Technical Appendix 8.8: Carbon Calculator

Glentarken Wind Farm

SSE Generation Ltd.

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Prepared by:

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SLR Project No.: 405.065137.00001

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Basis of Report

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1.0 Introduction

SLR was commissioned by SSE Renewables Services Ltd (‘the Agent) on behalf of SSE Generation Ltd (the ‘Applicant’), to calculate the carbon pay-back period for the proposed Glentarken Wind Farm (the ‘Proposed Development’). In absence of the online Carbon Calculator Tool this assessment has been undertaken in accordance with the associated guidance using the offline version spreadsheet provided by the ECU [1]. The results of which are provided in Annex A.

The Applicant is proposing to submit a Section 36 application to construct and operate a 12-turbine wind farm (up to 180 m tip height), battery energy storage system (BESS) and associated infrastructure with a total generation capacity of greater than 50 MW.

The Proposed Development is located within the Drummond Estate, approximately 2.8 km east of Lochearnhead, 15.5 km west of Crieff, 35 km north of Stirling, and 45 km west of Perth. All of the turbines within the Proposed Development will be located within the Perth and Kinross local authority area. However, the access track and the western part of the Proposed Development fall within Stirling local authority area.

The Proposed Development is characterised by areas of heathland, moorland and rough hill pasture. The southern edge of the Proposed Development has areas of arable land as well as forests and woodland. On the western border of the Proposed Development is an area of Ancient Woodland.

To calculate the pay-back period, the assessment considers the following carbon saving and carbon loss parameters:

- Carbon emissions savings, based on emissions from different power sources;
- Loss of carbon due to production, transportation, erection, operation and decommissioning of the wind farm;
- Loss of carbon from backup power generation;
- Loss of carbon-fixing potential of peatland;
- Loss and/or saving of carbon stored in peatland (by peat removal or changes in drainage); and
- Carbon saving due to improvement of habitat.

[1] Calculating Carbon Savings from Wind Farms on Scottish Peatlands – A New Approach (Nayak et al., 2008; Nayak et al., 2010 and Smith et al, 2011)

2.0 Input Data

The data inputs for the online calculator tool have been extracted from the sources listed below:

- Glentarken Wind Farm EIAR Chapter 2: Development Description (EIAR Volume 1);
- Glentarken Wind Farm EIAR Chapter 3: Evolution of Design and Alternatives (EIAR Volume 1);
- Glentarken Wind Farm EIAR Chapter 7: Ecology (EIAR Volume 1);
- Glentarken Wind Farm EIAR Technical Appendix 8.1: Peat Landslide Hazard Risk Assessment (EIAR Volume 4); and
- Glentarken Wind Farm EIAR Technical Appendix 8.2: Outline Peat Management Plan (EIAR Volume 4).

The calculation spreadsheet (as shown in Annex A) allows a range of data to be input in order to utilise expected, minimum and maximum values, where relevant and applicable. However, if several parameters are varied together, 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 the 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 Proposed Development.

3.0 Results

The assessment calculates carbon emissions savings and losses from the various aspects of the model; and also calculates a payback period based on the three counterfactual emission factors, coal-fired plant, normal grid mix and fossil fuel mix. The counterfactual emission factors are fixed within the calculator tool, the coal-fired and fossil fuel mix emission values are based on Digest of UK Energy Statistics (DUKES)[2] data for which the UK is annually updated. The grid mix emission factor is the list of emission factors used to report on 2023 greenhouse gas emissions as published by Department of Energy and Climate Change (DECC)[3].

Table 4-1 presents the estimates of CO_2 emissions savings for the Proposed Development when compared against coal-fired, grid-mix and fossil fuel electricity generation. It also provides the potential energy output from the Wind Farm over the 50 year lifetime.

