SEI Appendix 14.1: Carbon Balance Assessment

14.1 Update to Carbon Balance Assessment

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14 Carbon Balance Assessment

14.1 Update summary

14.1.1 This update to the Carbon Balance Assessment for Loch Liath Wind Farm (the Proposed Development) has been carried out to review the impact of additional peatland restoration areas on the overall carbon balance. The original 2023 EIA Report assessment used the Scottish Government's Carbon Calculator for wind farms on peat to assess the benefit of displacing electricity from fossil fuels with renewable generated electricity, compared to the emissions of carbon required for the construction and operation of Loch Liath Wind Farm (the Proposed Development) over its 35-year lifetime, including losses of stored carbon from disturbed peatland and reduction of carbon fixing vegetation cover. The Carbon Calculator provides an estimate of the carbon payback time for the Proposed Development. This update shows which parameters have been updated within the Calculator and shows how the results have been affected by the change to the restoration area. It should be read in conjunction with Appendix 14.1 of the 2023 EIA Report.

14.1.2 It should be noted that at the current time (as of 09/10/24), the online Carbon Calculator is not available on the SEPA website and therefore the excel version of the tool (v 2.14.1) has been used to produce these results. This is comparable to the online version that is currently available.

14.1.3 The results of the revised Carbon Calculator show that the wind farm component of the Proposed Development is estimated to produce annual carbon savings of around 42,000 tonnes of CO_2e per year, through the displacement of grid electricity, based on the current average grid mix. This is a small increase on the original assessment of around 40,000 tCO_2e. However, this increase in savings is due to updated grid emission factors within the Carbon Calculator compared to the period when the assessment was originally carried out.

14.1.4 The updated assessment of the carbon losses and gains during construction and operation has not changed the assessment of the overall losses but has significantly increased the gains from restoration. Compared to the original assessment where gains from restoration were estimated at 1,200 tonnes of CO_2e, the restoration of a much larger area has increased these to over 23,000 tonnes of CO_2e.

14.1.5 The payback time of the Proposed Development, using the Scottish Government Carbon Calculator, is now estimated at around 1.7 years, with a minimum/maximum range of 1.0 to 2.5 years. This has reduced from 2.4 years in the original assessment and consequently reduced the proportion of the payback in relation to the lifespan of the proposed development from 6.9% to 4.9%. The carbon intensity of the electricity produced by the Proposed Development is now estimated at 0.010 kgCO_2e/kWh compared to 0.013 kgCO_2e/kWh in the original assessment. This is even further below the outcome indicator for the electricity grid carbon intensity of 0.05 kgCO_2e/kWh required by the Scottish Government in the Climate Change Plan update (Scottish Government, 2020) and therefore the revised Proposed Development is evaluated to have an overall beneficial effect on the carbon balance and to be an improvement on the original Proposed Development.

14.2 Changes to input parameters

14.2.1 Table 14.1 shows the input parameters that have been changed in this update (highlighted in bold). The only change to the Proposed Development is the addition of the peat restoration areas. However, the updated version of the Carbon Calculator has required the update of the Counterfactual grid emission factors and has also resulted in the removal of an error that existed in the direct input of the emissions from the turbine lifecycle. As this error was corrected in as part of the 2023 EIA Report submission, the correction has also been removed in this version to maintain the same output.

Table 14.1 Input parameters used in the Carbon Calculator

Online calculator reference: CJIN-M077-ZQJ5					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Wind Farm Characteristics					
Total CO2 emission from turbine life (tCO2 MW^{-1})	**389.5**	**350.5**	**428.5**	Units of gCO2e/kWh of electricity over a standard 25 lifespan have been converted to tCO2e per MWh and scaled down for electricity generation over 35 years to not overestimate the emissions for the longer lifetime of the site. **For the update, a known error in v1.7.0 of the Carbon Calculator (the error of the estimated tCO_2/MW being incorrectly multiplied by the site capacity factor; in order to correct the error, the input parameter was divided by this factor) has been corrected in version 1.8.0 (and its equivalent excel version 2.14.1) and therefore this correction factor has been removed.**	A range of +/- 10% has been used to calculate the likely minimum and maximum.
Counterfactual emission factors					
Coal-fired plant emission factor (tCO_2 MWh^{-1})	**0.945**	**0.945**	**0.945**	Fixed counterfactual emission factors are provided in the Carbon Calculator. Values for both coal-fired and fossil fuel-mix emission factors are updated from DUKES data for the UK which is published annually. The source for the grid-mix emission factor is the list of emission factors used to report on greenhouse gas emissions by UK organisations published by BEIS. **These have been updated in the latest version of the Carbon Calculator with respect to the version used for the original submission.**	
Grid-mix emission factor (tCO_2 MWh^{-1})	**0.207**	**0.207**	**0.207**		

