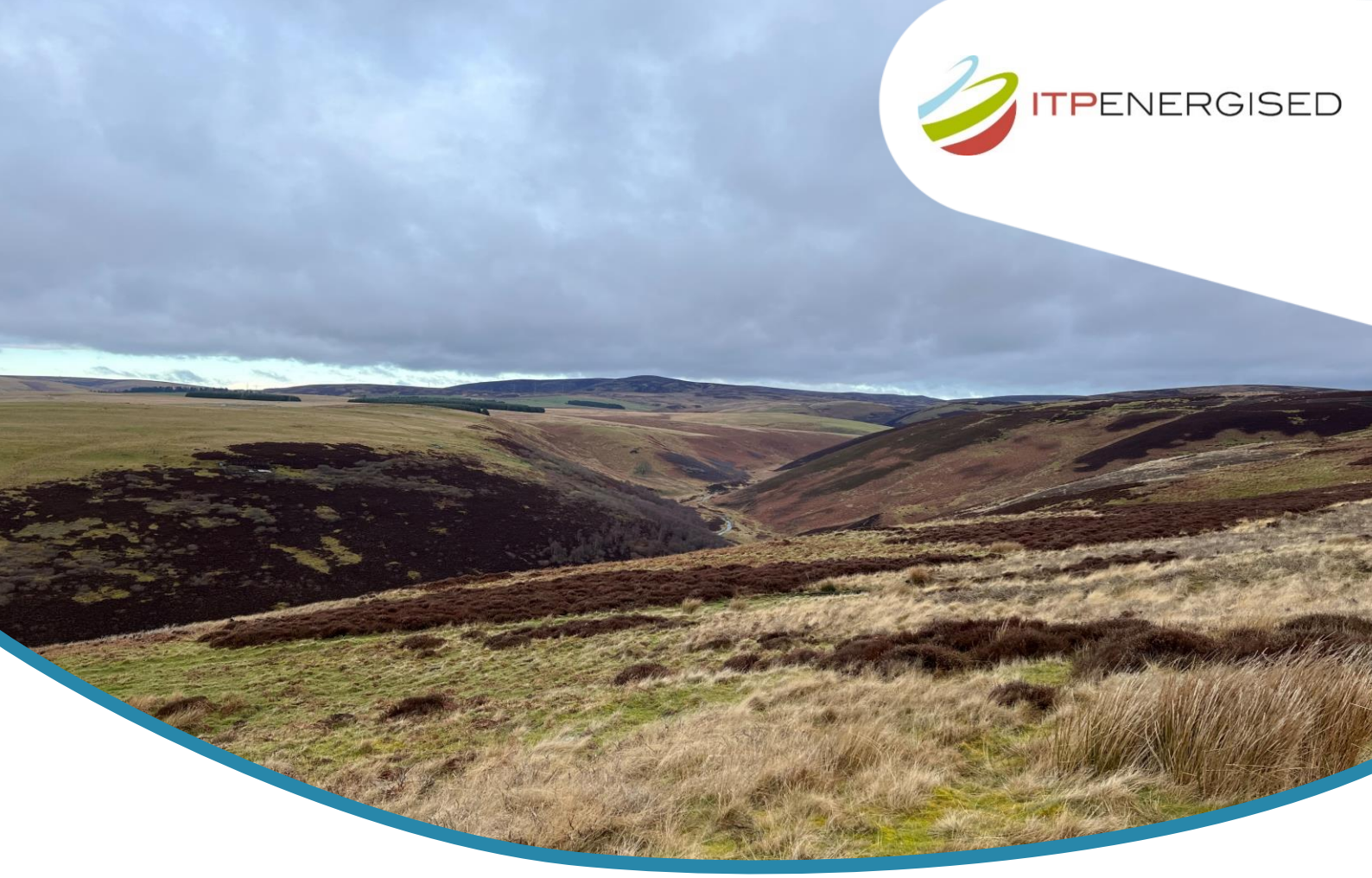

Longcroft Wind Farm

Technical Appendix 14.2 - Carbon Balance Assessment

Client:	Renewable Energy Systems UK and Ireland Ltd (RES)
Project/Proposal No:	5980
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Contents

1. Introduction

The 'carbon calculator' is the Scottish Government's tool provided to support the process of determining wind farm developments in Scotland. The purpose of the tool is to assess, in a comprehensive and consistent way, the carbon impact of wind farm developments. This is done by comparing the carbon costs of wind farm developments with the carbon savings attributable to the wind farm.

