16 Carbon Calculator

Contents

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16 Carbon Calculator

16.1 Executive Summary

16.1.1 This chapter considers the Carbon Balance Assessment of the Proposed Development and provides an update based on the 2021 Layout, compared to the 2020 Layout.

16.1.2 The results of the Carbon Calculator for the 2021 Layout show that the Proposed Development is estimated to produce annual carbon savings in the region of 143,000 tonnes of CO_2e, and lifetime savings of nearly 4.3 Mt of CO_2e through the displacement of grid electricity. This is in comparison to the annual carbon savings in the region of 180,000 tonnes of CO_2e, and lifetime savings of nearly 5.4 Mt of CO_2e, predicted for the 2020 Layout. Both layouts used were based on a counterfactual emission factor of 0.254 $kgCO_2e/kWh$, which represents displacing grid electricity at the current average annual grid mix. The lower savings of the 2021 Layout are a function of the reduced number of turbines and therefore generating capacity.

16.1.3 The assessment of the carbon losses and gains from the 2021 Layout has estimated overall losses of around 244,000 tonnes of CO_2e, mainly due to embodied losses from the manufacture of the turbines and provision of backup power to the grid, in comparison to the 334,000 tonnes of CO_2e predicted for the 2020 Layout. Ecological carbon losses account for 24 % of the total emissions resulting from the 2021 Layout construction and operation, compared to 28 % predicted for the 2020 Layout, indicating that the 2021 Layout has a lower impact on stored carbon on the site.

16.1.4 The estimated payback time of the 2021 Layout, using the Scottish Government Carbon Calculator, is estimated at 1.7 years, with a minimum/maximum range of 1.4 to 2.1 years, compared against the estimated 1.9 years payback time for the 2020 Layout. The carbon intensity of the electricity produced by the Proposed Development is estimated at 0.014 $kgCO_2e/kWh$. This is below the outcome indicator for the electricity grid intensity of 0.05 $kgCO_2e/kWh$ set by the Scottish Government in the Climate Change Plan (2018-2032) and therefore the Proposed Development is evaluated to have an overall beneficial effect on climate change mitigation.

16.2 Introduction

16.2.1 This chapter has been undertaken by Fluid Environmental Consulting (Fluid) and considers the Carbon Balance Assessment of the Proposed Development and provides an update to that undertaken as part of the 2020 Supplementary Environmental Information (SEI).

16.2.2 This chapter of the SEI 2 should be read in conjunction with Chapter 16 of the 2019 EIA Report which provides a background to the Carbon Balance Assessment, the legislation behind it and the methodology used and Chapter 16 of the 2020 SEI. This chapter assesses the effects of the 2021 Layout on the whole life carbon balance of the Proposed Development. With the removal of five turbines, reduction in number of borrow pit search areas from seven to four and other associated infrastructure changes from the 2020 Layout, the input parameters for the assessment have changed and the Carbon Calculator assessment has been updated.

16.2.3 The assessment has been carried out using the Scottish Government's Carbon Calculator (online version 1.6.1); the 2021 Layout has the online reference J027-YRZP-WP6J.

16.3 Response to Consultation Responses

SEPA

16.3.1 SEPA stated (letter dated 24/May/2021) that "*With respect to these issues, assessment of the proposals will focus on avoidance and minimisation of the loss of carbon during construction and operation of the wind farm, and the balance between the residual unavoidable carbon losses and carbon gains which have a high likelihood of being achieved through proposed compensatory* *restoration………It is welcome that the applicant will re-run the carbon calculator. In addition to payback period, the applicant should present the carbon calculator estimates of losses from soil organic matter (or drained peat), losses due to Dissolved organic carbon (DOC) and Particulate organic carbon (POC) leaching and losses due to reduced carbon fixing potential of the peatland vegetation. An estimate of carbon gains arising from proposed offsite peatland restoration works would be helpful to understand the degree of compensation that will be delivered – if an estimate using the carbon calculator can be obtained then that would be useful additional information*."

16.3.2 The Applicant can confirm that the Carbon Calculator has been re-run with updated parameters from the 2021 Layout which are detailed below in Table 16.1. Further detail from the Carbon Calculator about the breakdown of carbon losses from site has been presented in Table 16.2 and 16.3. Due to the restoration occurring off-site, it was excluded from previous iterations; however, it has been included in the Carbon Calculator for the 2021 Layout following SEPA's consultation response. The estimate of these off-site restoration gains is presented in Table 16.4.

