Technical Appendix 8.2: Updated Carbon Balance Assessment

8.1. Introduction

8.1.1. This Carbon Balance Assessment has been prepared to assess the carbon emission savings associated with the Proposed Varied Development. This Technical Appendix should be read in conjunction with **Chapter 8: Geology, Soils and Peat**, and replaces the 2018 Appendix 5.2 for the Consented Development, due to changes in the Site design resulting from the increase in turbine size and infrastructure for the Proposed Varied Development.

8.1.2. Increasing atmospheric concentrations of greenhouse gases (GHGs), also called carbon emissions, are resulting in global heating which will cause catastrophic changes to our climate (IPCC, 2023). A major contributor to global emissions is the burning of fossil fuels for primary energy or electricity generation (IEA, 2024). With concern growing over climate change, reducing its cause is of utmost importance. The replacement of traditional fossil fuel power generation with renewable energy sources provides high potential for the reduction of GHG emissions. This is reflected in UK and Scottish Governments' climate change and renewable energy policy (UK Government, 2008, and Scottish Government, 2009).

8.1.3. It is widely recognised that wind farms and other renewable energy developments have the potential to save carbon emissions during their operational life, when compared to traditional generation such as fossil fuels. One of the primary aims of any renewable energy development is to reduce carbon emissions by the generation of carbon-free electricity. To achieve such savings, it is important to ensure that the management of peat resources does not adversely affect the carbon balance of renewable energy projects. However, no form of electricity generation is completely carbon free; for onshore wind farms there will be emissions resulting from the manufacture of turbines, as well as emissions from both construction and decommissioning activities and associated traffic movements.

8.1.4. In addition to the lifecycle emissions from the turbines and associated wind farm infrastructure, where a wind farm is located on carbon rich soils such as peat, there are potential emissions resulting from direct action of excavating peat for construction and the indirect changes to hydrology that can result in losses of soil carbon. The footprint of a wind farm's infrastructure will also decrease the area covered by carbon-fixing vegetation. Conversely, restoration activities undertaken post-construction or post-decommissioning could have a beneficial effect on stored carbon through the restoration of modified bog habitat. Carbon losses and gains during the construction and lifetime of a wind farm, and the long-term impacts on the peatlands on which they are sited, need to be evaluated to understand the consequences of permitting such developments.

8.1.5. In Scotland, onshore wind farms are often built in upland areas due to the prevalence of wind resources, where peatland habitats are common. These habitats inherently act as carbon stores, which if disturbed during construction of a development, have the potential to release carbon into the atmosphere, which puts a responsibility on wind farm developers to ensure that their developments do not result in significant carbon losses.

8.2. Legislation, Policy and Guidance

8.2.1. This assessment has been carried out in accordance with the principles contained within the following legislation, policy and guidance.

Legislation

8.2.2. One of the key drivers for the development of renewable energy is the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 (Scottish Government, 2019), which sets a net-zero target for the Scottish emissions account by 2045 and challenging interim targets for emission reductions compared to the 1990 baseline. This was later supplemented by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2024 (Scottish Government, 2024), which has provisions for 5-yearly carbon budgets that align UK-wide reduction target periods.

Policy

8.2.3. The update to the Climate Change Plan (Scottish Government, 2020) recognises the need to continue the process of decarbonising the electricity grid and increasing generation capacity to support the delivery of electric heating and transport. However, the Climate Change Plan Update also recognises the importance of maintaining and restoring carbon storage in peat.

8.2.4. The Scottish Energy Strategy (Scottish Government, 2017) set a whole-system target to supply the equivalent of 50% by 2030 of all the energy for Scotland's heat, transport, and electricity consumption from renewable sources. The Draft Energy Strategy and Just Transition Plan was published 10 January 2023 and recognises that the peatland impacts of onshore wind farms can be significant, and Scotland needs to balance the benefits from onshore wind deployment and the impact on carbon rich habitats. The draft strategy commits to convening an expert group, including representatives from industry, agencies, and academia to provide advice to the Scottish Government on how guidance could be developed to support both peatland and onshore wind aims. Furthermore, the strategy states that the Scottish Government will ensure that adequate tools and guidance are available to inform the assessment of net carbon impacts of development proposals on peatlands and other carbon-rich soils.