Table 4-1 Estimate of CO_2 Emission Savings

Wind Farm CO_2 emission saving over…	Exp.	Min.	Max.
…coal-fired electricity generation (t CO_2/yr)	262,373	258,677	264,836
…grid-mix of electricity generation (t CO_2/yr))	57,472	56,663	58,012
…fossil fuel – mix of electricity generation (t CO_2/yr)	117,721	116,063	118,826
Energy output from Wind Farm over lifetime (MWh)	13,882,147	13,686,624	14,012,496

Table 4-2 and Table 4-3 present the estimated losses and gains from the various aspects of the wind farm construction and operation. This shows that the improvement of degraded bogs will have a positive impact on carbon capture.

Table 4-2 Estimated CO_2 Losses

Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
Losses due to turbine life (e.g. manufacture, construction, decommissioning)	67,318	67,318	67,318
Losses due to backup	69,085	0	69,085
Losses due to reduced carbon fixing potential	4,693	1,755	10,566
Losses from soil organic matter	74,376	56,739	86,944
Losses due to DOC & POC leaching	2,244	18	10,565
Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	217,716	125,830	244,478

[2] Department for Business, Energy & Industrial Strategy, Digest of UK Energy Statistics (DUKES)

[3] Department of Energy and Climate Change, Greenhouse gas reporting – Conversion Factors 2023

Table 4-3 Estimated CO_2 Gains

Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
Change in emissions due to improvement of degraded bogs	-86,809	0	-170,425
Change in emissions due to improvement of felled forestry	0	0	0
Change in emissions due to restoration of peat from borrow pits	-22,180	0	-21,461
Change in emissions due to removal of drainage from foundations & hardstandings	0	0	0
Total change in emissions due to improvements	-108,989	0	-191,886

Table 4-4 demonstrates that the net emissions of carbon dioxide are estimated at 108,726 tonnes of CO_2, with an estimated payback period of 0.9 years.

A summary of the anticipated carbon emissions and carbon payback of the Proposed Development are provided below:

Table 4-4 CO_2 Emissions and Payback Time

Results	Exp.	Min.	Max.
Net emissions of carbon dioxide (t $CO_{2\ eq}$) (carbon losses minus carbon gains)	108,727	-66,056	244,477
Carbon Payback Time			
…coal-fired electricity generation (years)	0.4	-0.25	0.9
…grid-mix of electricity generation (years)	1.9	-1.1	4.3
…fossil fuel – mix of electricity generation (years)	0.9	-0.56	2.1
Ratio of CO_2 eq. emissions to power generation (g/kWh)	8	-5	18

4.0 Conclusions

The calculations of total carbon dioxide emission savings and payback time for the Proposed Development indicates that the overall payback period will be around 0.9 years (11 months) when compared to the fossil fuel - grid fuel mix of electricity generation or 1.9 years when compared to the grid-mix. This means that the Proposed Development is anticipated to take around 0.9 or 1.9 years to repay (offset) the carbon exchange to the atmosphere (the CO_2 debt) through construction; the Site would in effect be in a net gain situation following this time period and can then claim to contribute to national emissions reduction objectives thereafter for its remaining operational life.

5.0 References

Calculating Carbon Savings from Wind Farms on Scottish Peatlands - A New Approach, Nayak et al; 2008 and 2010 and Smith et al; 2011. (http://www.gov.scot/Publications/2008/06/25114657/0)

Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., 2010, Calculating carbon budgets of wind farms on Scottish peatland. Mires and Peat 4: Art. 9. Online. (http://mires-and-peat.net/pages/volumes/map04/map0409.php)

Scottish Peat Resources and their Energy Potential. ETSU B 1204. London: Department of Energy. Birnie R.V., Clayton P., Griffiths P., Hulme P.D., Robertson, R.A., Sloane B.D., and S.A. Ward. (1991).

Peatbogs and Carbon: A Critical Synthesis Lindsey, R. (2010) for RSPB Scotland.

Scottish Natural Heritage (SNH), SEPA, Scottish Government & The James Hutton Institute. (2014). Peat Survey Guidance; Developments on Peatland: Site Surveys.