16.4 Changes to Input Parameters

16.4.1 Table 16.1 below details only the input parameters that have changed due to the 2021 Layout, along with the data range, the source, and the assumptions, and highlights how these have changed from the 2020 SEI.

Table 16.1 – Updated parameters for the Scottish Government Carbon Calculator

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Wind Farm Characteristics								
Dimensions								
No. of turbines	23	23	23	18	18	18	Chapter 3 (SEI 2) states that the Proposed Development comprises of 18 turbines.	None
Performance								
Turbine capacity (MW)	6.9	6.9	6.9	7.0	7.0	7.0	Chapter 3 (SEI 2) states that the overall capacity of the Proposed Development will be (subject to turbine procurement) approximately 126 MW, but would not exceed 200 MW. For the purposes of the carbon calculator, a 7 MW turbine based on a 126 MW capacity has been used, which is consistent with the socio-economic assessment.	None
Borrow Pits								
Number of borrow pits	7	7	7	4	4	4	Chapter 3 (SEI 2) states there will be four borrow pit search areas. All of these have been included in the assessment.	None

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Average length of pits (m)	147	140	154	141	134	148	The four borrow pits are of different sizes and shapes; in order to be able to enter an average value for length and width, the total area of the borrow pits was calculated from the GIS shapefile. This area was divided by the number of borrow pits and then the square root of this value was calculated to get an average length and width.	A range of +5 % has been used to calculate the likely expected and maximum values of both length and width.
Average width of pits (m)	147	140	154	141	134	148		
Average depth of peat removed from pit (m)	1.22	1.17	1.27	1.00	0.95	1.05	The volume of peat in each borrow pit was calculated from the area of each borrow pit multiplied by the average peat depth for that location (averaged from all of the peat probes within a 50 m buffer of the infrastructure). The total volume of peat was divided by the total borrow pit area to provide an average overall peat depth across all four locations.	A 95 % confidence interval (CI) has been calculated as mean +/- 2 standard error (SE) to estimate the likely minimum and maximum values of peat volume for each borrow pit. The total maximum and minimum volumes were divided by the total area to get an estimate of the range of the maximum and minimum average depth.

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Foundations and hard-standing area associated with each turbine								
Method used to calculate CO_2 loss from foundations and hard-standing	Simple method – whole site average			Simple method – whole site average			The Carbon Calculator provides two options for calculating losses from turbine foundations and hardstanding; where there are obvious groups of turbines in terms of different peat depths, structures or use of piling, these can be separated into different construction areas. Alternatively, there is a simple method that uses just rectangular shapes. For this site, the simple method has been used because there is no obvious grouping of turbines in terms of peat depths.	None
Average length of turbine foundations (m)	21	20	22	13.3	12.6	13.9	Chapter 3 (SEI 2) states that the turbine foundations have been refined and the dimensions reduced to 15m diameter. Since the 18 turbine foundations are circular in shape, to be able to enter an average value for length and width, the square root of the area of the foundations was calculated to get an average length and width.	A range of + 5% has been used to calculate the likely expected and maximum values of both length and width.
Average width of turbine foundations (m)	21	20	22	13.3	12.6	13.9		
Average depth of peat removed from turbine foundations (m)	1.47	1.39	1.55	1.53	1.43	1.63	The volume of peat at each turbine location was calculated from the turbine area multiplied by the average peat depth for each location (averaged from all the peat probes	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
							within a 50 m buffer of each turbine/hardstanding location). The total volume of peat was divided by the total foundation area to provide an average peat depth across all 18 turbine locations.	maximum values of peat volume for each turbine foundation. The total maximum and minimum volumes were divided by the total area to get an estimate of the range of the maximum and minimum average depth.
Average length of hard-standing (m)	57	54	60	60	57	63	Chapter 3 (SEI 2) states that permanent hardstanding areas would measure approximately 30 m wide by 60 m long.	A range of +5 % has been used to calculate the likely expected and maximum values of both length and width.
Average width of hard-standing (m)	57	54	60	30	28.5	31.5		
Average depth of peat removed from hard-standing (m)	1.47	1.39	1.55	1.53	1.43	1.63	The volume of peat at each hardstanding location was calculated from the hardstanding area multiplied by the average peat depth for each location (averaged from all the peat probes within a 50 m buffer of each turbine/hardstanding location). The total volume of peat was divided by the total hardstanding area to provide an average peat depth across all 18 turbine locations.	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and maximum values of peat volume for each hardstanding. The total maximum and minimum volumes were divided by the

