Corkey Windfarm Repowering

Technical Appendix 14.1: Carbon Calculator Assessment

Appendix - Volume 3
April 2019

SCOTTISHPOWER RENEWABLES

Carbon Calculator v1.5.1
Corkey Windfarm Location: 55.032255 -6.25923
ScottishPower Renewables

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	5	5	5	Chapter 3
Duration of consent (years)	40	25	70	Operation in perpetuity. For the purposes of this assessment a long lifetime has been assumed
Performance				
Power rating of 1 turbine (MW)	4	4	4	Chapter 3
Capacity factor	30.8	24	37	BEIS Energy Trends 2018 Report - Northern Ireland values
Backup				
Fraction of output to backup (%)	5	5	5	Calculated using suggested notes
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
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	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 8
Average annual air temperature at site (°C)	9.19	3.88	15	Publicly available Met Office data for 2018
Average depth of peat at site (m)	1	0.8	1.2	Chapter 7. Average depth at infrastructure.
C Content of dry peat (% by weight)	53.23	19.57	53.24	Scottish Government Guidance - Guidance on Developments on Peatland - Site survey
Average extent of drainage around drainage features at site (m)	5	4	6	Technical Estimation
Average water table depth at site (m)	0.216	0.072	0.75	Dipwell Data Technical Appendix
Dry soil bulk density (g cm^{-3})	0.132	0.072	0.293	Scottish Government Guidance - Guidance on Developments on Peatland - Site Surveys
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	15	10	20	Technical estimation

Input data	Expected value	Minimum value	Maximum value	Source of data
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 - Carbon Payback Calculator:Guidelines on Measurements
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	Not applicable to Development as no forestry onsite
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	0	0	0	Not applicable to Development as no forestry onsite
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	0.918	0.918	0.918	
Grid-mix emission factor (t CO2 MWh^{-1})	0.28088	0.28088	0.28088	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.46	0.46	0.46	
Borrow pits				
Number of borrow pits	0	0	0	Not applicable to Development as no borrow pits onsite
Average length of pits (m)	0	0	0	Not applicable to Development as no borrow pits onsite
Average width of pits (m)	0	0	0	Not applicable to Development as no borrow pits onsite
Average depth of peat removed from pit (m)	0	0	0	Not applicable to Development as no borrow pits onsite
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	20.8	17	25	Chapter 3
Average width of turbine foundations (m)	20.8	17	25	Chapter 3
Average depth of peat removed from turbine foundations(m)	0.7	0.6	0.8	Assessment Technical Assessment
Average length of hard-standing (m)	62.5	62.5	62.5	Chapter 3
Average width of hard-standing (m)	25	25	25	Chapter 3
Average depth of peat removed from hard-standing (m)	0.9	0.8	1	Peat Slide Risk Assessment Technical Assessment
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	2200	2000	2400	Technical estimate
Access tracks				
Total length of access track (m)	5034	4994	5074	Chapter 3
Existing track length (m)	2517	2517	2517	Chapter 3
Length of access track that is floating road (m)	0	0	0	Not applicable to Development as no floating road
Floating road width (m)	5	5	5	Not applicable to Development as no floating road
Floating road depth (m)	0	0	0	Not applicable to Development as no floating road
Length of floating road that is drained (m)	0	0	0	Not applicable to Development as no floating road

Input data	Expected value	Minimum value	Maximum value	Source of data
Average depth of drains associated with floating roads (m)	0	0	0	Not applicable to Development as no floating road
Length of access track that is excavated road (m)	1397	1377	1417	Chapter 3
Excavated road width (m)	5.5	5.5	5.5	Chapter 3
Average depth of peat excavated for road (m)	1.05	1.05	1.05	Peat Slide Risk Assessment Technical Appendix
Length of access track that is rock filled road (m)	1120	1100	1140	Chapter 3
Rock filled road width (m)	5.5	5.5	5.5	Chapter 3
Rock filled road depth (m)	0.6	0.5	0.7	Chapter 3
Length of rock filled road that is drained (m)	1120	1100	1140	Chapter 3
Average depth of drains associated with rock filled roads (m)	0.6	0.6	0.6	Chapter 3
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	All cable trenches will follow access tracks
Average depth of peat cut for cable trenches (m)	0	0	0	All cable trenches will follow access tracks
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	Not applicable to Development
Area of additional peat excavated (m^2)	0	0	0	Not applicable to Development
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)	9.41	9.41	9.41	Habitat Management Technical Appendix
Water table depth in degraded bog before improvement (m)	0.216	0.072	0.75	Dipwell Data Technical Appendix
Water table depth in degraded bog after improvement (m)	0.2	0	0.4	Technical estimation
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	15	11	20	Technical estimation
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	40	25	70	SPR have control of land in perpetuity.
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Not applicable to Development as no plantation onsite onsite
Water table depth in felled area before improvement (m)	0	0	0	Not applicable to Development as no plantation onsite