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Scottish Government. 2020. Update to the Climate Change Plan 2018 – 2032 Securing a Green Recovery on a Path to Net Zero. Available at https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2020/12/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/documents/update-climate-change-plan-2018-2032-securing-green-recovery-path-net-zero/update-climate-change-plan-2018-2032-securing-green-recovery-path-net-zero/govscot%3Adocument/update-climate-change-plan-2018-2032-securing-green-recovery-path-net-zero.pdf

Annex A

Technical Appendix 8.8: Carbon Calculator

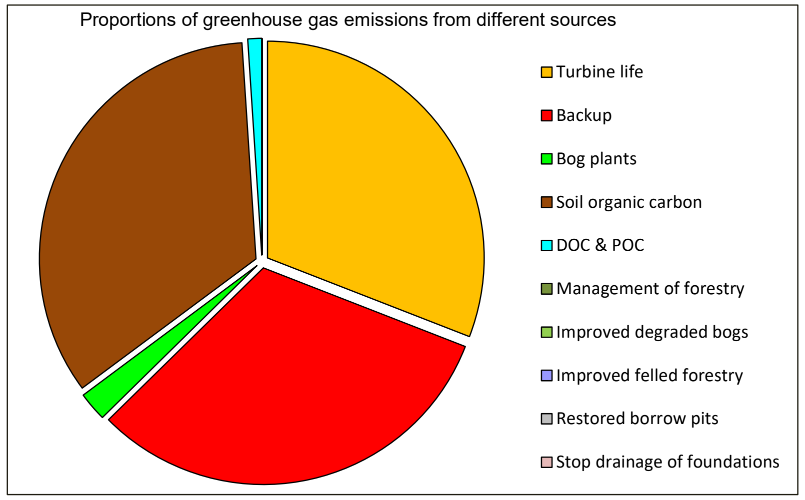
Glentarken Wind Farm

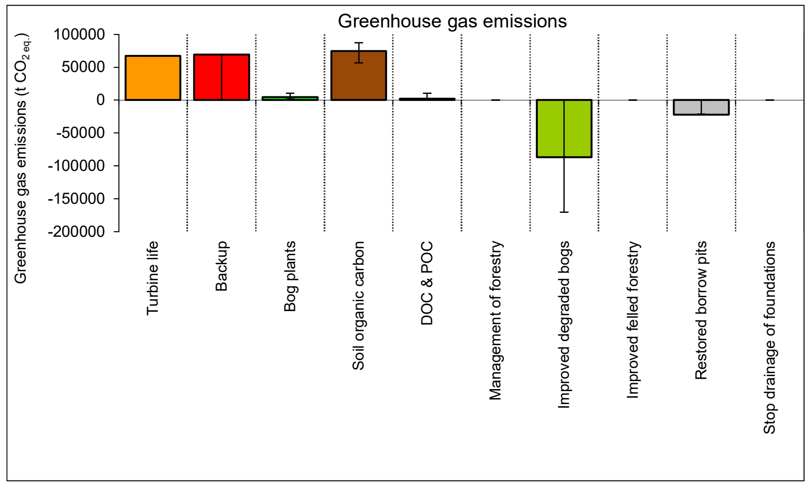
SSE Generation Ltd.

