Technical Appendix 16.1: Carbon Calculator

Carn Fearna Wind Farm

Carn Fearna Wind Farm Ltd

Prepared by:

SLR Consulting Limited

No. 50 Stirling Business Centre, Wellgreen, Stirling,
FK8 2DZ

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0	20 March 2025	R. Watson	A. Huntridge	G Hughes

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Annexes

1.0 Introduction

SLR has been commissioned by Carn Fearna Wind Farm Ltd (The Applicant) to calculate the carbon pay-back period for the proposed Carn Fearna 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 9-turbine wind farm (of which five are up to 200 m blade tip height, and four are up to 180 m blade tip height), energy storage and associated infrastructure, with a combined rated output in the region of 64.8 MW.

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 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] 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 are located on such sites applicants are expected to use the Carbon Calculator to determine the pay-back period of the Proposed Development 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:

- Carn Fearna Wind Farm EIA Report Chapter 3: Proposed Development Description;
- Carn Fearna Wind Farm EIA Report Technical Appendix 8.5: Outline Nature Enhancement and Management Plan;
- Carn Fearna Wind Farm EIA Report Technical Appendix 10.1: Peat Landslide Hazard Risk Assessment; and
- Carn Fearna Wind Farm EIA Report Technical Appendix 10.2: Peat Management Plan.

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.

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[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 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.

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)	170,047	170,047	170,047
…grid-mix of electricity generation (t CO_2/yr))	37,248	37,248	37,248
…fossil fuel – mix of electricity generation (t CO_2/yr)	76,296	76,296	76,296
Energy output from Wind Farm over lifetime (MWh)	8,997,221	8,997,221	8,997,221

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)	59,324	59,324	59,324
Losses due to backup	60,171	0	60,171
Losses due to reduced carbon fixing potential	2,549	812	7,185
Losses from soil organic matter	30,126	21,777	34,515
Losses due to DOC & POC leaching	1,750	61	9,313
Losses due to felling forestry	660	528	792
Total losses of carbon dioxide	154,580	82,502	171,300

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

[3] 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	0	0	-18,911
Change in emissions due to improvement of felled forestry	0	0	0
Change in emissions due to restoration of peat from borrow pits	-29,155	0	-48,954
Change in emissions due to removal of drainage from foundations & hardstanding	-1,399	0	-7,062
Total change in emissions due to improvements	-30,554	0	-74,927

A summary of the anticipated carbon emissions and carbon payback of the Proposed Development are provided below in Table 4-4.

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)	124,026	7,575	171,300
Carbon Payback Time			
…coal-fired electricity generation (years)	0.7	0.04	1.0
…grid-mix of electricity generation (years)	3.3	0.2	4.6
…fossil fuel – mix of electricity generation (years)	1.6	0.10	2.2
Ratio of CO_2 eq. emissions to power generation (g/kWh)	14	1	19

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 1.6 years when compared to the grid fuel mix of electricity generation. This means that the Proposed Development is anticipated to take around 1.6 years to repay the carbon exchange to the atmosphere (the CO_2 debt) through construction; the Proposed Development 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

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)

