Technical Appendix 14: Forestry

TA 14.1: Planting Year and Species in Hectares by Forest

TA 14.2: Photographic Records

TA 14.3: Total Felling Area in Hectares by Forest

TA 14.4: Total Permanent Felling Area in Hectares by Forest

Technical Appendix 14.1: Planting Year and Species by Forest

Technical Appendix 14.1

Planting year and species in hectares by forest							
Forest	**Planting year**	**Area in hectares by species**					**(ha)**
Artfield Forest		SS	UP				Total
	1982	166.51					166.51
	1983	238.42					238.42
			30.22				0
	Total	404.93	30.22				404.93
Meikle Cairn Forest		MB	JL	NS	SS	UP	Total
	1975				9.8		9.8
	1979		0.18		50.84		51.02
	1982				13		13
	2013	1.14		1.61	27.33		30.08
	2016	3.36			40.19		43.55
	2019				18.32		18.32
						20.94	20.94
	Total	4.5	0.18	1.61	159.48	20.94	186.71
Gass Forest		LARCH	MB	SS	UP		Total
	1976	0.5		12.4			12.9
	1984			21.7			21.7
	2009		0.1	3.8			3.9
	2011		1.3	18.6			19.9
	2012		1.6	15.8			17.4
	2013		0.5	7.2			7.7
	2016		0.6	12.7			13.3
					96.8		96.8
	Total	0.5	4.1	92.2	96.8		193.6
					Total forest units		**785.24**

Gass Farm has approximately 5.07 ha area of broadleaf scrub and riparian broadleaved, of which NWSS identifies 0.64 ha wet woodland and 2.67 ha lowland mixed deciduous woodland.

Technical Appendix 14.2: Photographic Records

Technical Appendix 14.2: Photographic Records

Photograph 1 Artfield forest best standing timber (T4)

Photograph 2 Artfield poor tree growth (T5)

Photograph 3 Gass forest current access and small tree size

Photograph 4 Meikle Cairn small tree size (T12)

Photograph 5 Gass Farm broadleaved scrub

Technical Appendix 14.3: Total Felling Area in Hectares by Forest

Technical Appendix 14.3

Total Felling Area in Hectares by Forest					
Artfield Forest					**Age at**
Cpt	**Planting Year**	**Species**	**Area (ha)**	**YC**	**2022**
1	1982	SS	13.7	16	40
2	1982	SS	0.34	16	40
3	1982	SS	19.59	22	40
4	1982	SS	0.38	20	40
5	1982	SS	7.43	12	40
6	1982	SS	4.44	16	40
7	1982	SS	7.53	6	40
8	1982	SS	1.43	16	40
9	1982	SS	2.34	22	40
10	1982	SS	8.32	16	40
11	1982	SS	3.96	18	40
12	1983	SS	4.08	10	39
13	1983	SS	4.87	10	39
14	1983	SS	15.99	16	39
18	1983	SS	1.23	18	39
19	1983	SS	2.68	16	39
24	1983	SS	0.12	18	39
			98.45		
Meikle Cairn Forest					**Age at**
Cpt	**Planting Year**	**Species**	**Area (ha)**	**YC**	**2022**
1	2013	SS	0.11	16	9
2	2013	SS	0.15	16	9
4	1979	SS	0.41	18	43
5	2019	SS	0.66	18	3
6	1979	SS	0.60	14	43
7	1979	SS	0.04	16	43
8	1979	SS	0.86	16	43
9	1975	SS	0.26	16	47
10	2016	SS	0.03	18	6
11	2016	SS	6.37	18	6
			9.48		
Gass Forest					Age at
Cpt	Planting Year	Species	Area (ha)	YC	2022
42	2011	SS	1.16	18	11
43	2016	NS	0.09	14	6
			1.25		
Gass Farm broadleaved scrub at access 0.08 ha					
		Total felling area (ha)			**109.26**

Technical Appendix 14.4: Total Permanent Felling Area in Hectares by Forest

Technical Appendix 14.4

Permanent Felling Area in Hectares by Forest

Artfield Forest					**Age at**
Cpt	**Planting Year**	**Species**	**Area (ha)**	**YC**	**2022**
1	1982	SS	4.01	16	40
2	1982	SS	0.34	16	40
3	1982	SS	5.40	22	40
4	1982	SS	0.23	20	40
5	1982	SS	3.00	12	40
6	1982	SS	3.69	16	40
7	1982	SS	3.54	6	40
8	1982	SS	1.43	16	40
9	1982	SS	2.34	22	40
10	1982	SS	1.61	16	40
11	1982	SS	3.96	18	40
12	1983	SS	2.37	10	39
13	1983	SS	2.72	10	39
14	1983	SS	5.12	16	39
18	1983	SS	1.23	18	39
19	1983	SS	2.68	16	39
24	1983	SS	0.12	18	39
			43.78		

Meikle Cairn Forest					**Age at**
Cpt	**Planting Year**	**Species**	**Area (ha)**	**YC**	**2022**
1	2016	SS	0.11	18	9
2	2013	SS	0.15	16	6
4	1979	SS	0.41	18	43
5	2019	SS	0.43	18	3
6	1979	SS	0.60	18	43
7	1979	SS	0.04	16	43
8	2021	SS	0.86	16	0
9	1975	SS	0.26	16	47
10	2016	SS	0.03	18	6
11	2016	SS	6.36	18	6
			9.25		

Gass Forest					**Age at**
Cpt	**Planting Year**	**Species**	**Area (ha)**	**YC**	**2022**
42	2011	SS	1.16	18	11
43	2016	NS	0.09	14	6
			1.25		

Gass Farm broadleaved scrub at access **0.08** ha

Total permanent felling area (ha)	**54.37**

Technical Appendix 16: Climate

TA 16.1: Carbon Balance Assessment

Technical Appendix 16.1: Carbon Balance Assessment

Technical Appendix 16.1: Carbon Balance Assessment

1.1 Introduction

1.1.1 This carbon assessment report has been prepared on behalf of the Applicant in support of an application for consent to construct and operate the Proposed Development.