Input data	Expected value	Minimum value	Maximum value	Source of data
Water table depth in felled area after improvement (m)	0	0	0	Not applicable to Development as no plantation onsite
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	Not applicable to Development as no plantation onsite
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	Not applicable to Development as no plantation onsite
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	Not applicable to Development as no borrow pits onsite
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	Not applicable to Development as no borrow pits onsite
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	Not applicable to Development as no borrow pits onsite
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	1	1	1	Not applicable to Development as no borrow pits onsite
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2	2	2	Not applicable to Development as no borrow pits onsite
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.5	0.4	0.6	Technical estimation
Water table depth around foundations and hardstanding after restoration (m)	0.216	0.072	0.59	Dipwell Data Technical Appendix
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	5	5	5	Technical estimate and information with Technical Appendix Habitat Management Plan
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	Will be managed during operational life of windfarm site
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	Will be managed during operational life of windfarm site
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	Will be managed during operational life of windfarm site
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	Will be managed during operational life of windfarm site

Input data	Expected value	Minimum value	Maximum value	Source of data
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

Results

Payback Time and CO_2 emissions			
1. Windfarm CO_2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	49,537	38,600	59,508
...grid-mix of electricity generation (t CO2 / yr)	15,157	11,810	18,208
...fossil fuel-mix of electricity generation (t CO_2 / yr)	24,822	19,342	29,819
Energy output from windfarm over lifetime (MWh)	2,158,464	1,051,200	4,537,680
Total CO_2 losses due to wind farm (tCO_2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	17,044	16,981	17,108
3. Losses due to backup	16,118	10,074	28,207
4. Losses due to reduced carbon fixing potential	282	74	661
5. Losses from soil organic matter	4,278	-688	11,310
6. Losses due to DOC & POC leaching	266	0	1,497
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	37,989	26,441	58,783
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-816	0	-8,464
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	-344	0	-306
Total change in emissions due to improvements	-1,160	0	-8,770
RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO_2 eq.)	36829	17671	58783
Carbon Payback Time			
...coal-fired electricity generation (years)	0.7	0.3	1.5
...grid-mix of electricity generation (years)	2.4	1	5
...fossil fuel-mix of electricity generation (years)	1.5	0.6	3
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	3.92	-0.08	No gains!
Ratio of CO_2 eq. emissions to power generation (g/kWh) (for info. only)	17.06	3.89	55.92

1. Windfarm CO_2 Emission Saving

Capacity factor (%)	Exp.	Min.	Max.
	30.8	24	37

	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
RESULTS			
Emissions saving over coal-fired electricity generation (tCO2/yr)	49,537	38,600	59,508
Emissions saving over grid-mix of electricity generation (tCO2/yr)	15,157	11,810	18,208
Emissions saving over fossil fuel - mix of electricity generation (tCO2/yr)	24,822	19,342	29,819

2. CO_2 Loss Due to Turbine Life

Calculation of emissions with relation to installed capacity	Exp.	Min.	Max.
Emissions due to turbine from energy output (t CO_2)	3270	3270	3270
Emissions due to cement used in construction (t CO_2)	695	632	758

RESULTS	Exp.	Min.	Max.
Losses due to turbine life (manufacture, construction, etc.) (t CO_2)	17,044	16,981	17,108
Additional CO2 payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	4	5	3
...grid-mix of electricity generation (months)	13	17	11
...fossil fuel - mix of electricity generation (months)	8	11	7

3. CO_2 Loss Due to Backup

	Exp.	Min.	Max.
Reserve energy (MWh/yr)	8,760	8,760	8,760
Annual emissions due to backup from fossil fuel-mix of electricity generation (tCO2/yr)	403	403	403
RESULTS			
Total emissions due to backup from fossil fuel-mix of electricity generation (tCO_2)	16,118	10,074	28,207