The assessment presented in this Technical Appendix has been produced to calculate the carbon emissions generated in the construction, operation and decommissioning of Longcroft Wind Farm (the proposed development).

The carbon calculator spreadsheet and online tool calculates payback time for wind farm sites on peatland, using methods given in Nayak et al, 2008[1] and revised equations for Greenhouse Gas (GHG) emissions (Nayak et al, 2010[2] and Smith et al, 2011[3], and the Wind Farm and Carbon Savings Technical Note[4] v2.2.10.0.

2. Methodology

2.1 Input Parameters

The carbon calculator (online version 1.7.0) submitted allows a range of data to be input to utilise expected, minimum and maximum values, where relevant and applicable. If several parameters are varied together, however, this can have the effect of 'cancelling out' a single parameter change. For this reason, the approach for this assessment, has been to include '*maximum values'* as those values which would result in longest (maximum) payback period; and *'minimum values'* as those values which would result in the shortest (minimum) payback period. The expected value is based on the most realistic option for the site.

The final turbine choice is not yet finalised but would likely be 6.6 MW. For this reason, the factors which have been used in this assessment include the following:

- The recommended capacity factor within the calculation spreadsheet has been amended to a site-specific value (46.4%).
- The choice of methodology for calculating the emission factors used the 'site-specific methodology' defined within the calculation spreadsheet.
- Default values for carbon content and bulk density of peat have been used for the assessment. The carbon content ranges from 49% to 62% with an expected value of 55% used. This reflects a range of values typical of the carbon content anticipated from Scottish Peatlands (Birnie et al 1991[5] and Lindsay 2010[6]). Typical bulk density values have been sourced from the Windfarm Carbon Calculator Web Tool, User Guidance.

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[1] Nayak D.R., Miller D., Nolan A., Smith P., Smith J.U. (2008) *Calculating carbon savings from windfarms on Scottish peatlands: a new approach.* Scottish Government.
[2] Nayak D.R., Miller D., Nolan A., Smith P., Smith J.U. (2010) *Mires and Peat*., Article 09 4, 1-23 http://www.mires-and-peat.net/, ISSN 1819-754X.
[3] Smith J.U., Graves P., Nayak D.R., Smith P., Perks M., Gardiner B., Miller D., Nolan A., Morrice J., Xenakis S., Waldron S., 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.
[4] Scottish Government (2016). *Calculating Potential carbon losses and savings from wind farms on Scottish peatlands*. Technical Note – Version 2.10.0
[5] Birnie R.V., Clayton P., Griffiths P., Hulme P.D., Robertson, R.A., Sloane B.D., and S.A. Ward. (1991). *Scottish peat resources and their energy potential*. Department of Energy
[6] Lindsay, R. (2010). *Peatbogs and Carbon: a critical synthesis*. RSPB