1.1.2 Whilst the Proposed Development would generate renewable energy and would contribute to carbon emissions reduction targets, it is recognised that the construction of the proposed infrastructure and subsequent operation and decommissioning would include activities that either directly or indirectly result in carbon dioxide (CO_2) emissions. In particular, the construction of the infrastructure could result in the potential loss of CO_2 from carbon stored within the peat deposits within the Site.

1.1.3 The Scottish Government has published an online calculation tool[1] (the 'carbon calculator') that is used to calculate the greenhouse gas (GHG) emissions and carbon payback times for wind farm developments on Scottish peatlands. This online tool, originally published in 2011 (described in Smith *et al*, 2011[2]), is supported by two further documents published by the Scottish Government, 2016[3] , and Scottish Renewables and SEPA, 2012[4].

1.1.4 The carbon calculator must be used for developments with a generating capacity of 50 MW or more. The calculation compares an estimate of the CO_2 emissions from the construction, operation and decommissioning of the Proposed Development to those emissions estimated from other electricity generation sources.

1.1.5 This Technical Appendix is supported by the following:

- Annex 16.1.1: Carbon Calculator Inputs; and
- Annex 16.1.2: Carbon Calculator Results and Charts.

1.2 Carbon Assessment Methodology

1.2.1 The online carbon calculator tool calculates carbon losses and savings over the lifetime of an onshore wind farm sited on peatlands. The methodology adopted to calculate the impact on the carbon balance of the Site as a result of the Proposed Development has been outlined in various literature sources (Nayak *et al.*, 2008[5]; Smith *et al*, 2011[2]; and Scottish Government, 2016[3]).

1.2.2 This report should be read in conjunction with the online carbon calculator inputs (which are detailed in Annex 16.1.1 and summarised in this Technical Appendix) and the Development Description in EIAR Volume 2: Chapter 2. Whilst various guidance indicates that actual measurements of the Site infrastructure are utilised in the calculations, for projects in the planning stage no infrastructure has been constructed. Therefore, the assumptions for the infrastructure are either based on information provided for the Proposed Development (where practical) or standard, default information that is representative for the Site. In each case, an explanation of the assumptions adopted and their respective source is provided in the following section.

1.3 Carbon Balance Assessment Input Parameters

1.3.1 Information relating to the design, construction and operation of the Proposed Development was collated, including details of the proposed infrastructure, local ecology and potential for loss of stored carbon, potential restoration proposals and the benefits of replacing fossil fuel generated electricity with electricity generated from renewable energy sources. This information was entered into the online carbon calculator[6]. The information entered is explained below.

Wind Farm Characteristics

Measurements

1.3.2 The detailed description of the Proposed Development provided in Chapter 2: Development Description (EIAR Volume 2), which states that planning consent will be sought for twelve turbines with an operational life of 30 years. The carbon balance assessment presented below is based on these considerations.

Capacity Factor

1.3.3 The capacity factor (sometimes referred to as load factor) for the Proposed Development is determined by dividing the annual generation output (MWh) by the installed capacity (MW) multiplied by the number of operational hours per annum. Generation output is a function of a wind turbine's power curve and the prevailing wind resource at the Site.

1.3.4 Chapter 2 (EIAR Volume 2) states that the wind turbines would have a total installed capacity of between 60 MW and 84 MW[7].

1.3.5 The capacity factor for the Proposed Development is estimated to be between 35% and 40%. These values have been generated from the Applicant's internal wind analysis based from on-site wind data and have been used as the minimum and maximum values in the online tool.

Backup

1.3.6 It is recognised that, due to the inherent variability of wind generated electricity, conventional generation facilities will be required to provide stability in the overall supply of electricity. Nayak *et al.* (2008)[5] refers to 'backup power generation' and identifies that the balancing capacity required is estimated as 5% of the rated capacity of the wind farm. However, this balancing capacity is only necessary where wind power contributes more than 20% of the national supply. Where the balancing capacity is obtained from fossil fuel generating stations, emissions will increase by 10% due to reduced thermal efficiency of the reserve generation stations.

1.3.7 The carbon assessment assumes the minimum and maximum values of 0% and 5% respectively to address the thermal inefficiencies of balancing generation units (Scottish Government, 2016[3]) which represents no contribution and full contribution from balancing plants.

[1] https://informatics.sepa.org.uk/CarbonCalculator/index.jsp

[2] Smith, J.U., Graves, P., Nayak, D.R., Smith, P., Perks, M., Gardiner, B., Miller, D., Nolan, A., Morrice, J., Xenakis, G., Waldron, S., and Drew, S. (2011). *Carbon Implications of Windfarms Located on Peatlands – Update of the Scottish Government Carbon Calculator Tool: CR/2010/05: Final Report*: http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/V2UpdReport.

[3] Scottish Government (2016). *Calculating Potential Carbon Losses & Savings from Wind Farms on Scottish Peatlands, Technical Guidance, Version 2.10.0:* https://www.gov.scot/publications/carbon-calculator-technical-guidance.