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
								total area to get an estimate of the range of the maximum and minimum average depth.
Volume of concrete								
Volume of concrete used (m^3) in the entire area	41,599	39,519	43,679	12,717	12,081	13,353	Chapter 3 (SEI 2) states that the turbine foundations are 15 m diameter and between 3 to 5 m in depth. The average of these dimensions has been used to calculate an estimated volume of concrete per foundation. The total volume is estimated by multiplying by the number of turbines.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Access tracks								
Total length of access track (m)	15,290	14,526	16,055	11,390	10,821	11,960	Chapter 3 (SEI 2) provides track lengths for all the categories below: New permanent floated access track New permanent dug access track New temporary floated access track Upgraded existing track.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Existing track length (m)	1,040	988	1,092	0	0	0	It is assumed that all existing track will require upgrading and therefore it has been included in the category above.	
Length of access track that is floating road (m)	13,200	12,540	13,860	8,560	8,132	8,988	Chapter 3 (SEI 2) provides track length for permanent floating track and temporary floating track that will be restored post-construction.	A range of +/- 5 % has been used to calculate the likely minimum and maximum
Floating road width (m)	6.0	5.7	6.3	6.9	6.5	7.2	The average width has been calculated from the area of floating track in the shapefile, divided by the length provided in Chapter 3 (SEI 2). This gives an average width value of 6.9m, which includes all the widening at junctions and bends.	A range of +/-5 % has been used to calculate the likely maximum and maximum.
Floating road depth (m)	0	0	0.38	0	0	0.39	This parameter accounts for sinking of floating road. The Carbon Calculator states that it should be entered as the average depth of the road expected over the lifetime of the Proposed Development. If no sinking is expected, enter as zero. It is not anticipated that sinking of the floating track would be minimal and therefore this parameter has been set as zero for the expected and minimum values. A cautious estimate of 25 % of the average peat depth under floating	Zero value for expected and minimum values. The maximum is estimated at 25 % of the average peat depth for all the floating road locations on-site.

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
							roads (1.57m) has been entered for the maximum to represent the worst case scenario.	
Length of floating road that is drained (m)	13,200	12,540	13,860	8,560	8,132	8,988	SEI 2 Appendix 10.1 Revised Peat Management and Restoration Plan states that floated track includes V drains. Therefore, it is assumed that the full length of floating road access track will be drained.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Length of access track that is excavated road (m)	1,050	998	1,103	2,830	2,689	2,972	Chapter 3 (SEI 2) provides track length for permanent dug access track and upgraded existing track, which has been included here.	A range of +/- 5 % has been used to calculate the likely minimum and maximum
Excavated road width (m)	6.0	5.7	6.3	8.8	8.0	9.2	The average width has been calculated from the area of excavated track in the shapefile, divided by the length. This gives a higher average width value of 8.8m but this include widening at junctions and bends.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Average depth of peat excavated for road (m)	1.38	1.31	1.45	1.52	1.49	1.55	The average peat depth under excavated track has been calculated using the peat probe data within the track shape and within a 25 m buffer each side. Count = 1255	A 95 % CI has been calculated as mean +/- 2 SE to estimate the likely minimum and maximum values.

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
							Mean = 1.52 m SE = 0.0016 m	
Additional peat excavated (not accounted for above)								
Volume of additional peat excavated (m^3)	9,070	8,603	9,357	9,693	9,209	10,178	The volume of additional peat excavated has been calculated from compound 1 and the widened section of access track at the entrance. The area of these components was estimated from the GIS shape file. The average peat depth at the location (area of component + 50 m buffer) was calculated from GIS, with the standard deviation.	The variation of this component was calculated as a minimum and maximum volume using the 95 % CI calculated as mean +/- 2 SE to estimate the peat depth and +/- 5 % to estimate the area.
Additional area of land lost due to windfarm construction (m^2)	65,214	61,953	68,475	80.595	76,565	84,625	The additional area of land lost to construction includes the excavated infrastructure components above and also the infrastructure that will be floated. This includes: 2 compounds, including the substation Temporary laydown areas, temporary boom assembly area, temporary assistant crane hardstanding – restored after construction	A range of +/- 5 % has been used to calculate the likely minimum and maximum