4. Loss of CO_2 Fixing Potential

	Exp.	Min.	Max.
Area where carbon accumulation by bog plants is lost (ha)	5.59	4.79	6.47
Total loss of carbon accumulation up to time of restoration (tCO_2 eq./ha)	50	15	102
RESULTS			
Total loss of carbon fixation by plants at the site (t CO_2)	282	74	661
Additional CO2 payback time of windfarm due to loss of CO_2 fixing potential			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

5. Loss of Soil CO_2

5. Loss of CO_2	Exp.	Min.	Max.
CO2 loss from removed peat (t CO_2 equiv.)	3592.98	-687.77	9790.93
CO2 loss from drained peat (t CO_2 equiv.)	684.53	0	1518.71
RESULTS			
Total CO_2 loss from peat (removed + drained) (t CO_2 equiv.)	4277.51	-687.77	11309.64
Additional CO_2 payback time of windfarm due to loss of soil CO_2			
...coal-fired electricity generation (months)	1.04	-0.21	2.28
...grid-mix of electricity generation (months)	3.39	-0.7	7.45
...fossil fuel - mix of electricity generation (months)	2.07	-0.43	4.55

5a. Volume of Peat Removed	Exp.	Min.	Max.
Peat removed from borrow pits			
Area of land lost in borrow pits (m^2)	0	0	0
Volume of peat removed from borrow pits (m^3)	0	0	0
Peat removed from turbine foundations			
Area of land lost in foundation (m^2)	2163.2	1445	3125
Volume of peat removed from foundation area (m^3)	1514.24	867	2500
Peat removed from hard-standing			
Area of land lost in hard-standing (m^2)	7812.5	7812.5	7812.5
Volume of peat removed from hard-standing area (m^3)	7031.25	6250	7812.5
Peat removed from access tracks			
Area of land lost in floating roads (m^2)	0	0	0
Volume of peat removed from floating roads (m^3)	0	0	0
Area of land lost in excavated roads (m^2)	7683.5	7573.5	7793.5

Volume of peat removed from excavated roads (m^3)	8067.68	7952.18	8183.18
Area of land lost in rock-filled roads (m^2)	6160	6050	6270
Volume of peat removed from rock-filled roads (m^3)	3696	3025	4389
Total area of land lost in access tracks (m^2)	13843.5	13623.5	14063.5
Total volume of peat removed due to access tracks (m^3)	11763.68	10977.18	12572.18
RESULTS			
Total area of land lost due to windfarm construction (m^2)	23819.2	22881	25001
Total volume of peat removed due to windfarm construction (m^3)	20309.17	18094.18	22884.68

5b. CO_2 Loss from Removed Peat	Exp.	Min.	Max.
CO_2 loss from removed peat (t CO_2)	5232.36	934.84	13089.58
CO_2 loss from undrained peat left in situ (t CO_2)	1639.38	1622.61	3298.66
RESULTS			
CO_2 loss attributable to peat removal only (t CO_2)	3592.98	-687.77	9790.93

5c. Volume of Peat Drained	Exp.	Min.	Max.
Total area affected by drainage around borrow pits (m^2)	0	0	0
Total volume affected by drainage around borrow pits (m^3)	0	0	0
Peat affected by drainage around turbine foundation and hardstanding			
Total area affected by drainage of foundation and hardstanding area (m^2)	6955	5180	8970
Total volume affected by drainage of foundation and hardstanding area (m^3)	3129.75	2072	4485
Peat affected by drainage of access tracks			
Total area affected by drainage of access track(m^2)	25170	19816	30684
Total volume affected by drainage of access track(m^3)	10694.25	8423.4	13031.1
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m^2)	0	0	0
Total volume affected by drainage of cable trenches (m^3)	0	0	0
Drainage around additional peat excavated			
Total area affected by drainage (m^2)	0	0	0
Total volume affected by drainage (m^3)	0	0	0
RESULTS			
Total area affected by drainage due to windfarm (m^2)	32125	24996	39654
Total volume affected by drainage due to windfarm (m^3)	13824	10495.4	17516.1