[4] Scottish Renewables and SEPA (2012). *Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste:* http://www.gov.scot/Resource/0045/00455955.pdf

[5] Nayak D.R., Miller D., Nolan A., Smith P., Smith J.U. (2008). *Calculating Carbon Savings from Windfarms on Scottish Peatlands - Revision of Guidelines. October 2007 to January 2008. Final Report.*

[6] Due to SEPA being under cyber attack, link of the online tool is not available. (Reference OGV1-BJ8C-O6X8 v4)

[7] Total installed capacity of between 60 MW and 84 MW currently does not include energy storage facility. It is noted that the grid connection capacity is currently limited to 67.2 MW.

Emissions from Turbines

1.3.8 CO_2 emissions during the life of a turbine include those emissions that occur during the manufacturing, transportation, erection, operation, dismantling and removal of the structures. The expected value has been calculated based on the default values embedded within the carbon calculator.

1.4 Peatland Characteristics of the Site

1.4.1 The Site is located approximately 8 km northwest of Kirkcowan and 15 km west of Newton Stewart, Dumfries and Galloway, and covers an area of approximately 800 hectares (ha). The Site is centred at approximate Ordnance Survey Grid Reference NX 24367 66928 (as shown in EIAR Volume 3a: Figure 1.1: Site Location).

1.4.2 The Site is dominated by commercially managed plantation forestry. The Site also supports areas of sheep grazed pasture in the south east and recently felled and replanted woodland together with compartments of mixed plantation woodland.

1.4.3 The Site location and setting are described in more detail within Chapter 2: Development Description (EIAR Volume 2).

1.4.4 The Site topography is generally undulating at elevations of between 182 m and 110 m Above Ordnance Datum (AOD), (as shown on EIAR Volume 4: Figure 2.5.1).

1.4.5 The majority of the Site is currently used for plantation forestry. An area of the Site to the south is currently used for grazing sheep and cattle.

1.4.6 The plantation forestry within Artfield Forest is predominantly mature tree growth which has not undergone felling/ restructuring. Forestry within the Meikle Cairn area of the Site is a mixture of primary and secondary plantation. Gass Forest has recently been subject to a series of felling and secondary forestry plantation.

1.4.7 The Site has historically been intensively managed with significant areas of commercial forestry plantation and felling, with artificial drainage measures used. In some areas diffuse natural drainage systems were also noted. Within the commercial plantation and forestry areas it was noted that the acrotelmic peat was highly modified as a result of planting and felling activities. No evidence of peat erosion or instability were generally noted.

1.4.8 No significant evidence of instability features were identified, with very few haggs, groughs, and other features noted. No pipes were observed (e.g. through collapsed pipe ceilings or underground water flow). No major instability features, evidence of incipient instability or past landslides were noted.

1.4.9 The Site is underlain by Wacke of the Portpatrick Formation and Glenwhargen Formation. The superficial geology of the Site predominantly comprises peat with the south east of the Site comprising Diamicton Till. Some areas are mapped as having no superficial deposits present which could imply that rockhead is relatively shallow in these areas.

1.4.10 The NatureScot carbon rich soils, deep peat and priority habitat mapping shows the Site as predominantly 'Class 4' or 'Class 5' soils, which are defined as mineral or peat soils with no peatland vegetation. These areas are predominantly forested or clear-felled land. Small areas of 'Class 1' and 'Class 2' soils (priority peatland habitat), which are of national importance are present along the northern boundary, and southern parts of the Site, shown on Figure 2.5.4 (EIAR Volume 4).

1.4.11 The peat survey reports (EIAR Volume 4: Technical Appendix 2.3: Peat Depth Survey Results) indicate that most of the peatland present on-site is acidic in nature, and for the purpose of the carbon assessment, the type of peatland has been designated as ‘acid bog’.

1.4.12 Two peat depth probing surveys were undertaken at the Site, with a combined total of 1,708 peat probes taken. This comprised 338 peat depth probes during the Phase 1 survey, as part of a low resolution survey across the developable area of the Site, and a further 1,370 probes during Phase 2 survey based on a more mature development layout. An additional 517 peat probes taken as part of the previous Gass Wind Farm application were also used. The combined peat depth dataset was 2,225 probes. The results of the surveys were used to inform the design layout of the Proposed Development and are presented in EIAR Volume 4: Technical Appendix 2.3 Peat Depth Survey Results.

1.4.13 Overall, the peats sampled across the developable area of the Site were relatively shallow, particularly in the southern and central parts of the Site. Deeper areas of peat were noted, particularly in the north western, north eastern and south western areas of the Site. The peat was found to be generally dry and in a state of advanced decomposition. This is likely to be as a result of the presence of coniferous plantation across the Site, which has resulted in modification to the integrity and composition of the peat and carbon rich soils.

1.4.14 The maximum depth of peat recorded at the Site was 6.4 m, located in the south western part of the Site during the peat survey for the Gass Wind Farm. The maximum depth of peat recorded during the Phase 1 peat probe survey was 5.5 m, located to the north western part of the Site. The maximum depth of peat recorded during the Phase 2 peat probe survey was 5.7 m, located east of Turbine 10. The mean peat depth recorded was 0.87 m.

1.4.15 For the purpose of the carbon assessment, the expected, minimum and maximum values relevant for the Site are 0.87 m, 0 m and 6.4 m respectively.

1.4.16 For the purposes of the carbon assessment, the expected value for the mean annual temperature is 10.2°C, and the minimum and maximum vales of 3°C and 18°C respectively, have been adopted. These values have been calculated from the mean annual air temperature for Newton Stewart, 2016 to 2020[8].

1.4.17 The assessment of peat/ soil depth assumes peat exists to the full depth of the probed depth value. Therefore, some peat probes may classify organic soils or underlying clay as peat for the purposes of the carbon calculator, and consequently may represent an overestimation of volume of peat present.