- Generic hydrological parameters have been used for average groundwater. A value of 0.3 m has been used as the expected value. A 'minimum' value of 0.1 m has been used to represent areas of intact peat (the higher the water table, the longer the payback period), and a 'maximum' value of 0.5 m has been used to represent areas of eroded peat. Although limited peat was identified through peat probing, ecological surveys identified much of the site to comprise degraded blanket bog.
- A review of the available literature (Nayak et al., 2008) found that the extent of drainage effects is reported as being anything from 2 m to 50 m horizontally around a site of disturbance. Research into the effects of moor gripping and water table data from other sites yielded a horizontal draw down distance typically of about 2 m. It is thought that in extreme cases, this may extend between 15 m and 30 m, though 15 m is considered an appropriate distance.
- Smith et al. (2011), identified the average extent of drainage impact at three sites (Cross Lochs, Farr Windfarm and Exe Head) as ranging from 3 m to 9 m. However, the actual extent of drainage at any given location will be dependent on local site conditions, including underlying substrata and topography.
- As site specific values are not available, the standard values from 'Windfarm Carbon Calculator Web Tool, User Guidance' have been used. Therefore, the expected value is 10 m (minimum 5 m, maximum 50 m).
- The most recent values for the three required counterfactual factors provided in the online carbon calculator have been included are: Grid Mix 0.19338 t CO_2 MWh^{-1}, fuel mix: 0.432 t CO_2 MWh^{-1} and coal: 1.002 t CO_2 MWh^{-1}.
- Infrastructure dimensions, including estimated excavation size for turbine foundations, hardstands and track lengths is outlined in Chapter 3. Although not all proposed borrow pits are sited on peatland, conservatively, each location has been included in the assessment. The final dimensions of each borrow pit have yet to be defined. Average dimensions from the search areas identified have been used, however it is unlikely that actual borrow pits would be as large.
- The assessment is based on a series of average soil depths taken from peat surveys undertaken at the site. Probe locations sited on mineral / organic soils (<0.5 m) are conservatively included within the averages.
- An estimate of the total volume of concrete has been included, based on an anticipated 910 m^3 concrete being required for each turbine foundation.

A full summary of input parameters are presented in Annex 1 and can be viewed online using reference WZ1Z-O5IW-NPTL.

3. Results

A summary of the anticipated carbon emissions and carbon payback of the proposed development is presented in Plate 2-1 and can be viewed online using reference WZ1Z-O5IW-NPTL.

Plate 3-1
Estimated Payback Period

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	218,151	201,852	277,377
Carbon Payback Time			
...coal-fired electricity generation (years)	0.4	0.4	0.5
...grid-mix of electricity generation (years)	2.2	2.0	2.8
...fossil fuel-mix of electricity generation (years)	1.0	0.9	1.3
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	-0.67	-1.22	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	8.56	7.90	10.91

4. Conclusion

The calculations of total carbon dioxide emission savings and payback time for the proposed development indicates the overall payback period for 19 turbines with installed capacity of around 6.6 MW would be around 0.9 to 1.3 years, when compared to the fossil fuel mix of electricity generation.

This means that the proposed development is anticipated to take around 1 year to repay the carbon exchange to the atmosphere (the CO_2 debt) following its construction; the site would, in effect, be in a net gain situation following this time period and could then claim to contribute to Scottish Government's national objectives on reducing emissions.

Annex 1 – Carbon Calculator Input Parameters

Carbon Calculator v1.7.0
Longcroft Wind Farm Location: 55.795188 -2.71929
Renewable Energy Systems (RES) UK and Ireland Ltd

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	19	19	19	EIAR Ch3
Duration of consent (years)	50	50	50	EIAR Ch3
Performance				
Power rating of 1 turbine (MW)	6.6	6.6	6.6	EIAR Ch3
Capacity factor	46.4	46.3	46.5	EIAR Ch1
Backup				
Fraction of output to backup (%)	5	5	5	Carbon Calculator Guidance Doc
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	EIAR Ch8
Average annual air temperature at site (°C)	7.5	5	8	Met Office Weather Data
Average depth of peat at site (m)	0.2	0.19	0.21	EIAR Ch10
C Content of dry peat (% by weight)	55	49	62	Birnie R.V., Clayton P., Griffiths P., Hulme P.D., Robertson, R.A., Sloane B.D., and S.A. Ward. (1991). Scottish peat resources and their energy potential. Department of Energy
Average extent of drainage around drainage features at site (m)	10	5	50	Windfarm Carbon Calculator Web Tool, User Guidance
Average water table depth at site (m)	0.3	0.1	0.5	EIA Ch10
Dry soil bulk density (g cm^{-3})	0.132	0.072	0.293	Windfarm Carbon Calculator Web Tool, User Guidance
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	6	4	8	Conservative values
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.12	0.31	NatureScot Guidance
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	n/a

