# Technical Appendix 14.1: Carbon Calculator

## Windburn Wind Farm

### Windburn Wind Farm Ltd

Prepared by:

**SLR Consulting Limited**

The Tun, 4 Jackson's Entry, Edinburgh, EH8 8PJ

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## Revision Record

| Revision | Date | Prepared By | Checked By | Authorised By |
|---|---|---|---|---|
| 01 | 2 June 2025 | R. Watson | A. Huntridge | A. Smith |

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# Annexes

# 1.0 Introduction

SLR has been commissioned by Windburn Wind Farm Ltd (The Applicant) to calculate the carbon pay-back period for the proposed Windburn 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 proposed development would comprise 13 three-bladed horizontal axis turbines up to 149.9m tip height with a combined rated output in the region of approximately 65MW. The proposed development would include associated infrastructure including turbine foundations, crane hardstandings, new access tracks, underground cabling, a substation compound including a control building and up to 35MW of battery storage, up to two borrow pits and three temporary construction compounds.

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 2050, the Scottish Government aims to have decarbonised Scotland's energy system and economy completely.

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:

- Windburn Wind Farm EIA Report **Chapter 3: Description of Development**;
- Windburn Wind Farm EIA Report **Technical Appendix 10.1: Peat Landslide Hazard Risk Assessment**; and
- Windburn Wind Farm EIA Report **Technical Appendix 10.2: Peat Management Plan**.

The calculation spreadsheet 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[2], 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) | 215,233 | 215,233 | 215,233 |
| …grid-mix of electricity generation (t $CO_2$/yr)) | 47,146 | 47,146 | 47,146 |
| …fossil fuel – mix of electricity generation (t $CO_2$/yr) | 99,531 | 99,531 | 99,531 |
| **Energy output from Wind Farm over lifetime (MWh)** | 9,110,400 | 9,110,400 | 9,110,400 |

**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) | 58,968 | 58,968 | 58,968 |
| Losses due to backup | 49,766 | 0 | 49,766 |
| Losses due to reduced carbon fixing potential | 2,134 | 619 | 6,758 |
| Losses from soil organic matter | 19,237 | 12,031 | 21,689 |
| Losses due to DOC & POC leaching | 1,330 | 37 | 7,923 |
| Losses due to felling forestry | 475 | 380 | 570 |
| **Total losses of carbon dioxide** | 131,910 | 72,036 | 145,675 |

[2] It is noted that there has been no UK coal fired electricity generation since late 2024, however electricity generated from coal can still form part of the UK electricity grid mix through imports.

[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 | 0 | 0 | -17,563 |
| Change in emissions due to improvement of felled forestry | 0 | 0 | 0 |
| Change in emissions due to restoration of peat from borrow pits | -211 | 0 | -302 |
| Change in emissions due to removal of drainage from foundations & hardstanding | -1,490 | 0 | -7,613 |
| **Total change in emissions due to improvements** | -1,701 | 0 | -25,478 |

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)** | 130,209 | 46,557 | 145,675 |
| **Carbon Payback Time** | | | |
| …coal-fired electricity generation (years) | 0.6 | 0.22 | 0.7 |
| …grid-mix of electricity generation (years) | 2.8 | 1.0 | 3.1 |
| **…fossil fuel – mix of electricity generation (years)** | 1.3 | 0.47 | 1.5 |
| **Ratio of $CO_2$ eq. emissions to power generation (g/kWh)** | 14 | 5 | 16 |

# 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 1.3 years when compared to the grid fuel mix of electricity generation. This means that the proposed development is anticipated to take around 1.3 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)

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.

http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/PSG2011

Scottish Renewables & SEPA. (2012). Developments on Peatland Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste. http://www.scottishrenewables.com/static/uploads/publications/a4_developments_on_peatland.pdf

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: Carbon Calculator Spreadsheet Outputs