1.4.18 From the laboratory test results Technical Appendix 2.3: Peat Depth Survey Results (EIAR Volume 4) the mean total carbon (%) from the cores is 75.7%; with minimum and maximum values of 0.8% and 98% respectively.

1.4.19 The extent of drainage incorporated into the Proposed Development influences the total volume of peat impacted by the construction of the Proposed Development. Therefore, the extent of drainage has an impact on the carbon payback time calculated for the Proposed Development.

1.4.20 A review of the available literature (Nayak *et al*., 2008)[5] found that the extent of drainage effects is reported as being anything from 2 m to 50 m horizontally around the Site of disturbance. Research into the effects of moor gripping and water table data from other sites yielded a horizontal draw down distance typically of about 2 m. It is thought that in extreme cases, this may extend between 15 m and 30 m, though 15 m is considered to be an appropriate distance.

1.4.21 Smith *et al.* (2011)[2], identified the average extent of drainage impact at three sites (Cross Lochs, Farr Windfarm and Exe Head) as ranging from 3 m to 9 m. However, the actual extent of drainage at any given location will be dependent on local site conditions, including underlying substrata and topography.

[8] https://www.worldweatheronline.com/newton-stewart-weather-averages/dumfries-and-galloway/gb.aspx

1.4.22 Site specific values are not available, so the standard values from 'Windfarm Carbon Calculator Web Tool, User Guidance' have been used. Therefore, the expected value is 10 m, minimum is 5 m and maximum 50 m.

1.4.23 When determining the carbon loss from peat removed as part of the construction of the drainage works, the area where peat is removed is not included in the extent of drainage calculations because this has already been accounted for in the direct losses.

1.4.24 Guidance provided in 'Calculating Potential Carbon Losses and Savings from Wind Farms on Scottish Peatlands' (Scottish Government, 2016)[3] indicates that on intact peat sites, the depth to water table may be less than 0.1 m, but up to 0.3 m on eroded peat sites. Site-specific values are not available, so the values for 'degraded peat' from 'Windfarm Carbon Calculator Web Tool, User Guidance' have been used given the quality of the peatland present as described. Therefore, the expected value is 0.3 m, minimum is 0.1 m and maximum is 0.5 m.

1.4.25 For dry soil bulk density a value of 0.105 g/cm^3 has been used. The online calculator restricts the maximum value to between 0.05 g/cm^3 and 0.3 g/cm^3, so a value of 0.3 g/cm^3 has been used.

Vegetation Characteristics

1.4.26 The Site is relatively low altitude compared to other wind farms in Scotland and therefore a shorter restoration period than average may be reasonably expected. Regeneration should occur rapidly across restored areas of the Site. The speed of regeneration will also depend on species present and their colonising ability and traits, as well as the methods of restoration and maintenance of hydrology. Restoration may be quickly colonised by soft rush as this species is a quick coloniser of disturbed organic soils. Typical bog plants may take longer to establish where suitable conditions exist. The values stated take this into account considering available literature and anectodical observations of wind farms in Scotland. Five years is assumed as a reasonable precautionary estimate for regeneration of most bog plants, some taking hold sooner (minimum value) and some requiring longer to establish (maximum value). A minimum and maximum of 2 and 10 years is assumed.

1.4.27 There are a number of factors controlling the carbon cycle in peatlands, including plant community, temperature range, extent and type of drainage, depth to water table and peat chemistry. The estimated global average for apparent carbon accumulation rate in peatland ranges from 0.12 tC to 0.31 tC ha^{-1} yr^{-1} [9,10].

1.4.28 The carbon calculator guidance suggests a mid-range value of 0.25 tC ha^{-1} yr^{-1}, which falls within the range quoted above. For the purposes of the carbon assessment, this accumulation rate of 0.25 tC ha^{-1} yr^{-1} has been used as the expected value, with the accumulation rates of 0.12 tC ha^{-1} yr^{-1} and 0.31 tC ha^{-1} yr^{-1} adopted as the minimum and maximum values respectively.

1.4.29 The counterfactual emission factors for three methods of energy generation is fixed in the carbon assessment. These values are shown in Table 16.1.1.

Table 16.1.1: CO_2 Emissions from Electricity Generation

Fuel Source	CO_2 Emission (tCO_2 MWh^{-1})
Coal fired power station	0.920
Grid mix	0.25358
Fossil fuel mix	0.450

Proposed Development

1.4.30 The turbine foundations are made up of a central excavation of approximately 22 m diameter and an approximate depth of 3 m to 5 m subject to prevailing ground conditions.

1.4.31 Based on the peat probing undertaken, the average peat depth at the turbine footprint is estimated to be 0.8 m. The minimum and maximum expected peat depths are 0.1 m and 2.0 m respectively.

1.4.32 The proposed dimensions of the crane hardstandings are 40 m by 35 m, with the same excavation footprint.

1.4.33 Based on the peat probing survey results, the average peat depth at the crane hardstandings is calculated as 0.8 m. For the purposes of the carbon calculator, minimum and maximum depths recorded around crane hardstandings of 0.1 m and 2.0 m respectively are used.

1.4.34 It is expected that the total volume of concrete used for the Proposed Development would be 16,076 m^3.

1.4.35 A total of 7,090 m of new access tracks would be constructed as part of the Proposed Development. All of the tracks are proposed to be excavated with the exception of approximately 1,550 m which are proposed to be floated in sections of deeper peat, subject to confirmation following ground investigation post-consent. Where the peat depth is less than 1 m, the proposed access track would likely be constructed by excavating the peat, with the aim of minimising the haulage of excavated material. The proposed width of the excavated access track is 5 m with 0.5 m to 1 m shoulders on both sides.