8.2.5. National Planning Framework 4 (Scottish Government, 2023) sets the national spatial strategy for Scotland, including spatial principles, regional priorities, national developments, and national planning policy. Several of these reference climate and nature in relation to planning policy, as listed here:

- Policy 1 states:

When considering all development proposals significant weight will be given to the global climate and nature crises.

Local Development Plans (LPDs) must address the global climate emergency and nature crisis by ensuring the spatial strategy will reduce emissions and adapt to current and future risks of climate change by promoting nature recovery and restoration in the area.

- Policy 2 states:

a) Development proposals will be sited and designed to minimise lifecycle greenhouse gas emissions as far as possible.

c) Development proposals to retrofit measures to existing developments that reduce emissions or support adaptation to climate change will be supported.

- Policy 5 states:

c) Development proposals on peatland, carbon-rich soils and priority peatland habitat will only be supported for:

> *i) Essential infrastructure and there are a specific locational need and no other suitable site;*
>
> *ii) The generation of energy from renewable sources that optimises the contribution of the area to greenhouse gas emissions reductions targets; and*
>
> *iv) Restoration of peatland habitats.*

Where development on peatland, carbon-rich soils or priority peatland habitat is proposed, a detailed site-specific assessment will be required to identify:

> *i) the baseline depth, habitat condition, quality and stability of carbon rich soils;*
>
> *ii) the likely effect of the development on peatland, including on soil disturbance; and*
>
> *iii) the likely net effect of the development on climate emissions and loss of carbon.*

- Policy 11 states:

a) Development proposals for all forms of renewable, low-carbon and zero emissions technologies will be supported. These include:

> *i) wind farms including repowering, extending, expanding and extending the life of existing wind farms*

In considering these impacts, significant weight will be placed on the contribution of the proposal to renewable energy generation targets and on greenhouse gas emissions reduction targets.

Grid capacity should not constrain renewable energy development. It is for developers to agree connections to the grid with the relevant network operator. In the case of proposals for grid infrastructure, consideration should be given to underground connections where possible.

Guidance

8.2.6. The Environmental Impact Assessment Guide to Assessing Greenhouse Gas Emissions and Evaluating their Significance (IEMA, 2022) provides guidance for assessing the baseline against which the impact of a new project can be compared against, how to set an appropriate study boundary and how to communicate the impacts. This guidance has been considered to inform this Carbon Balance Assessment.

8.3. Assessment Methodology

8.3.1. The potential releases of CO_2 during wind farm construction will be quantified and offset against the gains over the lifetime of the Proposed Varied Development. The carbon payback of the wind turbine component of the Proposed Varied Development has been estimated using the latest offline version of the Scottish Government's Carbon Calculator (v2.14.1).

8.3.2. GHG emissions are measured in tonnes of carbon dioxide equivalents (tCO_2eq) which is a quantity that describes, for a given mixture and amount of GHG, the amount of carbon dioxide (CO_2) that would have the same global warming potential (GWP), when measured over a 100-year timescale. These units therefore enable comparison of different GHGs emitted, or saved, at different project stages.

8.4. The Scottish Government's Carbon calculator for Wind Farms on Peatlands

8.4.1. As a portion of the Proposed Varied Development sits within peatland, the latest Scottish Government Carbon Calculator for wind farms on Scottish Peatlands was used to estimate the carbon losses and gains generated by the Proposed Varied Development. The tool takes into account a range of factors including wind farm characteristics, peat removal, alteration of drainage and site restoration.

8.4.2. Note, the online version of the Carbon Calculator is currently unavailable. This appendix has therefore been prepared using the offline version of the Carbon Calculator, version 2.14.1.

8.4.3. The methodology for the calculator is based on calculating carbon savings from wind farms on Scottish peatlands – A New Approach, which was designed in response to concerns on the reliability of methods used to calculate reductions in GHG emissions arising from large scale wind farm developments on peatland. The calculator looks at the benefit of displacing conventionally generated electricity in the grid compared to the predicted direct and indirect emissions of carbon from construction, operation and decommissioning of a wind farm. It provides an estimate of the carbon payback time for the Proposed Varied Development based on predicted emissions from construction materials and grid backup and losses and gains of stored carbon on site but excludes minor sources such as result of traffic generated during construction or operation.