5d. CO_2 Loss from Drained Peat	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning			
Total GHG emissions from Drained Land (t CO_2 equiv.)	3561.55	542.25	10018.9
Total GHG emissions from Undrained Land (t CO_2 equiv.)	2719.58	542.25	7764.91
Calculations of C Loss from Drained Land if Site IS Restored after Decommissioning			
Losses if Land is Drained			
CH_4 emissions from drained land (t CO_2 equiv.)	-9.58	-61.52	201.5
CO_2 emissions from drained land (t CO_2)	2905.14	1834.11	6549.2
Total GHG emissions from Drained Land (t CO_2 equiv.)	2895.56	1772.59	6750.7
Losses if Land is Undrained			
CH_4 emissions from undrained land (t CO_2 equiv.)	75.81	-61.52	1287.62
CO_2 emissions from undrained land (t CO_2)	2135.23	1834.11	3944.37
Total GHG emissions from Undrained Land (t CO_2 equiv.)	2211.03	1772.59	5231.99
RESULTS			
Total GHG emissions due to drainage (t CO_2 equiv.)	684.53	0	1518.71

5e. Emission Rates from soils	Exp.	Min.	Max.
Calculations following IPCC default methodology			
Flooded period (days/year)	178	178	178
Annual rate of methane emission (t CH_4-C/ha year)	0.04	0.04	0.04
Annual rate of carbon dioxide emission (t CO_2/ha year)	35.2	35.2	35.2
Calculations following ECOSSE based methodology			
Total area affected by drainage due to wind farm construction (ha)	3.21	2.5	3.97
Average water table depth of drained land (m)	0.43	0.75	0.44
Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (t CO_2/ha year)	16.44	20.96	18.35
Rate of carbon dioxide emission in undrained soil (t CO_2/ha year)	7.51	20.96	3.38
Rate of methane emission in drained soil (t CH_4-C/ha year)	0	-0.02	0.02
Rate of methane emission in undrained soil (t CH_4-C/ha year)	0.03	-0.02	0.22
RESULTS			
Selected rate of carbon dioxide emission in drained soil (t CO_2/ha year)	16.44	20.96	18.35
Selected rate of carbon dioxide emission in undrained soil (t CO_2/ha year)	7.51	20.96	3.38
Selected rate of methane emission in drained soil (t CH_4-C/ha year)	0	-0.02	0.02
Selected rate of methane emission in undrained soil (t CH_4-C/ha year)	0.03	-0.02	0.22

6. CO_2 Loss by DOC and POC Loss

	Exp.	Min.	Max.
Gross CO_2 loss from restored drained land (t CO_2)	769.91	0	2604.82
Gross CH_4 loss from restored drained land (t CO_2 equiv.)	0	0	0
Gross CO_2 loss from improved land (t CO_2)	0	0	0
Gross CH_4 loss from improved land (t CO_2 equiv.)	145.3	0	4346.09
Total gaseous loss of C (t C)	213.51	0	816.63
Total C loss as DOC (t C)	55.51	0	326.65
Total C loss as POC (t C)	17.08	0	81.66
RESULTS			
Total CO_2 loss due to DOC leaching (t CO_2)	203.55	0	1197.73
Total CO_2 loss due to POC leaching (t CO_2)	62.63	0	299.43
Total CO_2 loss due to DOC & POC leaching (t CO_2)	266.18	0	1497.16
Additional CO_2 payback time of windfarm due to DOC & POC			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	1
...fossil fuel - mix of electricity generation (months)	0	0	1

7. Forestry CO_2 Loss

	Exp.	Min.	Max.
Area of forestry plantation to be felled (ha)	0	0	0
Carbon sequestered (t C ha-1 yr-1)	0	0	0
Lifetime of windfarm (years)	40	25	70
Carbon sequestered over the lifetime of the windfarm (t C ha-1)	0	0	0
RESULTS			
Total carbon loss due to felling of forestry (t CO_2)	0	0	0
Additional CO_2 payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

8. CO_2 Gain – Site Improvement

Degraded Bog	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	9.41	0	9.41
Depth of peat above water table before improvement (m)	0.216	0	0.75
Depth of peat above water table after improvement (m)	0.2	0.4	0
2. Losses with improvement			
Improved period (years)	25	59	5
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.038	-0.018	0.516
CH4 emissions from improved land (t CO_2 equiv.)	134.18	0	4286.56
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	6.772	13.998	1.865
CO2 emissions from improved land (t CO_2 equiv.)	816.208	0	530.406
Total GHG emissions from improved land (t CO_2 eqiv.)	950.388	0	4816.96
3. Losses without improvement			
Improved period (years)	25	59	5
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.031	0.183	0.016
CH4 emissions from improved land (t CO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	7.507	0.427	23.922
CO2 emissions from unimproved land (t CO_2 equiv.)	1766.015	0	13281.451
Total GHG emissions from unimproved land (t CO_2 eqiv.)	1766.015	0	13281.451
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO_2 equiv.)	815.627	0	8464.488