1.4.36 In addition, there would also be 2,450 m upgrade to existing forest tracks, and 2,150 m of existing forest tracks would be utilised where no improvements are required.

1.4.37 Up to four borrow pits are proposed as part of the Proposed Development.

1.4.38 Temporary infrastructure such as construction compounds, and cable trenches are not expected to result in a permanent displacement of peat.

Peat Landslide Hazard

1.4.39 The peat landslide hazard is automatically defined by the online carbon calculator and is shown to be 'negligible'. This value is fixed in the carbon calculator.

Opportunities for Carbon Sequestration

1.4.40 Any local improvements to carbon sequestration, such as areas of peatland habitat restoration, would result in a reduction in the net carbon emissions from the Proposed Development.

1.4.41 Given the degraded and modified condition of the peat at the Site as a result of the plantation and associated artificial drainage, there are opportunities, as part of the Proposed Development, to restore and enhance the peat condition as part of the Habitat Management Plan (HMP). This Outline HMP (EIAR Volume 4: Technical Appendix 7.3) presents a commitment to restore and enhance areas of permanent felling, with a minimum of 30 ha of rewetted habitat proposed, subject to site investigation works.

1.4.42 Temporary drainage would be constructed around the wind turbine foundations and crane hardstandings as part of the Proposed Development. This drainage would be removed on completion of the construction works, and therefore, the area surrounding the foundations and hardstandings can be assumed to be drained only up to the time of completion of backfilling, and removal of any temporary surface water drains. Subsequently, the hydrological regime adjacent to the foundation and hardstanding is assumed to return to its pre-construction condition. For the purposes of the carbon calculator the expected value for completion of backfilling, removal of any surface drains, and

[9] Botch, M. S., Kobak, K. I., Vinson, T. S., and Kolchugina, T. P. (1995). Carbon pools and accumulation in peatlands of the former Soviet Union. Global Biogeochem. Cycles 9:(1), 37–46, doi:10.1029/94GB03156. *https://agupubs.onlinelibrary.wiley.com/doi/10.1029/94GB03156*

[10] Turunen, J., Tahvanainen, T., Tolonen, K., and Pitkänen, A. (2001). Carbon accumulation in West Siberian Mires, Russia Sphagnum peatland distribution in North America and Eurasia during the past 21,000 years. https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2000GB001312

restoration of the hydrology is 0.25 years, and the minimum and maximum are assumed to be 0.1 year and 3 years respectively.

Site Restoration

1.4.43 The restoration work undertaken as part of the decommissioning phase would be likely to result in a reduction in total carbon lost. By restoring the hydrological conditions and returning the remaining stored carbon to anaerobic conditions, further oxidative loss would be limited or prevented. The restoration of existing habitats represents an opportunity to enhance carbon sequestration. For the purposes of the carbon assessment no benefit has been assumed for the post-decommissioning restoration works, and therefore 100% loss of carbon from the drained volume of soil has been accounted for. During construction and decommissioning, good industry practice would be employed to minimise any disruption to peatland hydrology. It has been assumed that the access tracks constructed would remain in situ following decommissioning.

1.4.44 In the event that any gullies in peat have formed due to erosion during the operational phase, these would be blocked using good industry practice techniques to promote restoration of the local hydrological conditions. This approach has been assumed in the carbon assessment.

1.4.45 It is assumed any drainage channels constructed with the access tracks would be blocked to facilitate re-wetting of adjacent habitats.

1.4.46 It has also been assumed that surplus peat generated by the Proposed Development could be used to restore borrow pits created to generate aggregate.

Calculating Emission Factors

1.4.47 Whilst two methodologies exist, namely the IPCC method (IPCC, 1997[11]) and Ecosse project method (Smith *et al*., 2007)[2], the latter method is required to be adopted for an application for consent. The Ecosse method, which is based on site-specific values, is considered to provide appropriate site-specific results, whereas the values determined from the IPCC method are considered to be rough estimates.

1.5 Results

1.5.1 The factors used in the assessment are included in the online carbon calculator**Error! Bookmark not defined.**, and a summary of the total carbon losses is summarised in Table 16.1.2 below.

Table 16.1.2: Total Carbon Losses

Source	Expected CO_2 Losses (tCO_2)	Minimum Value CO_2 Losses (tCO_2)	Maximum Value CO_2 Losses (tCO_2)
Turbine life	55,530	55,530	77,955
Backup	35,478	0	49,669
Reduced carbon fixing potential	1,160	283	6,767
Soil organic matter	11,382	-4,801	141,886
Dissolved Organic Carbon and Particulate Organic Carbon leaching	359	0	24,697
Forestry felling	65,788	59,401	66,551
Total	**169,699**	**110,413**	**367,525**

1.5.2 The carbon losses calculated are independent of the generation mix used to calculate the overall carbon balance with the exception of the back-up generation capacity (which is assumed to be from conventional fossil fuel sources).

1.5.3 The predicted payback time for the proposed development, as determined from the carbon calculator tool, is shown in Table 16.1.3.

Table 16.1.3: Carbon Payback Period

Source	Counterfactual Emission Factors (2019) ($t\ CO_2\ MWh^{-1}$)	Carbon Payback Period (years)		
		Expected Value	Minimum Value 0% Balancing Capacity	Maximum Value 5% Balancing Capacity
Coal fired power station	0.920	0.9	0.3	2.2
Grid mix	0.25358	3.4	1.2	7.9
Fossil fuel mix	0.450	1.9	0.7	4.4

1.5.4 The 'grid mix' generation source includes renewable energy sources that are operational, therefore the 'fossil fuel mix' represents the most likely scenario when considering replacing existing generation capacity with electricity generated from the proposed development.

