,838
Total losses of carbon dioxide	143,169	63,973	181,718

8. Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-313	0	-19,489
8b. Change in emissions due to improvement of felled forestry	-111	0	-2,903
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	-18	0	-91
Total change in emissions due to improvements	-442	0	-22,483

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	142,727	41,490	181,718
Carbon Payback Time			
...coal-fired electricity generation (years)	0.7	0.2	1.3
...grid-mix of electricity generation (years)	2.3	0.6	4.2
...fossil fuel-mix of electricity generation (years)	1.4	0.3	2.6
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	33.31	0.21	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	21.47	5.15	47.57