Felled Forestry	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.496	0.477	0.516
CH_4 emissions from improved land (t CO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	0.319	-1.093	1.865
CO_2 emissions from improved land (t CO_2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO_2 eqiv.)	0	0	0

3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.496	0.477	0.516
CH_4 emissions from improved land (t CO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	0.319	-1.093	1.865
CO_2 emissions from unimproved land (t CO_2 equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO_2 eqiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO_2 equiv.)	0	0	0

Borrow Pits	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	1	1	1
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.496	0.477	0.516
CH_4 emissions from improved land (t CO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	0.319	-1.093	1.865
CO_2 emissions from improved land (t CO2 equiv.)	0	0	0
Total GHG emissions from improved land (t CO_2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	1	1	1
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.496	0.477	0.516
CH_4 emissions from improved land (t CO2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	0.319	-1.093	1.865
CO_2 emissions from unimproved land (t CO_2 equiv.)	0	0	0
Total GHG emissions from unimproved land (t CO_2 eqiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO_2 equiv.)	0	0	0

Foundations and Hard Standings	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0.696	0	0.897
Depth of peat above water table before improvement (m)	0.5	0.4	0.6
Depth of peat above water table after improvement (m)	0.216	0.59	0.072
2. Losses with improvement			
Improved period (years)	35	20	65
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	0.031	-0.019	0.017
CH_4 emissions from improved land (t CO_2 equiv.)	11.12	0	59.537
Selected annual rate of carbon dioxide emissions (t CO_2 ha-1 yr-1)	7.507	18.959	3.384
CO_2 emissions from improved land (t CO_2 equiv.)	93.622	0	31.107
Total GHG emissions from improved land (t CO_2 eqiv.)	104.742	0	90.643
3. Losses without improvement			
Improved period (years)	35	20	65
Selected annual rate of methane emissions (t CH_4-C ha-1 yr-1)	-0.003	-0.019	0.017
CH_4 emissions from improved land (t CO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (t CO2 ha-1 yr-1)	18.453	13.998	22.088
CO_2 emissions from unimproved land (t CO_2 equiv.)	449.201	0	396.267
Total GHG emissions from unimproved land (t CO_2 eqiv.)	449.201	0	396.267
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (t CO_2 equiv.)	344.459	0	305.624

Corkey Windfarm Repowering

Technical Appendix A14.2: Health and Safety Statement

Appendix - Volume 3
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SCOTTISHPOWER RENEWABLES

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Date: 23rd May 2019
Reference: MA19035-P01-LET01

FAO Causeway Coast and Glens Borough Council

Planning Reference: Corkey Windfarm Repowering

I write to you on behalf of my client, ScottishPower Renewables (SPR), who has instructed us to carry out an independent and detailed analysis of the risks associated with blade "throw" from five wind turbines proposed as part of the Corkey Windfarm repowering project.

MMI Thornton Tomasetti's Credentials

MMI Thornton Tomasetti, previously known as MMI Engineering, is a professional services consultancy, which specialises in a number of areas including: risk management; safety engineering; and structural engineering. We have a wide range of clients across a range of industrial sectors, which include commercial organisations, "duty holders", government bodies, industry bodies and regulatory organisations. (A "duty holder" is the person or body responsible for safety and for putting in place suitable procedures and measures to control the risks.)

In 2008, we carried out a programme of research for the UK Health and Safety Executive (HSE) to define a standard methodology to determine the risks to persons in the vicinity of onshore wind turbines. The result of that programme of work was a HSE Research Report, number RR968, which is publicly available from the HSE website (http://www.hse.gov.uk/research/rrhtm/rr968.htm). In parallel with the HSE research report, we developed in-house software known as "MMI-RAPTur". This is based on the risk assessment methodology we defined in HSE RR968 and automates many of the processes in the risk assessment. The HSE has a copy of this software for their internal use.