1.5.5 Based on the assumptions detailed above, the expected payback time, assuming a requirement for back up generation capacity, and therefore the predictions for the growth in the contribution of wind energy generation to be met, is calculated to be approximately 1.9 years, if replacing generation capacity from the 'fossil fuel mix'. Using the worst-case scenario, represented by adopting the maximum values entered in the carbon assessment and taking account of a requirement for back up generation capacity, the payback time is calculated to be 4.4 years.

1.6 Summary

1.6.1 The output from the carbon balance assessment indicates, based on the best estimate values determined from the information currently available, that the Proposed Development would pay back the carbon emissions associated with its construction, operation and subsequent decommissioning in 1.8 years. This result has been based on a conservative approach and no allowance has been accounted for in the carbon assessment for any site improvements that are incorporated into the final design of the proposed development, that would reduce further any carbon losses.

1.6.2 Changes to the factors incorporated into the carbon assessment could impact on the overall carbon payback period calculated, however, the sensitivity analysis embedded within the carbon calculator tool takes such variations into account by considering a range of values for each factor considered. Furthermore, by adopting conservative input values for various factors contributing to the overall carbon payback calculation, the carbon savings resulting from the operation of the Proposed Development (and the diversion of energy generation from a fossil fuel-mix), could be significantly greater than the carbon emissions predicted to occur from the construction, operation and subsequent decommissioning of the Proposed Development.

[11] International Panel on Climate Change, IPCC (1997) Revised 1996 IPCC guidelines for national greenhouse gas inventories workbook, vol. 2. Cambridge, UK. Cambridge University Press.

Annex 16.1.1: Carbon Calculator Inputs

Carbon Calculator v1.6.1
Artfield Forest Wind Farm Location: 54.957885 -4.737516
Statkraft

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	12	12	12	EIAR Chapter 2 Development Description
Duration of consent (years)	30	30	30	EIAR Chapter 2 Development Description
Performance				
Power rating of 1 turbine (MW)	5	5	7	EIAR Chapter 2 Development Description
Capacity factor	37.25	35	40	Generated from the Applicant's internal windanalysis for the Proposed Development
Backup				
Fraction of output to backup (%)	5	0	5	Calculating Potential Carbon Losses and Savingsfrom Wind Farms on Scottish Peatlands, TechnicalNote.
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life (tCO2 MW^{-1}) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	EIAR Volume 4 Technical Appendix 7 Habitats andVegetation
Average annual air temperature at site (°C)	10.2	3	15	Data derived based on local weather station at Newton Stewart for period 2016-2020 https://www.worldweatheronline.com/newton-stewart-weather-averages/dumfries-and-galloway/gb.aspx. Maximum temperature of 15 degrees used based on tool maximum value.
Average depth of peat at site (m)	0.87	0	6.4	EIAR Volume 4 Technical Appendix 2.3 Peat Depth Survey
C Content of dry peat (% by weight)	65	19	65	EIAR Volume 4 Technical Appendix 2.3 Peat Depth Survey and Result. Maximum and minimum value of 65% and 9% used as per tool limitations.
Average extent of drainage around drainage features at site (m)	10	5	50	Windfarm Carbon Calculator Web Tool, UserGuidance
Average water table depth at site (m)	0.3	0.1	0.5	Windfarm Carbon Calculator Web Tool, UserGuidance
Dry soil bulk density (g cm^{-3})	0.105	0.05	0.3	Maximum value of 0.3g cm-3 used as per tool limitations.
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	5	2	10	Five years used as a precautionary approach basedon location and elevation of the site
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.12	0.31	Windfarm Carbon Calculator Web Tool, UserGuidance
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	54.37	54	55	EIAR Volume 2 Chapter 14 Forestry
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	11	10	11	Based on value for coniferous species in Carbon Asssessment Tool (Sitka, 13.2) . Maximum value included of 11 based on tool limitation
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	0.92	0.92	0.92	
Grid-mix emission factor (t CO2 MWh^{-1})	0.25358	0.25358	0.25358	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.45	0.45	0.45	
Borrow pits				
Number of borrow pits	4	4	4	EIAR Volume 4 Technical Appendix 2.2 Borrow Pit Assessment
Average length of pits (m)	196.75	100	347	EIAR Volume 4 Technical Appendix 2.2 Borrow Pit Assessment
Average width of pits (m)	95.75	60	126	EIAR Volume 4 Technical Appendix 2.2 Borrow Pit Assessment
Average depth of peat removed from pit (m)	0.1	0	0.2	EIAR Volume 4 Technical Appendix 2.2 Borrow Pit Assessment
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	22	22	22	EIAR Chapter 2 Development Description
Average width of turbine foundations (m)	22	22	22	EIAR Volume 4 Technical Appendix 2.3 Peat Depth Survey
Average depth of peat removed from turbine foundations(m)	0.8	0.1	2	EIAR Volume 4 Technical Appendix 2.3 Peat Depth Survey
Average length of hard-standing (m)	40	40	40	EIAR Chapter 2 Development Description
Average width of hard-standing (m)	35	35	35	EIAR Chapter 2 Development Description
Average depth of peat removed from hard-standing (m)	0.8	0.1	2	EIAR Volume 4 Technical Appendix 2.3 Peat Depth Survey