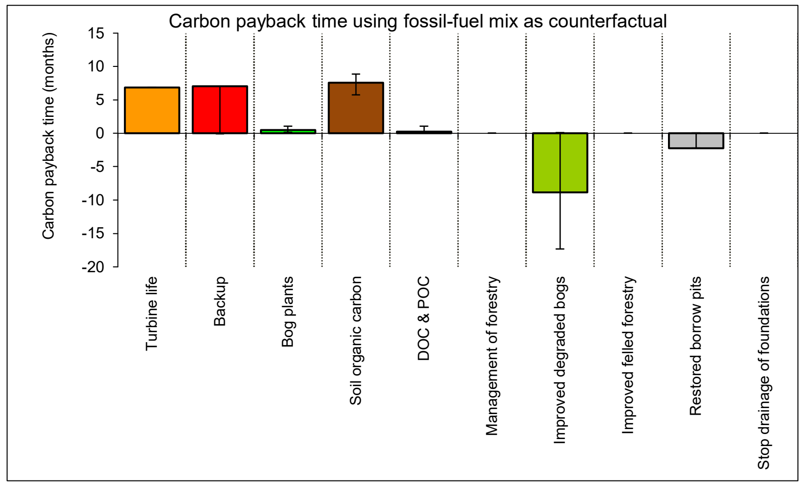
SLR Project No.: 405.065137.00001

	Exp.	Min.	Max.
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation ($tCO_2\ yr^{-1}$)	262373	258677	264836
…grid-mix of electricity generation ($tCO_2\ yr^{-1}$)	57472	56663	58012
…fossil fuel - mix of electricity generation ($tCO_2\ yr^{-1}$)	117721	116063	118826
Energy output from windfarm over lifetime (MWh)	13882147	13686624	14012496
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	67318	67318	67318
3. Losses due to backup	69085	0	69085
4. Losses due to reduced carbon fixing potential	4693	1755	10566
5. Losses from soil organic matter	74376	56739	86944
6. Losses due to DOC & POC leaching	2244	18	10565
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	217715	125830	244477
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	-86809	0	-170425
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	-22180	0	-21461
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	-108989	0	-191886

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**108726**	**-66056**	**244477**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.4	-0.25	0.9
…grid-mix of electricity generation (years)	1.9	-1.1	4.3
…fossil fuel - mix of electricity generation (years)	**0.9**	**-0.56**	**2.1**
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	**No gains!**	**No gains!**	**No gains!**
Ratio of CO_2 eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	**8**	**-5**	**18**







Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions

	Exp.	Min	Max
Turbine life	67318	0	0
Backup	69085	69085	0
Bog plants	4693	2938	5873
Soil organic carbon	74376	17636	12568
DOC & POC	2244	2226	8321
Management of forestry	0	0	0
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	719
Stop drainage of foundations	0	0	0

Data used in barchart of carbon payback time using fossil-fuel mix as counterfactual

Greenhouse gas emissions				Carbon payback time (months)		
	Exp.	Min.	Max.	Exp.	Min.	Max.
Turbine life	67318	0	0	7	0	0
Backup	69085	69085	0	7	7	0
Bog plants	4693	2938	5873	0	0	1
Soil organic carbon	74376	17636	12568	8	2	1
DOC & POC	2244	2226	8321	0	0	1
Management of forestry	0	0	0	0	0	0
Improved degraded bogs	-86809	-86809	-83616	-9	-9	-8
Improved felled forestry	0	0	0	0	0	0
Restored borrow pits	-22180	-22180	719	-2	-2	0
Stop drainage of foundations	0	0	0	0	0	0
	108726			11		