Input data	Expected value	Minimum value	Maximum value	Source of data
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	0	0	0	n/a
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh^{-1})	0.19338	0.19338	0.19338	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.432	0.432	0.432	
Borrow pits				
Number of borrow pits	3	3	3	EIAR Ch3
Average length of pits (m)	243	185	315	EIAR Ch3
Average width of pits (m)	264	200	298	EIAR Ch3
Average depth of peat removed from pit (m)	0.11	0.1	0.13	EIAR Ch10 TA 10.2
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	30	30	30	EIAR Ch3
Average width of turbine foundations (m)	30	30	30	EIAR Ch3
Average depth of peat removed from turbine foundations(m)	0.16	0.16	0.16	EIAR Ch10 TA 10.2
Average length of hard-standing (m)	55	55	55	EIAR Ch3
Average width of hard-standing (m)	35	35	35	EIAR Ch3
Average depth of peat removed from hard-standing (m)	0.16	0.16	0.16	EIAR Ch10 TA 10.2
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	17290	17290	17290	EIAR Ch3
Access tracks				
Total length of access track (m)	19454	19453.9	19454.1	EIAR Ch3
Existing track length (m)	3340	3340	3340	EIAR Ch3
Length of access track that is floating road (m)	0	0	0	No floating track currently proposed.
Floating road width (m)	0	0	0	
Floating road depth (m)	0	0	0	
Length of floating road that is drained (m)	0	0	0	
Average depth of drains associated with floating roads (m)	0	0	0	
Length of access track that is excavated road (m)	16114	16113.9	16114.1	EIAR Ch3
Excavated road width (m)	5	5	5	EIAR Ch3
Average depth of peat excavated for road (m)	0.22	0.22	0.22	EIAR Ch10 TA 10.2
Length of access track that is rock filled road (m)	0	0	0	No rock filled road proposed.
Rock filled road width (m)	0	0	0	
Rock filled road depth (m)	0	0	0	
Length of rock filled road that is drained (m)	0	0	0	

Input data	Expected value	Minimum value	Maximum value	Source of data
Average depth of drains associated with rock filled roads (m)	0	0	0	
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	
Average depth of peat cut for cable trenches (m)	0	0	0	
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	
Area of additional peat excavated (m^2)	0	0	0	
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				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	70.92	70.91	70.93	EIAR Ch8
Water table depth in degraded bog before improvement (m)	0.3	0.1	0.5	Windfarm Carbon Calculator Web Tool, User Guidance
Water table depth in degraded bog after improvement (m)	0.1	0.05	0.3	Windfarm Carbon Calculator Web Tool, User Guidance
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	5	2	15	Conservative values
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	50	50	50	Duration of consent
<u>Improvement of felled plantation land</u>				
Area of felled plantation to be improved (ha)	0	0	0	n/a
Water table depth in felled area before improvement (m)	0	0	0	
Water table depth in felled area after improvement (m)	0	0	0	
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	0	0	0	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	0	0	0	
<u>Restoration of peat removed from borrow pits</u>				

Input data	Expected value	Minimum value	Maximum value	Source of data
Area of borrow pits to be restored (ha)	7.65	7.65	7.65	EIAR Ch3
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.3	0.1	0.5	Windfarm Carbon Calculator Web Tool, User Guidance
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.1	0.05	0.3	Windfarm Carbon Calculator Web Tool, User Guidance
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	5	2	15	Conservative estimates.
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	50	50	50	Duration of consent
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.3	0.1	0.5	Windfarm Carbon Calculator Web Tool, User Guidance
Water table depth around foundations and hardstanding after restoration (m)	0.1	0.05	0.3	Windfarm Carbon Calculator Web Tool, User Guidance
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0.25	0.1	3	EIAR Ch3
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	EIAR Ch3
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	EIAR Ch3
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	EIAR Ch3
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	EIAR Ch3
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

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