Input data	Expected value	Minimum value	Maximum value	Source of data
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	16076	16076	16076	EIAR Volume 4 Technical Appendix 10 Transport Assessment
Access tracks				
Total length of access track (m)	10790	10760	10820	EIAR Chapter 2 Development Description
Existing track length (m)	2150	2140	2160	EIAR Chapter 2 Development Description
Length of access track that is floating road (m)	1550	1540	1560	EIAR Chapter 2 Development Description
Floating road width (m)	5	5	5	EIAR Chapter 2 Development Description
Floating road depth (m)	0.25	0	0.5	EIAR Chapter 2 Development Description
Length of floating road that is drained (m)	0	0	0	EIAR Chapter 2 Development Description
Average depth of drains associated with floating roads (m)	0	0	0	EIAR Chapter 2 Development Description
Length of access track that is excavated road (m)	7090	7080	7100	EIAR Chapter 2 Development Description
Excavated road width (m)	5	5	5	EIAR Chapter 2 Development Description
Average depth of peat excavated for road (m)	0.8	0	2	EIAR Technical Appendix 2.3
Length of access track that is rock filled road (m)	0	0	0	
Rock filled road width (m)	0	0	0	
Rock filled road depth (m)	0	0	0	
Length of rock filled road that is drained (m)	0	0	0	
Average depth of drains associated with rock filled roads (m)	0	0	0	
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	EIAR Chapter 2 Development Description. All trackswill follow access tracks.
Average depth of peat cut for cable trenches (m)	0	0	0	EIAR Chapter 2 Development Description. Nopermanent displacement of peat anticipated and can be reinstated in trenches.
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	15125	15125	15125	EIAR Volume 4 Technical Appendix 2.5 PMP
Area of additional peat excavated (m^2)	15625	15625	15625	EIAR Volume 4 Technical Appendix 2.5 PMP
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed
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)	15	10	20	Assumption based on 15ha of peat restoration areas, blocking of drains etc. Total habitat restoration area is approximately 30 ha but this considers ecological habitat improvement as well as peat restoration, it's been calculated 15ha will be ditch backfilling and has been used as expected value
Water table depth in degraded bog before improvement (m)	0.3	0.1	0.5	Same assumptions as used previously for average water table depth
Water table depth in degraded bog after improvement (m)	0.2	0	0.4	Assumption based on an improvement to water table following improvement
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	5	2	10	Assumption based on professional experience
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	5	2	10	Assumption based on professional experience
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	54.37	54	55	Assumed that area will be improved based on removal of trees
Water table depth in felled area before improvement (m)	0.3	0.1	0.5	Same assumptions as used previously for average water table depth
Water table depth in felled area after improvement (m)	0.2	0	0.4	Assumption based on an improvement to water table following improvement
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	5	2	10	Assumption based on professional experience forrestoration
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	5	2	10	Assumption based on professional experience
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	1.71	1.7	1.72	Based on EIAR Volume 2 Chapter 2
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.2	0	0.4	Assumption based on an improvement to water table following improvement
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.1	0	0.3	Assumption based on an improvement to water table following improvement
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	5	2	10	Assumption based on an improvement to water table following improvement

Input data	Expected value	Minimum value	Maximum value	Source of data
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	30	30	30	Assumption based on an improvement to water table following improvement and scheme operation
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.3	0.1	0.5	Windfarm Carbon Calculator Web Tool, UserGuidance
Water table depth around foundations and hardstanding after restoration (m)	0.1	0.05	0.3	Windfarm Carbon Calculator Web Tool, UserGuidance
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	0.25	0.1	3	Windfarm Carbon Calculator Web Tool, UserGuidance
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	This will form part of a decommissioning andrestoration plan for the site in future.
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	This will form part of a decommissioning andrestoration plan for the site in future.
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	This will form part of a decommissioning andrestoration plan for the site in future.
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	This will form part of a decommissioning andrestoration plan for the site in future.
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

Annex 16.1.2: Carbon Calculator Results and Charts

Payback Time and CO_2 emissions • OGV1-BJ8C-O6X8 v4

1. Windfarm CO2 emission saving over...	Exp.	Min.	Max.
...coal-fired electricity generation (t CO2 / yr)	180,123	169,243	270,789
...grid-mix of electricity generation (t CO2 / yr)	49,647	46,649	74,638
...fossil fuel-mix of electricity generation (t CO2 / yr)	88,104	82,782	132,451
Energy output from windfarm over lifetime (MWh)	5,873,580	5,518,800	8,830,080