8.4.4. The current methodology provides a straightforward way to model the impacts of the installation and operation of wind farms on peat soils, considering the wider potential impacts on peatland hydrology and decomposition of organic matter.

8.5. Scope and Assumptions

8.5.1. Table 1 shows the potential sources, and savings, of carbon emissions from the three key project stages that are covered by the Carbon Balance Assessment.

Table 1. Carbon emissions and savings included in the assessment

Project phase	Included in assessment	Excluded from assessment
Construction	Carbon emissions resulting from the extraction, production and manufacture of turbine components and concrete required for foundations.	Carbon emissions resulting from manufacture and transport of other materials required for foundations and tracks, e.g. steel, sand, rock and geotextile. These materials are not explicitly included in the Scottish Government Carbon Calculator for wind farms on peat.
	Carbon emissions resulting from the direct excavation of peat on-site for building tracks, hardstanding, turbine foundations and other infrastructure.	Carbon emissions resulting from the transport of labour to the construction site. This element is not included in the Scottish Government Carbon Calculator for wind farms on peat.
Operation	Carbon emissions from the indirect impact of drainage on peat surrounding the Proposed Varied Development infrastructure.	Carbon emissions resulting from manufacture and transport of spare parts and materials for repair or transport of labour required throughout the lifetime of the Proposed Varied Development. These elements are not explicitly included in the Scottish Government Carbon Calculator for wind farms on peat.
	Carbon savings resulting from the generation of electricity by wind turbines and displacement of grid electricity generated by fossil fuels.	
	Carbon emissions resulting from the provision of back up generation.	
	Carbon emissions during the lifetime of the Proposed Varied Development resulting from the loss of active carbon-absorbing habitat.	Carbon removals resulting from the creation or restoration of active carbon-absorbing habitat. The Scottish Government Carbon Calculator does not estimate future sequestration from restored vegetation, only the change to the existing carbon balance of soils in restored areas.
	Changes to the methane/CO_2 balance resulting from the restoration of degraded bog habitat.	
Decommissioning	-	No explicit assessment of decommissioning emissions has been carried out as these are not included within the Scottish Government Carbon Calculator.

8.5.2. The following is a list of the assumptions used within the carbon assessment:

- The peat within the Proposed Varied Development is acid bog.
- The closest weather station (Paisley) was used to obtain temperature data for the Development Site.
- Carbon emission factors used to calculate the carbon payback period were sourced from Digest of UK Energy Statistics (DUKES) 2025. The gas-fired plant, grid-mix, and fossil fuel-mix emission factors stated in DUKES 2025 were used to account for the worst-case scenario.
- Number of households in the Argyll and Bute Council area is 42,831 and is based on data from National Records of Scotland (2025).
- To account for the worst-case scenario, peatland restoration has been omitted from this assessment. Additionally, no measures to improve the carbon sequestration by raising water levels has been proposed.

8.6. Input Parameters Used in Carbon Calculator

8.6.1. Table 2 outlines the inputs to the Carbon Calculator and identifies the sources of information used alongside the justification used. The data sources used and a summary of the justifications for the selected values are also detailed within the table.

Table 2: Carbon Balance Data Sheet

Input	Expected Values	Minimum Values	Maximum Values	Source	Justification
No. of turbines	16	16	16	The Applicant	Site specific value
Lifetime of wind farm (years)	50	50	50	The Applicant	Site specific value
Power rating of turbines (turbine capacity) (MW)	5.7	5.7	5.7	The Applicant	Site specific value Based on candidate turbine
Capacity Factor (%)				The Applicant	Site specific value, redacted due to commercial sensitivity
Fraction of Output to backup (%)	5	0	15	Dale et al 2004, Energy Policy 32, pg. 1949-56	Best available data
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed	Fixed parameter

