Technical Appendix 12.2: Carbon Calculator

Clune Wind Farm

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Basis of Report

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1.0 Introduction

SLR has been commissioned by Renewable Energy Systems Ltd (The Applicant) to calculate the carbon pay-back period for the proposed Clune Wind Farm (the 'Proposed Development') using the Scottish Government Carbon Calculator Tool[1] in accordance with the associated guidance[2].

The Proposed Development is located approximately 20 km south-east of Inverness, and approximately 3 km south of the village of Tomatin. The Proposed Development is predominately managed upland grouse moorland with agricultural fields and mixed woodland in lower altitude areas.

The Carbon Calculator Tool has been developed by the Scottish Government to support the process of determining the carbon pay-back period for wind farm developments in Scotland. The carbon payback period is derived by comparing the carbon costs of wind farm developments (particularly during construction) with the carbon savings likely to be achieved through their operation.

The Carbon Calculator Tool v2.14.1 uses methods given in Nayak et al, 2008 (http://www.scotland.gov.uk/Publications/2008/06/25114657/0) and revised equations for GHG emissions (Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U., 2010 & 2011, and Wind Farm and Carbon Savings – Technical Note v.2 2.10.0. Input Parameters).

To calculate the pay-back period, the Scottish Government's Carbon Calculator Tool considers the following carbon saving and carbon loss parameters, as shown in Annex A:

- 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);
- Carbon saving due to improvement of habitat.; and
- Loss and/or saving of carbon-fixing potential as a result of forestry clearance.

[1] Scottish Government Wind Farm Developments on Peat Land: Carbon Calculator Tool v2.14.1, provided by the ECU as the online calculator is currently unavailable.

[2] 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 Context

By 2030, the Scottish Government aims to have reduced greenhouse gas emissions by at least 75% compared to 1990 levels and generate 50% of Scotland’s overall energy consumption from renewable sources, with aims to have decarbonised Scotland’s energy system and economy completely by 2050.

Large scale wind farm development in Scotland has raised concerns about the reliability of methods used to calculate the time taken for these proposals to reduce greenhouse gas emissions, largely due to the potential siting of wind farms on peatland which represent large stores of carbon. The implication for carbon emissions is therefore a factor that should be included in the consideration of proposed wind farm development.

Applications for wind farms (or extensions of wind farms) submitted under Section 36 of the Electricity Act (50 MW capacity or above) are screened to establish whether they are on deep peat sites (i.e. greater than 0.5 metres) and where loss or disturbance to peat could occur. Where they do applicants are expected to use the Carbon Calculator to determine the pay-back period of the proposal and submit this with the Section 36 application.

3.0 Input Data

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

- Clune Wind Farm EIAR Chapter 2: Proposed Development Description;
- Clune Wind Farm EIAR Chapter 3: Site Description and Design Evolution;
- Clune Wind Farm EIAR Technical Appendix 9.1: Peat Landslide Hazard Risk Assessment; and
- Clune Wind Farm EIAR Technical Appendix 9.2: Peat Management Plan.

The calculation spreadsheet within the Carbon Calculator Tool allows a range of data to be input in order to utilise expected, minimum and maximum values, where relevant and applicable. The input data is presented within **Annex A** of this report. 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.

4.0 Results

The model 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 DUKES[3] 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 DECC[4].

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.

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)	660,163	650,865	666,362
…grid-mix of electricity generation (t CO_2/yr))	144,607	142,570	145,965
…fossil fuel – mix of electricity generation (t CO_2/yr)	296,200	292,028	298,981
Energy output from Wind Farm over lifetime (MWh)	27,943,419	27,549,850	28,205,798

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 (eg. manufacture, construction, decommissioning)	169,327	169,327	169,327
Losses due to backup	139,061	0	139,061
Losses due to reduced carbon fixing potential	3,988	1,369	10,315
Losses from soil organic matter	50,431	39,753	56,400
Losses due to DOC & POC leaching	3,035	123	14,711
Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	365,842	210,572	389,814

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

[4] Department for Business, Energy & Industrial Strategy, 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	-93,713	0	-190,794
Change in emissions due to improvement of felled forestry	0	0	0
Change in emissions due to restoration of peat from borrow pits	-5,959	0	-5,676
Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	-99,672	0	-196,469

Table 4-4 demonstrates that the net emissions of carbon dioxide are estimated at 266,169 tonnes of CO_2, with an estimated payback period of 0.9 years. Therefore, the proposed development will produce a reduction in emissions from the electricity grid of around 296,200 tonnes of CO_2 per year (this assumes that the wind farm replaces grid electricity generated from a fossil fuel mix).

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)	266,169	14,103	389,814
Carbon Payback Time			
…coal-fired electricity generation (years)	0.4	0.02	0.6
…grid-mix of electricity generation (years)	1.8	0.1	2.7
…fossil fuel – mix of electricity generation (years)	0.9	0.05	1.3
Ratio of CO_2 eq. emissions to power generation (g/kWh)	10	1	14

5.0 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 grid fuel mix of electricity generation. This means that the proposed development is anticipated to take around 0.9 years to repay 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.