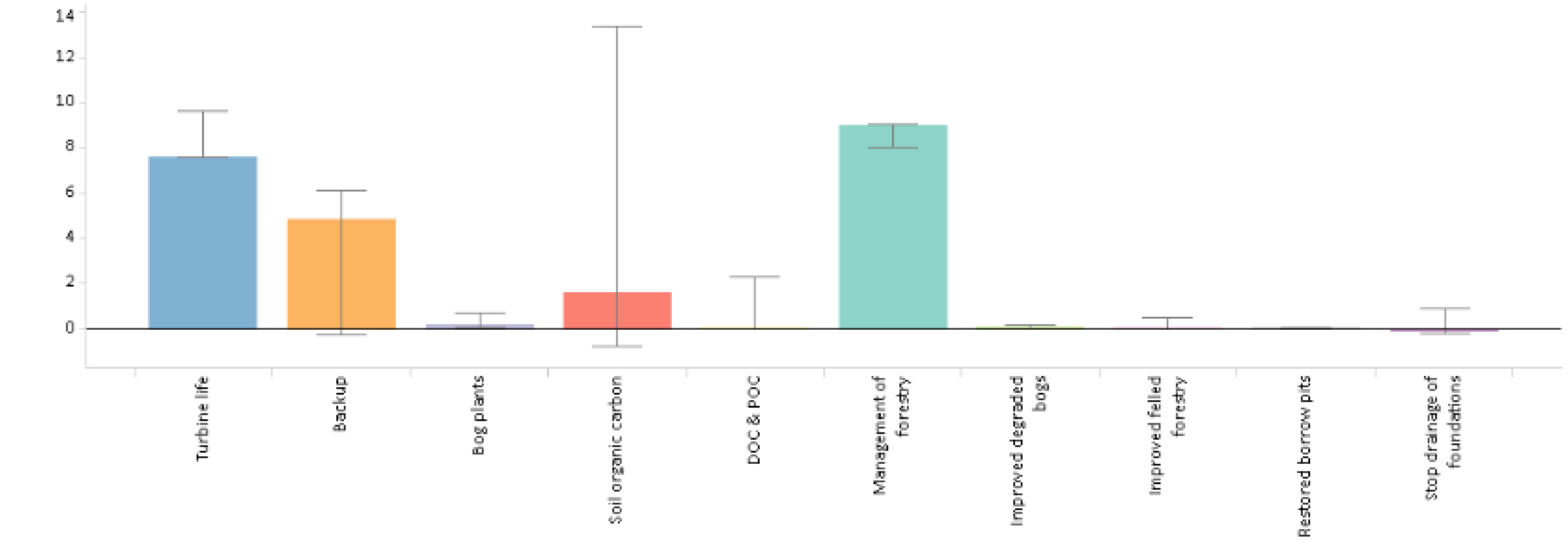
Total CO2 losses due to wind farm (tCO2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	55,530	55,530	77,955
3. Losses due to backup	35,478	0	49,669
4. Lossess due to reduced carbon fixing potential	1,160	283	6,767
5. Losses from soil organic matter	11,382	-4,801	141,886
6. Losses due to DOC & POC leaching	359	0	24,697
7. Losses due to felling forestry	65,788	59,401	66,551
Total losses of carbon dioxide	169,699	110,413	367,525

8. Total CO2 gains due to improvement of site (t CO2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	0	0	-1,812
8b. Change in emissions due to improvement of felled forestry	0	0	-4,982
8c. Change in emissions due to restoration of peat from borrow pits	31	0	17
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-789	0	-11,221
Total change in emissions due to improvements	-758	0	-17,998

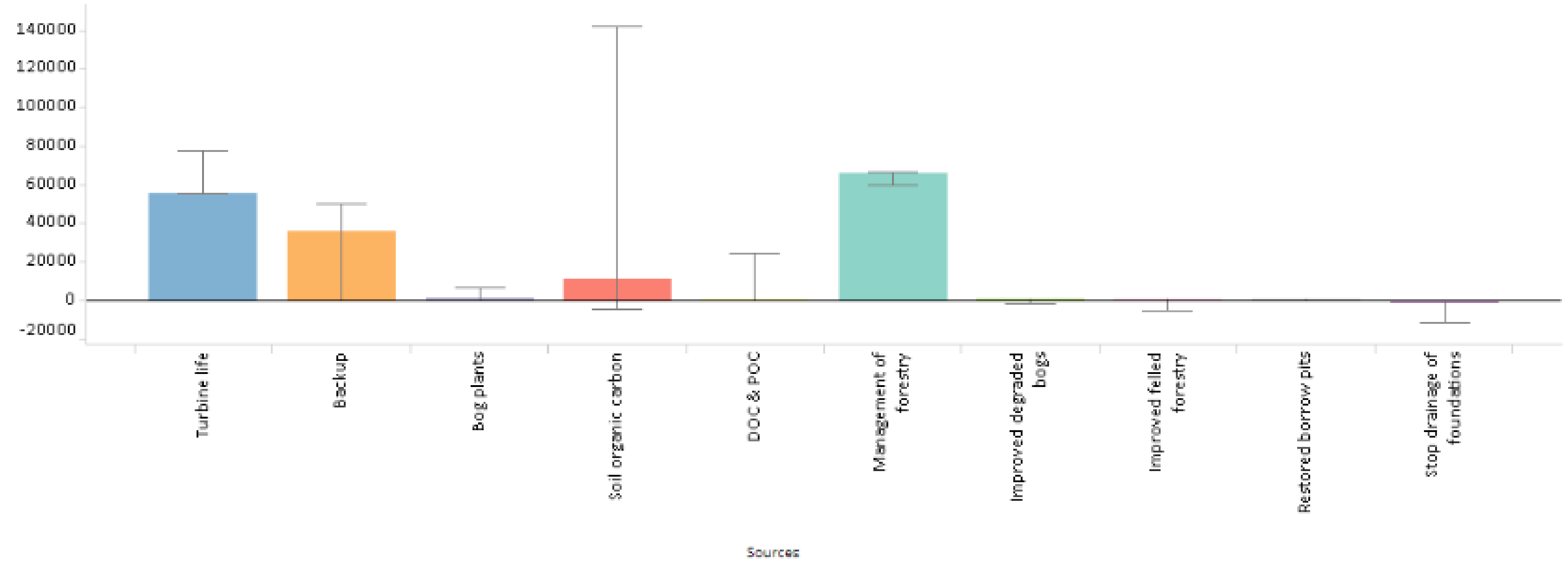
RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	168,941	92,415	367,525
Carbon Payback Time			
...coal-fired electricity generation (years)	0.9	0.3	2.2
...grid-mix of electricity generation (years)	3.4	1.2	7.9
...fossil fuel-mix of electricity generation (years)	1.9	0.7	4.4
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	15.49	-0.27	No gains!
Ratio of CO2 eq. emissions to power generation (g/kWh) (for info. only)	28.76	10.47	66.60

Payback Time and CO_2 emissions • OGV1-BJ8C-O6X8 v4

Carbon payback time (months) using fossil-fuel mix as conterfactual



Greenhouse gas emissions (t CO2 eq.)



Proportions of greenhouse gas emissions from different sources