Input data	Expected values: Enter expected value here	Record source of data	Possible range of values: Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	12		12		12	
Lifetime of windfarm (years)	50	Fixed	50		50	
Performance						
Power rating of turbines (turbine capacity) (MW)	6.2		6.2		6.2	
Capacity factor	Direct input of capacity fac		Direct input of capacity fact		Direct input of capacity fact	
Enter estimated capacity factor (percentage efficiency)	42.6		42.0		43.0	
Backup						
Extra capacity required for backup (%)	5		0		5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10		10	
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed capa		Calculate wrt installed capa		Calculate wrt installed capa	
Characteristics of peatland before windfarm development						
Type of peatland	Acid bo		Acid bo		Acid bo	
Average annual air temperature at site (°C)	11		5		11	
Average depth of peat at site (m)	0.60		0.00		5.00	
C Content of dry peat (% by weight)	55.5		49		62	
Average extent of drainage around drainage features at site (m)	10.00		5.00		25.00	
Average water table depth at site (m)	0.10		0.05		0.20	
Dry soil bulk density (g cm^{-3})	0.20		0.18		0.22	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	5		2		15	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25		0.12		0.31	
Forestry Plantation Characteristics						
Method used to calculate CO_2 loss from forest felling	Enter simple data		Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	0		0		0	
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.00		2.40		3.60	
Counterfactual emission factors						
To update counterfactual emission factors from the web [Click here (not yet operational)]						
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.945		0.945		0.945	
Grid-mix emission factor (t CO_2 MWh^{-1})	0.207		0.207		0.207	
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.424		0.424		0.424	
Borrow pits						
Number of borrow pits	6		6		6	
Average length of pits (m)	350		350		350	
Average width of pits (m)	200		200		200	
Average depth of peat removed from pit (m)	0.30		0.30		0.30	
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO_2 loss from foundations and hard-standing	Enter detailed information		Enter detailed information		Enter detailed information	
Please enter construction data in sheet: Construction input data						
Average depth of peat removed from turbine foundations (m)	0.97		0.97		0.97	
Average depth of peat removed from hard-standing (m)	0.97		0.97		0.97	
Access tracks						
Total length of access track (m)	16165		16165		16165	
Existing track length (m)	972		972		972	
Length of access track that is floating road (m)	2793		2793		2793	
Floating road width (m)	6		6		6	
Floating road depth (m)	0.00		0.00		0.00	
Length of floating road that is drained (m)	0		0		0	
Average depth of drains associated with floating roads (m)	0.00		0.00		0.00	
Length of access track that is excavated road (m)	12400		12400		12400	
Excavated road width (m)	8		8		8	
Average depth of peat excavated for road (m)	0.37		0.37		0.37	
Length of access track that is rock filled road (m)	0		0		0	
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	
Average depth of drains associated with rock filled roads (m)	0.00		0.00		0.00	
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)	0.00		0.00		0.00	
Additional peat excavated (not already accounted for above)						
Volume of additional peat excavated (m^3)	85402		85402		85402	
Area of additional peat excavated (m^2)	68750.0		68750.0		68750.0	
Peat Landslide Hazard						
Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments						
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)	270.95		270.95		270.95	
Water table depth in degraded bog before improvement (m)	0.30		0.10		0.50	
Water table depth in degraded bog after improvement (m)	0.10		0.05		0.30	
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10		5		15	
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	50		50		50	
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)	0		0		0	
Water table depth in felled area before improvement (m)	0.00		0.00		0.00	
Water table depth in felled area after improvement (m)	0.00		0.00		0.00	
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	
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)	69		69		69	
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.30		0.10		0.50	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.10		0.05		0.30	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	10		5		15	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	50		50		50	
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)	0.30		0.10		0.50	
Water table depth around foundations and hardstanding after restoration (m)	0.10		0.05		0.30	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0.25		0.1		3	
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 you attempt to block all artificial ditches and facilitate rewetting?	Yes		Yes		Yes	
Will the habitat of the site be restored on decommissioning?	Yes		Yes		Yes	
Will you control grazing on degraded areas?	Yes		Yes		Yes	
Will you manage areas to favour reintroduction of species	Yes		Yes		Yes	

Input data	Expected values: Enter expected value here ↓	Record source of data	Possible range of values: Enter minimum value here ↓	Record source of data	Enter maximum value here ↓	Record source of data
Construction design **Note - total number of turbines already specified:**	**12**		**12**		**12**	
AREA 1						
Number of turbines in this area						
Turbine foundations						
Average depth of peat removed when constructing foundations (m)						
Approximate geometric shape of whole dug when constructing foundations	Rectangular		Rectangular		Rectangular	
Length at surface (m)	28		28		28	
Width at surface (m)	28		28		28	
Length at bottom (m)	28		28		28	
Width at bottom (m)	28		28		28	
Hardstanding						
Average depth of peat removed when constructing hardstanding (m)						
Approximate geometric shape of whole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular	
Length at surface (m)	80		80		80	
Width at surface (m)	30		30		30	
Length at bottom (m)	80		80		80	
Width at bottom (m)	30		30		30	
Piling						
Is piling used?	No		No		No	
Volume of Concrete						
Volume of concrete used (m^3)	10800		10800		10800	

Making Sustainability Happen