6.0 References

Carbon Calculator Tool v1.7.0. Available at https://informatics.sepa.org.uk/CarbonCalculator/

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Annex A

Technical Appendix 12.2: Carbon Calculator

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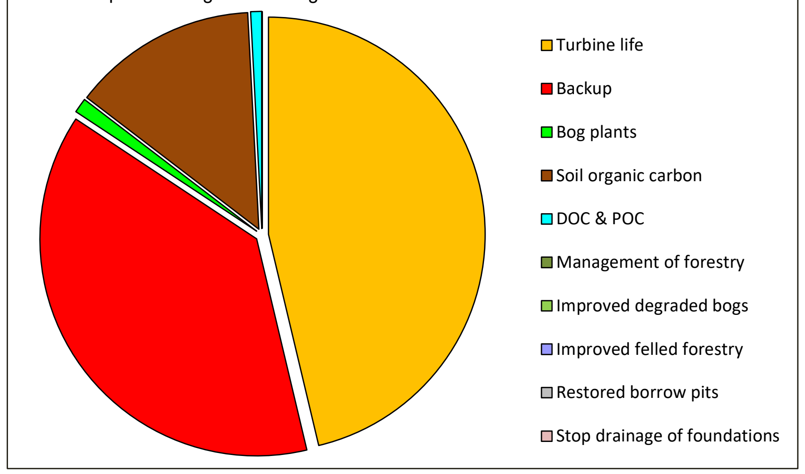
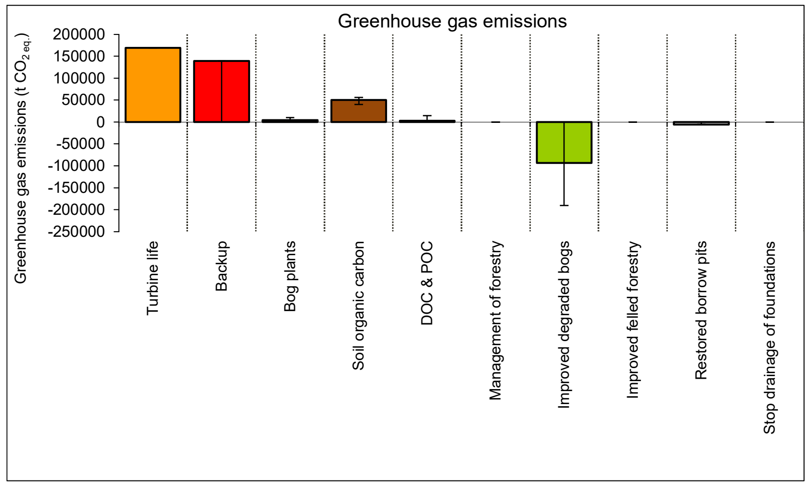
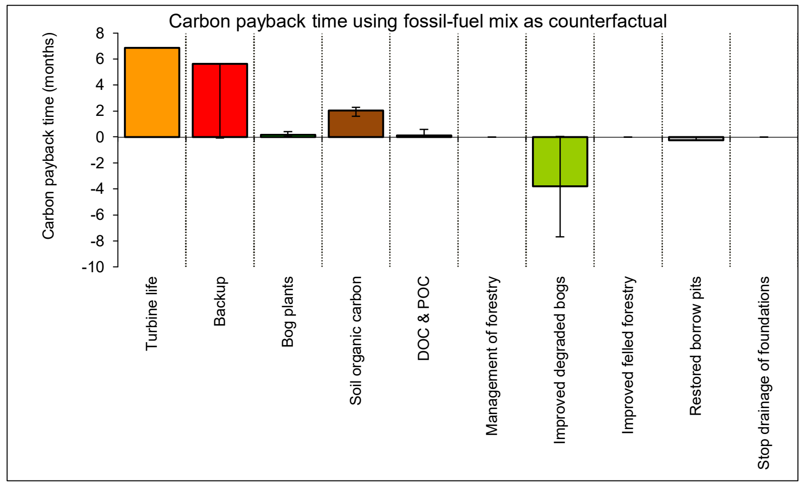
4 November 2024

	Exp.	Min.	Max.
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation ($tCO_2\ yr^{-1}$)	660163	650865	666362
…grid-mix of electricity generation ($tCO_2\ yr^{-1}$)	144607	142570	145965
…fossil fuel - mix of electricity generation ($tCO_2\ yr^{-1}$)	296200	292028	298981
Energy output from windfarm over lifetime (MWh)	27943419	27549850	28205798
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	169327	169327	169327
3. Losses due to backup	139061	0	139061
4. Losses due to reduced carbon fixing potential	3988	1369	10315
5. Losses from soil organic matter	50431	39753	56400
6. Losses due to DOC & POC leaching	3035	123	14711
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	365842	210572	389814
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	-93713	0	-190794
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	-5959	0	-5676
8d. Change in emissions due to removal of drainage from foundations & hardstanding	0	0	0
Total change in emissions due to improvements	-99672	0	-196469

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**266169**	**14103**	**389814**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.4	0.0	0.6
…grid-mix of electricity generation (years)	1.8	0.1	2.7
…fossil fuel - mix of electricity generation (years)	**0.9**	**0.0**	**1.3**
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)	**10**	**1**	**14**







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

Greenhouse gas emissions

	Exp.	Min	Max
Turbine life	169327	0	0
Backup	139061	139061	0
Bog plants	3988	2619	6327
Soil organic carbon	50431	10679	5968
DOC & POC	3035	2911	11677
Management of forestry	0	0	0
Improved degraded bogs	0	0	0
Improved felled forestry	0	0	0
Restored borrow pits	0	0	284
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	169327	0	0	7	0	0
Backup	139061	139061	0	6	6	0
Bog plants	3988	2619	6327	0	0	0
Soil organic carbon	50431	10679	5968	2	0	0
DOC & POC	3035	2911	11677	0	0	0
Management of forestry	0	0	0	0	0	0
Improved degraded bogs	-93713	-93713	-97080	-4	-4	-4
Improved felled forestry	0	0	0	0	0	0
Restored borrow pits	-5959	-5959	284	0	0	0
Stop drainage of foundations	0	0	0	0	0	0
	266169			11		

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