Type of peatland	Acid Bog	Acid Bog	Acid Bog	Peat Survey	Peat is likely blanket bog
Average air temperature at site (°C)	7.77	5.03	10.52	Met Office historic weather data for Paisley	Nearest Weather Station
Average depth of peat at site (m)	0.60	0.48	0.72	The Applicant	Average peat depth across site found during peat probing exercises (+/- 20% for max/min)
Carbon Content of dry peat (% by weight)	53.23	19.57	64.28	Scottish Soils Knowledge and Information Base (SSKIB)	SSKIB terms this a 'constant' across all sites
Average extent of drainage around drainage features at site (m)	37.50	25.00	50.00	SEPA Correspondence	Previous SEPA guidance for similar projects
Average water table depth at site (m)	0.10	0.05	0.30	SEPA Correspondence	Previous SEPA guidance for similar projects. Generic characteristic of peatlands before wind farm developments
Dry soil bulk density (g cm^3)	0.13	0.08	0.27	Unpublished data from National Soil Inventory of Scotland (2007-2009)	Assume it is decomposed peat as this gives a worst case scenario
Time required for regeneration of bog plants after restoration (years)	30	30	30	Wind farm life, based on guidance from Renewable Foundation (Hall, 2006)	Best available data
Carbon accumulation due to Carbon fixation by bog plants in undrained peat (tC ha^{-1} yr^-1)	0.25	0.12	0.31	NatureScot guidance	Best available data
Area of forestry plantation to be felled (ha)	225	225	225	The Applicant	Site specific value

Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.6	3.15	3.61	NatureScot Guidance (Turunen et al.)	Best available data
Gas-fired plant emission factor (tCO_2 MWh^{-1})	0.382	0.382	0.382	Digest of UK Energy Statistics (DUKES) 2025, 5.14	Gas-fired plant emission factor (EF) from electricity supplied in 2024
Grid-mix emission factor (tCO_2 MWh^{-1})	0.154	0.154	0.154	Digest of UK Energy Statistics (DUKES) 2025, 5.14	Grid-Mix EF for 2024
Fossil fuel-mix emission factor (tCO_2 MWh^{-1})	0.448	0.448	0.448	Digest of UK Energy Statistics (DUKES) 2025, 5.14	The emission factor from electricity supplied in 2024 from all fossil fuels.
Number of Borrow Pits	4	4	4	The Applicant	Site specific values
Average Length of Borrow Pits (m)	200	150	300	The Applicant	Site Specific values (-50/+100 for max/min)
Average Width of Borrow Pits (m)	163.45	113.45	263.45	The Applicant	Site Specific values (-50/+100 for max/min)
Average depth of peat removed from pit (m)	0.020	0.016	0.024	The Applicant	Average peat depth underlying infrastructure found during peat probing exercises (+/- 20% for max/min)
Diameter at bottom of turbine foundations (m)	50	50	50	The Applicant	Site specific values
Diameter at surface of turbine foundations (m)	40.65	40.65	40.65	The Applicant	Site specific values
Average depth of peat removed from turbine foundations (m)	0.45	0.30	0.75	The Applicant	Average peat depth underlying infrastructure found during peat probing exercises (+/- 20% for max/min)

Average length of hard standing (m) [Crane Pad]	50	50	50	The Applicant	Site specific values
Average width of hard standing (m) [Crane Pad]	70.40	70.40	70.40	The Applicant	Site specific values
Average depth of peat removed from hard standings (m)	0.53	0.38	0.83	The Applicant	Average peat depth underlying infrastructure found during peat probing exercises (+/- 20% for max/min)
Total length of access track (m)	5,385	5,385	5,385	The Applicant	Site specific values based on length of new access track overlaying peat
Existing track length (m)	0	0	0	The Applicant	Existing tracks will be upgraded. Carbon impact included in Additional Peat Excavated
Length of new access track that is floating road (m)	903	903	903	The Applicant	Site specific values based on length of new access track overlaying peat
Length of new access track that is excavated road (m)	4,482	4,482	4,482	The Applicant	Site specific values based on length of new access track overlaying peat
Excavated Road Width (m)	6	6	6	The Applicant	Site specific values
Average depth of peat excavated for access track (m)	1.07	0.86	1.29	The Applicant	Average peat depth underlying infrastructure found during peat probing exercises (+/- 20% for max/min)
Volume of Additional Peat Excavated (m^3)	10,220	10,220	10,220	The Applicant	Peat excavation volume for upgrade to existing track, substation, and