Online calculator reference: CJIN-M077-ZQJ5					
Parameter	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Fossil fuel- mix emission factor (tCO_2 MWh^{-1})	**0.424**	**0.424**	**0.424**		
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)	**104.8**	**94.3**	**115.3**	**This has been updated to include 3.65 ha of peat restoration from excavated peat being reinstated in eroded areas and a large increase in additional peat restoration areas (through reprofiling, blocking, seeding, etc) to a total of 101.2 hectares. This is based on 36.1 hectares of direct restoration plus 65.1 hectares of indirect restoration (based on a 10m buffer zone of effect around the restored areas). The total area of restoration is 104.8 ha.**	A range of +/- 10% has been used to calculate the likely minimum and maximum.

14.3 Results of Carbon Balance Assessment

14.3.1 This section provides a summary of the tables where the updated parameters have changed the results. There were no changes to the Carbon Balance Assessment – Emissions as the losses from the site remain the same as the original assessment. The gains from restoration have changed, as have the estimated savings due to the updated counterfactual emissions factors in the latest version of the Carbon Calculator.

Carbon Balance Assessment – Gains

14.3.2 Table 14.2 shows the estimated carbon gains over the lifetime of the Proposed Development from improvements through restoration of degraded bog and restoring peat in borrow pits. The gains from restored bog are negative because they are atmospheric removals or avoided emissions. It should be noted that the Carbon Calculator is conservative about estimating the gains from restoration, only accounting for changes in the balance of methane to carbon dioxide emissions from the restoration of degraded bogs. There is an increase in avoided emissions from -1,255 tCO_2e to around -23,000 tCO_2e due to the much larger area of bog restoration.

Table 14.2 – Estimated Carbon Gains

Source of gains	Estimated gains (tCO_2e)			% of overall gains (expected scenario)
	Expected	Minimum	Maximum	
Change in emissions due to improvement of degraded bogs	-23,284	-11,499	-37,304	99.9%
Change in emissions due to restoration of peat from borrow pits	-21	-8	-40	0.1%
Total estimated gains	**-23,284**	**-11,499**	**-37,304**	**99.9%**

Comparison of Soil Carbon Losses with Carbon Gains from Restoration

14.3.3 Table 14.3 shows a comparison of soil carbon losses with the estimated carbon gains from restoration. The estimated carbon is shown for the expected value within the carbon calculator.

Table 14.3 – Comparison of soil carbon losses with restoration gains

Soil carbon loss category	Expected tCO_2e	Restoration gain category	Expected tCO_2e
CO_2 loss from removed peat	**1,972**	Change in emissions due to improvement of degraded bogs	**-23,284**
CO_2 loss from drained peat	**-528**	Change in emissions due to restoration of peat from borrow pits	**-21**
Losses due to reduced carbon fixing potential	**4,347**	-	

Losses due to Dissolved Organic Carbon (DOC) & Particulate Organic Carbon (POC) leaching	**147**	-	
Total soil carbon losses	**5,937**	**Total restoration gains**	**-23,305**

14.3.4 Table 14.3 shows that the ratio between soil carbon loss and restoration gains is now -0.3, down from +4.7 in the 2023 EIA Report. This means that, instead of losing more stored carbon than is gained, due to the much larger area of restoration there is now predicted to be around 3 times more gains through restoration than emissions from disturbing peat through construction.

Carbon Balance Assessment – Savings

14.3.5 Table 14.4 shows the estimated annual and lifetime CO_2 savings, based on the three different counterfactual emission factors. The highest estimated savings are for replacement of coal-fired electricity generation but there is minimal coal-fired generation remaining in the UK to be displaced. The average grid-mix of electricity generation represents the overall carbon emissions from the grid per unit of electricity and includes nuclear and renewables as well as fossil fuels. In the latest version of the Carbon Calculator, these counterfactual emission factors were updated and therefore the estimated annual and lifetime savings have changed.