Method Used

"Risk" is usually determined as the product of the likelihood of an event occurring (i.e the "frequency" of the event) and the consequence of that event. In safety engineering, the consequence is typically that a fatality, or fatalities, will occur as a result of the event. The output of a risk assessment is then a number of "fatalities per year" and this value can be compared with limits which are generally held to be "tolerable" or "unacceptable".

The methodology we defined in HSE RR968 uses Newtonian mechanics to determine the trajectory of a blade or blade fragment thrown from a wind turbine, under specific wind turbine and wind conditions. The trajectory determines the location that the blade or fragment will land, and also the velocity and impact energy. The methodology has a model that determines the level of "harm" that a person will be subjected to due to this impact energy, and whether it causes a fatality.

There are many variables that determine the trajectory of thrown blade fragments; these include: the wind speed and direction; the wind turbine design; the operational conditions (rotor speed) at the time the blade or fragment is thrown, and so on. The advantage of automating the risk assessment in MMI-RAPTur, is that we can look at many combinations of these variables in what is called a Monte Carlo analysis. We typically determine 100,000s of different sets of variables and calculate the trajectories for each of these. This large number of results allows us to draw a statistical contour map around the location of the wind turbine – the

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contours show the probability that a blade will hit any specific location, and the probability that a fatality will occur if someone is at that location.

These "risk contours" provide values that are known as Location Specific Individual Risk (LSIR). We use LSIR to calculate the "Individual Risk" and "Societal Risk". Individual Risk is the risk posed to a single person who passes the site on a regular basis, Societal Risk considers the risks to all persons passing the site, and the potential for multiple fatalities resulting from a single incident (e.g. a car or other vehicle with multiple occupants)

Scenarios Evaluated

SPR provided us with input data for the proposed Corkey Windfarm repowering project, including: site maps with the turbine layout; information on the location of properties; wind conditions (direction, speed, frequency); proposed wind turbine component dimensions and masses; and rotational speeds over a range of operating conditions.

We have evaluated a number of different wind turbine failure scenarios. These included: failure during normal operation, failure due to overspeed, and failure due to fire. The combined frequency of failure encompassing all these events was conservatively set to 1 failure in 1000 years (10^{-3} per annum).

We have assessed the Individual Risks that are posed to a number of different groups of individuals. These include: occupants of nearby houses (including any vulnerable occupants); users of Reservoir Road; Altnahinch Road; maintenance workers; and recreational users, such as joggers passing through the site. In this work, we have defined a "vulnerable" occupant of a house as a person who must remain in the house for 24 hours per day.

The HSE produces a very good document called "Reducing Risk, Protecting People" which is sometimes referred to as "R2P2" (http://www.hse.gov.uk/risk/theory/r2p2.pdf). This is intended as a general guideline and description of risk for the public, and to describe the HSE's decision making process. It is useful to compare the potential risks for the Corkey Windfarm with other risks cited by the HSE in their R2P2 document to help place the level of risk into broader perspective.

Results of Analysis

Our analysis concludes that the risks posed by blade throw on this wind farm are low and within the "Broadly Acceptable" region defined by the HSE. This is the case for the Individual Risks posed to the different persons that we have defined for the analysis, including the risk to a vulnerable occupant of nearby properties as well as to persons travelling past or working on the site. It is also the case for the Societal Risk – the risk to all persons in the vicinity of the wind turbines. Further risk-mitigation is not normally required when risks are in the Broadly Acceptable region.

Summary

We note that in Northern Ireland there is some "best practice" planning guidance in BPG Planning Policy Statement 18 "Renewable Energy". This recommends a separation distance of 10 times rotor diameter to nearby occupied property. We are not aware of the origin for this recommended separation distance. Our assessment has been carried out on the basis of site specific factors, taking account of recorded wind conditions and the wind turbine design proposed for the site. Based on this detailed analysis, our conclusion is that the risks related to blade throw and fragmentation posed by the proposed wind turbines at Corkey Windfarm are well within the "Broadly Acceptable" region and therefore that no further mitigation is required. "Broadly Acceptable" is the lowest category of risk defined by the HSE and to provide this in context, the same

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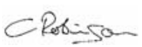
order of magnitude can be attached to the likelihood of a fatality from a lightning strike (1 in 18,700,000 fatalities per year in the UK).

Yours sincerely,



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