					construction compounds
Area of degraded bog to be improved (ha)	0	0	0	Worst Case Scenario	Site specific value
Area of borrow pits to be restored (ha)	0	0	0	Worst Case Scenario	Site specific value
Will you attempt to block any gullies that have been formed due to the wind farm?	No	No	No	Worst Case Scenario	Site specific value
Will you attempt to block all artificial	No	No	No	Worst Case Scenario	Site specific value
Ditches and facilitate rewetting?	No	No	No	Worst Case Scenario	Site specific value
Will you control grazing on degraded areas?	No	No	No	Worst Case Scenario	Site specific value
Will you manage areas of favour reintroduction of species?	No	No	No	Worst Case Scenario	Site specific value

8.7. Output Parameters Used in the Carbon calculator

8.7.1. As shown in Table 3, the expected total carbon payback time of the Proposed Varied Development, based on the carbon losses, is 2.2 years compared with electricity generation from traditional sources such as fossil fuels. The table also presents the findings for the minimum and maximum inputs from Table 3 and outputs from the Scottish Government's offline carbon calculator.

Table 3: Carbon Balance and Pay Back Time

Criteria	Expected Values	Best Case Scenario	Worst Case Scenario
Total Wind Farm CO_2 emission saving over fossil fuel mix of electricity generation (t CO_2 eq.)	7,793,546	7,793,546	7,793,546
Net carbon emissions from Proposed Varied Development (t CO_2 eq.)	342,923	198,781	604,697
Total carbon savings over lifetime of the Proposed Varied Development (t CO_2 eq.)	7,450,623	7,594,765	7,188,850
Number of houses' electrical carbon emissions offset by Wind Farm*	96,038	97,896	92,664
Total payback time (years)	2.2	1.3	3.9
Percentage to pay back time to wind farm lifespan (%)	4.4	2.6	7.8

* Assumed 3,463.4kWh average household use per annum (Department for Energy Security and Net Zero, 2026)

8.7.2. Based on the expected scenario, the Proposed Varied Development could prevent over 7,700,000 tonnes of CO_2 equivalent emissions (t CO_2 eq.) being released into the atmosphere over the project's 50-year lifetime, compared to a fossil fuel mix of electricity generation. This is equivalent to the electrical emissions from 96,038 average households over the lifetime of the Proposed Varied Development.

8.7.3. The Argyll and Bute Council area has an estimated 42,831 households. Therefore, the Proposed Varied Development could offset the emissions from the fossil fuel mix supplied electricity to all households in the Argyll and Bute Council area.

8.7.4. The operations of the Proposed Varied Development have a lifetime carbon intensity of about 0.020 kg CO_2eq/kWh. This is equivalent to the range of 0.005 to 0.026 kg CO_2eq/kWh anticipated for onshore wind across the sector, and it is far lower than the UK grid carbon intensity, which is 0.177 kg CO_2eq/kWh in 2025 (Department for Energy Security and Net Zero, 2025). It is important to note that operational GHG emissions from the production of electricity, which are mostly from fossil fuels used to power gas-fired power plants, are the sole factor included in the published UK grid carbon intensity statistic.

8.8. Conclusion

8.8.1. The calculation of carbon balance and payback has been based on expected values where site specific data is available, and worst-case assumptions where it is not. It is therefore expected that the actual payback time of the Proposed Varied Development will be less than currently estimated by the model.

8.8.2. It is expected that the carbon loss due to the Proposed Varied Development will be paid back in approximately 2.2 years, 4.4% of the design life.

8.8.3. The Proposed Varied Development is expected to provide a total carbon saving of over 7,700,000 tonnes over its lifetime, equivalent to the emissions from supplying fossil-fuel source electricity to 96,038 average homes.

8.8.4. Even considering the scenario with the maximum values, the Proposed Varied Development will have achieved carbon balance with 3.9 years (7.8% of the design life) and, as such, will be beneficial to the Scottish Government's carbon emission targets.

8.9. References

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