Table 14.4 – Estimated Annual and Lifetime Carbon Savings from the Operation of the Proposed Development from the Displacement of Grid Electricity

Counterfactual emission factor – annual savings	**Estimated savings (tCO_2e per year)**		
	Expected	**Minimum**	**Maximum**
Coal-fired electricity generation	**193,193**	**181,829**	**205,268**
Grid-mix of electricity generation	**42,319**	**39,829**	**44,963**
Fossil fuel - mix of electricity generation	**86,681**	**81,583**	**92,099**
Counterfactual emission factor – lifetime savings	**Estimated savings (tCO_2e over lifetime)**		
Coal-fired electricity generation	**6,761,766**	**6,364,015**	**7,184,377**
Grid-mix of electricity generation	**1,481,149**	**1,394,022**	**1,573,721**
Fossil fuel - mix of electricity generation	**3,033,851**	**2,855,389**	**3,223,466**

Payback Time and Carbon Intensity

14.3.6 There are two useful metrics for comparing different projects and different technologies. The Carbon Calculator tool calculates an estimated payback time, which is the net emissions of carbon (total of carbon losses and gains) divided by the annual estimated carbon savings. However, an alternative metric is the carbon intensity of the generated units of electricity; calculated by dividing the net emissions by the total units of electricity expected to be produced over the lifetime of the

Proposed Development. This calculation is useful as it is independent of the grid emission factor of displaced electricity.

14.3.7 Table 14.5 shows the estimated payback time, if the electricity generated by the Proposed Development is assumed to displace electricity generated by the grid for a range of different displaced fuels, and also the carbon intensity of the units produced.

Table 14.5 – Estimated Payback Time in Years and Carbon Intensity of the Units of Electricity Produced

Counterfactual emission factor	Estimated time to payback (years)		
	Expected	Minimum	Maximum
Coal-fired electricity generation	**0.4**	**0.2**	**0.5**
Grid-mix of electricity generation	**1.7**	**1.0**	**2.5**
Fossil fuel - mix of electricity generation	**0.8**	**0.5**	**1.2**
Carbon intensity ($kgCO_2e/kWh$)	**0.010**	**0.006**	**0.015**

14.3.8 Table 14.5 shows that the Proposed Development is estimated to have a payback of 1.7 years based on the current grid mix compared to 2.4 years for the original assessment. Around 0.2 years reduction is due to the change in the counterfactual emission factor within the Carbon Calculator, but the remaining 0.5 years reduction is due to the increase in restoration of bog at the site and the impact this has on the estimated avoided losses. The carbon intensity of units produced has come down from 0.013 to 0.010 kgCO2e/kWh.

14.4 Conclusions

14.4.1 The results of the revised Carbon Calculator show that the wind farm component of the Proposed Development is estimated to produce annual carbon savings of around 42,000 tonnes of CO_2e per year, through the displacement of grid electricity, based on the current average grid mix. This is a small increase on the original assessment of nearly 40,000 tCO_2e. However, this increase in savings is due to updated emission factors within the Carbon Calculator compared to the period when the assessment was originally carried out.

14.4.2 The updated assessment of the carbon losses and gains during construction and operation has not changed the assessment of the overall losses but has significantly increased the gains from restoration. Compared to the original assessment where gains from restoration were estimated at around 1,200 tonnes of CO_2e, the restoration of a much larger area has increased these to over 23,000 tonnes of CO_2e.

14.4.3 The payback time of the Proposed Development, using the Scottish Government Carbon Calculator, is now estimated at around 1.7 years, with a minimum/maximum range of 1.0 to 2.5 years. This has reduced from 2.4 years in the original assessment. This has reduced the proportion of the payback in relation to the lifespan of the Proposed Development from 6.9% to 4.9%. The carbon intensity of the electricity produced by the Proposed Development is now estimated at 0.010 $kgCO_2e/kWh$. This is even further below the outcome indicator for the electricity grid carbon intensity of 0.05 $kgCO_2e/kWh$ required by the Scottish Government in the Climate Change Plan update (Scottish Government, 2020) and therefore the Proposed Development is now evaluated to have an overall beneficial effect on the carbon balance and to be an improvement on the 2023 EIA Report submission.