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Annex A

Technical Appendix 16.1: Carbon Calculator

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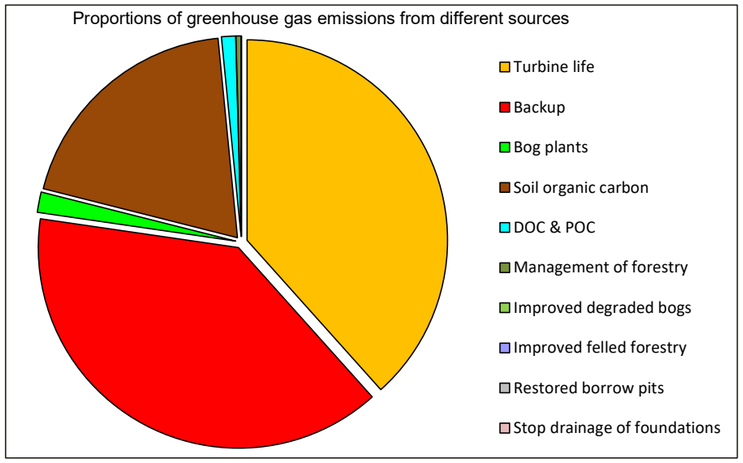
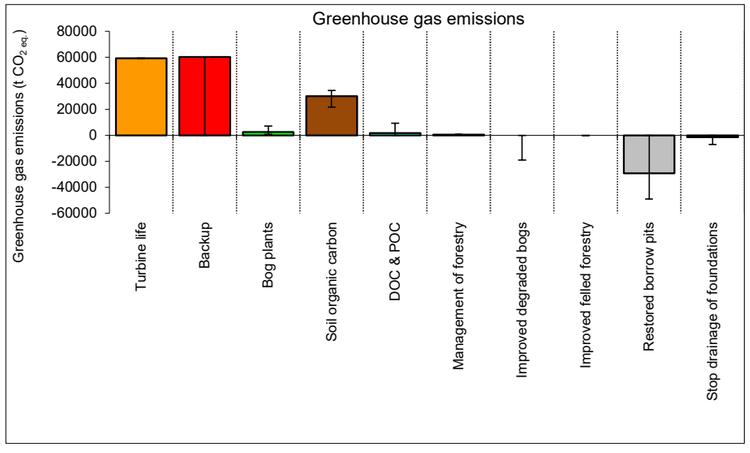
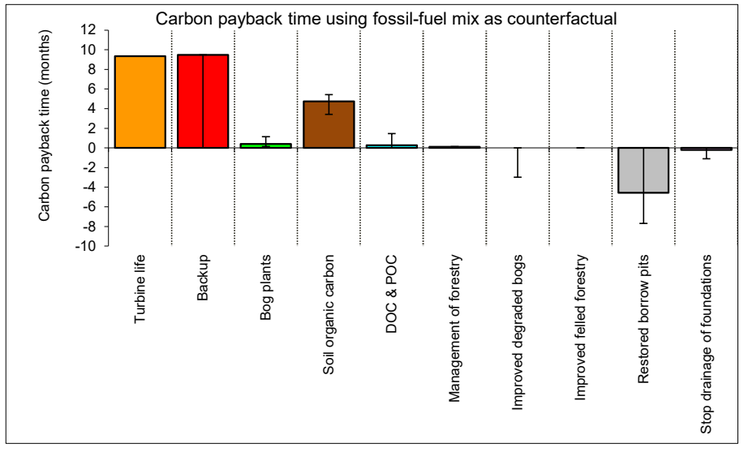
20 March 2025