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### Windburn Wind Farm

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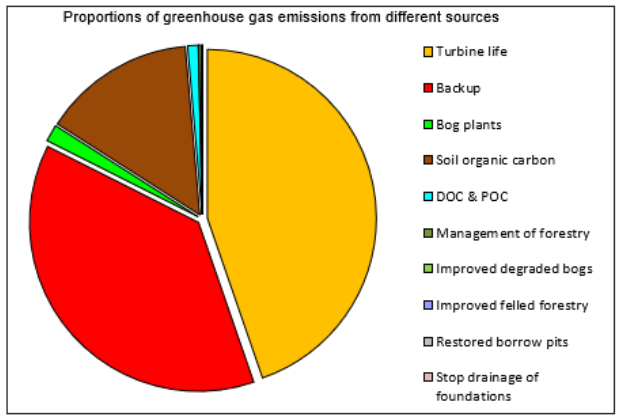
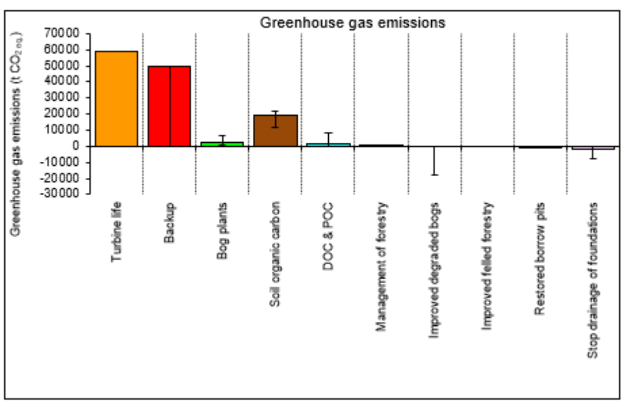
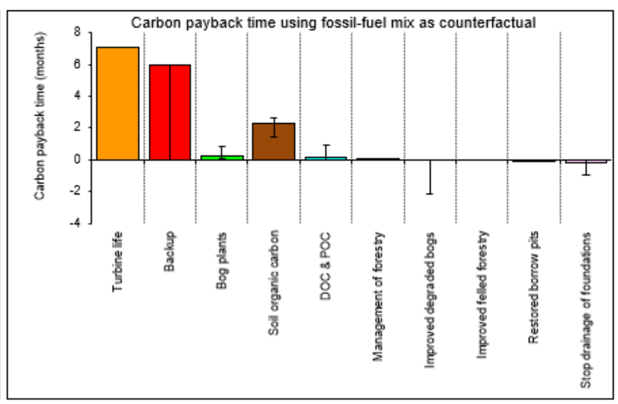
| | *Exp.* | *Min.* | *Max.* |
|---|---|---|---|
| **1. Windfarm $CO_2$ emission saving over...** | | | |
| ...coal-fired electricity generation ($tCO_2\ yr^{-1}$) | 215233 | 215233 | 215233 |
| ...grid-mix of electricity generation ($tCO_2\ yr^{-1}$) | 47146 | 47146 | 47146 |
| ...fossil fuel - mix of electricity generation ($tCO_2\ yr^{-1}$) | 99531 | 99531 | 99531 |
| Energy output from windfarm over lifetime (MWh) | 9110400 | 9110400 | 9110400 |
| **Total $CO_2$ losses due to wind farm (t $CO_2$ eq.)** | | | |
| 2. Losses due to turbine life (eg. manufacture, construction, decomissioning) | 58968 | 58968 | 58968 |
| 3. Losses due to backup | 49766 | 0 | 49766 |
| 4. Losses due to reduced carbon fixing potential | 2134 | 619 | 6758 |
| 5. Losses from soil organic matter | 19237 | 12031 | 21689 |
| 6. Losses due to DOC & POC leaching | 1330 | 37 | 7923 |
| 7. Losses due to felling forestry | 475 | 380 | 570 |
| Total losses of carbon dioxide | 131910 | 72036 | 145675 |
| **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 | -17563 |
| 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 | -211 | 0 | -302 |
| 8d. Change in emissions due to removal of drainage from foundations & hardstanding | -1490 | 0 | -7613 |
| Total change in emissions due to improvements | -1701 | 0 | -25478 |

| **RESULTS** | *Exp.* | *Min.* | *Max.* |
|---|---|---|---|
| **Net emissions of carbon dioxide (t $CO_{2\ eq.}$)** | **130209** | **46557** | **145675** |
| **Carbon Payback Time** | | | |
| ...coal-fired electricity generation (years) | 0.6 | 0.22 | 0.7 |
| ...grid-mix of electricity generation (years) | 2.8 | 1.0 | 3.1 |
| **...fossil fuel - mix of electricity generation (years)** | **1.3** | **0.47** | **1.5** |
| **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** | **5** | **16** |



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