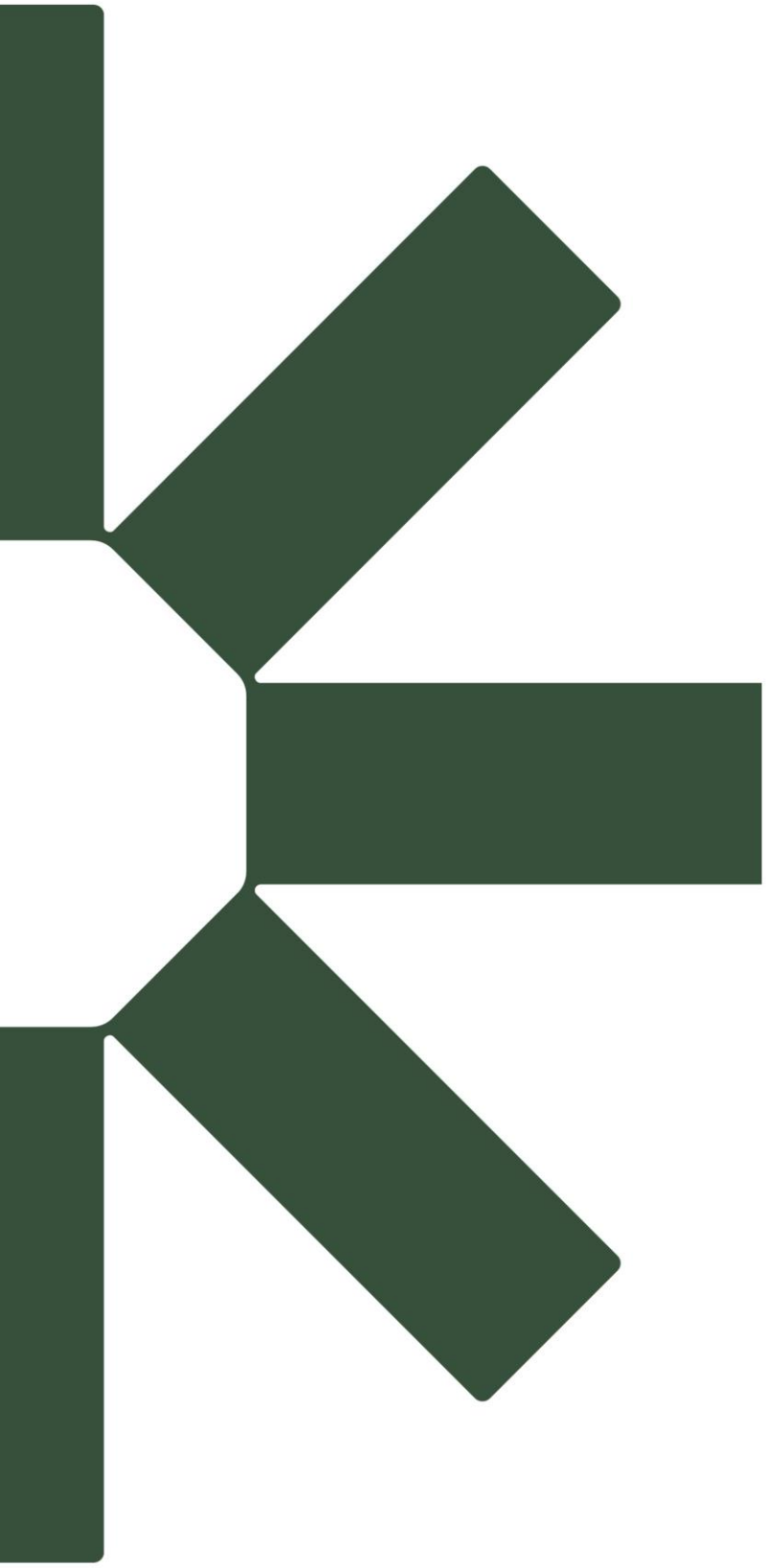
	Exp.	*Min.*	*Max.*
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation (tCO_2 yr^{-1})	170047	170047	170047
…grid-mix of electricity generation (tCO_2 yr^{-1})	37248	37248	37248
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	76296	76296	76296
Energy output from windfarm over lifetime (MWh)	8997221	8997221	8997221
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	59324	59324	59324
3. Losses due to backup	60171	0	60171
4. Losses due to reduced carbon fixing potential	2549	812	7185
5. Losses from soil organic matter	30126	21777	34515
6. Losses due to DOC & POC leaching	1750	61	9313
7. Losses due to felling forestry	660	528	792
Total losses of carbon dioxide	154580	82502	171300
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Change in emissions due to improvement of degraded bogs	0	0	-18911
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	-29155	0	-48954
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-1399	0	-7062
Total change in emissions due to improvements	-30554	0	-74927

RESULTS	*Exp.*	*Min.*	*Max.*
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**124026**	**7575**	**171300**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.7	0.04	1.0
…grid-mix of electricity generation (years)	3.3	0.2	4.6
…fossil fuel - mix of electricity generation (years)	**1.6**	**0.10**	**2.2**
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)	**14**	**1**	**19**









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