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
							The area of each component was estimated from the GIS shape file.	
Improvement of C sequestration at site by blocking drains, restoration of habitat etc.								
Improvement of degraded bog							In previous versions of the carbon calculator for the Proposed Development, this section was not included because the habitat restoration was outside the site boundary and limited information was available. However, as detailed in Section 16.3, SEPA have requested an estimate of carbon gains arising from proposed offsite peatland restoration works and therefore it has been included in this iteration. The wide range of parameters reflects the ongoing discussions regarding pre and post restoration habitat.	
Area of degraded bog to be improved (ha)				53	51	55	There are two candidate areas, both comprising degraded peatland with hags and other areas of bare peat. The main issue is overgrazing; neither has been systematically drained. Area A is a minimum of 124.3 ha; the estimated 'net restoration benefit' will be 55 ha.	The median value of the two net restoration areas has been selected as the expected value.

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
							Area B is minimum of 75.5 ha; the estimated 'net restoration benefit' will be 51 ha.	
Water table depth in degraded bog before improvement (m)				0.19	0.08	0.3	Although neither area has been systematically drained, in degraded peat it is expected that the water table will be sub-optimal for peat development. A value of 0.3m has been selected for the maximum, with the minimum set as the same as the average expected value on this site.	The median value of the minimum and maximum has been selected as the expected value.
Water table depth in degraded bog after improvement (m)				0.08	0.00	0.16	To restore the bog habitat in the borrow pits, it is expected that the average annual water table depth needs to be restored to around 0.1 m from the surface. The average annual water table depth is set as the site average as measured from the cores.	The minimum value has been set at zero, and the maximum value 0.16 m which represents the average depth of the acrotelm/catotelm boundary.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)				15	10	20	Due to the larger restoration area and potentially more complex restoration activities, it is anticipated that the hydrology and habitat would take longer to restore than the borrow pits and therefore the time has been set at 50% longer.	A range of +/- 33 % has been used to calculate the likely minimum and maximum

	2020 Layout			2021 Layout				
Parameter	**Expected**	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**	**Data Source**	**Key Assumptions**
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)				30	30	30	The Carbon Calculator states that if the time required for hydrology and habitat to return to its previous state is 15 years and the restoration can be guaranteed over the lifetime of the Proposed Development (30 years), the period of time when the improvement can be guaranteed should be entered as 30 years.	
Restoration of peat removed from borrow pits								
Area of borrow pits to be restored (ha)	15.1	13.7	16.7	8.0	7.6	8.4	The four borrow pit areas are of different sizes and shapes; the total area of the borrow pits was calculated from the GIS shapefile.	A range of +/- 5 % has been used to calculate the likely minimum and maximum.
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	1.22	1.17	1.27	1.00	0.95	1.05	This is a difficult parameter to estimate; however, it is assumed that the water table would be significantly lowered by drainage prior to restoration. It is estimated that the water table would be at middle of the peat column before restoration with respect to the restored surface, therefore at 1m depth.	A range of +/– 5 % has been used to calculate the likely minimum and maximum.

16.5 Assessment of Residual Effects

Carbon Balance Assessment – Emissions

16.5.1 The results from the Carbon Balance Assessment are presented below with comparison against the results from the 2020 Layout. The results are divided into losses from activities resulting in the emission of carbon, gains from site restoration activities that should result in uptake of atmospheric carbon, comparison with the baseline stored carbon and savings from the avoidance of carbon emissions by displacing grid electricity from other fuel sources.

Table 16.1 - Estimated Carbon Emissions During the Construction Phase

	2020 Layout				2021 Layout			
Emission source	**Estimated emissions (tCO_2e)**			**% of overall emissions (expected scenario)**	**Estimated emissions (tCO_2e)**			**% of overall emissions (expected scenario)**
	Expected	**Minimum**	**Maximum**		**Expected**	**Minimum**	**Maximum**	
Losses due to turbine life	150,673	150,016	151,330	44 %	113,331	113,130	113,532	45.6 %
CO_2 loss from excavated peat	51,717	29,580	80,621	15%	24,119	12,832	39,351	9.7 %
Subtotal of emissions during construction	**202,390**	**179,596**	**231,951**	**59%**	**137,450**	**125,962**	**152,883**	**55.3 %**

16.5.2 Table 16.2 shows that for the 2021 Layout, the losses during construction have decreased but this is mainly in line with the reduced number of turbines. However, the percentage of construction phase losses that are attributable to excavated peat have reduced from 15% to 9.7% which indicates that the 2021 Layout has reduced the amount of affected peat in comparison with the 2020 Layout.

Table 16.2 - Estimated Carbon Emissions During the Operational Phase

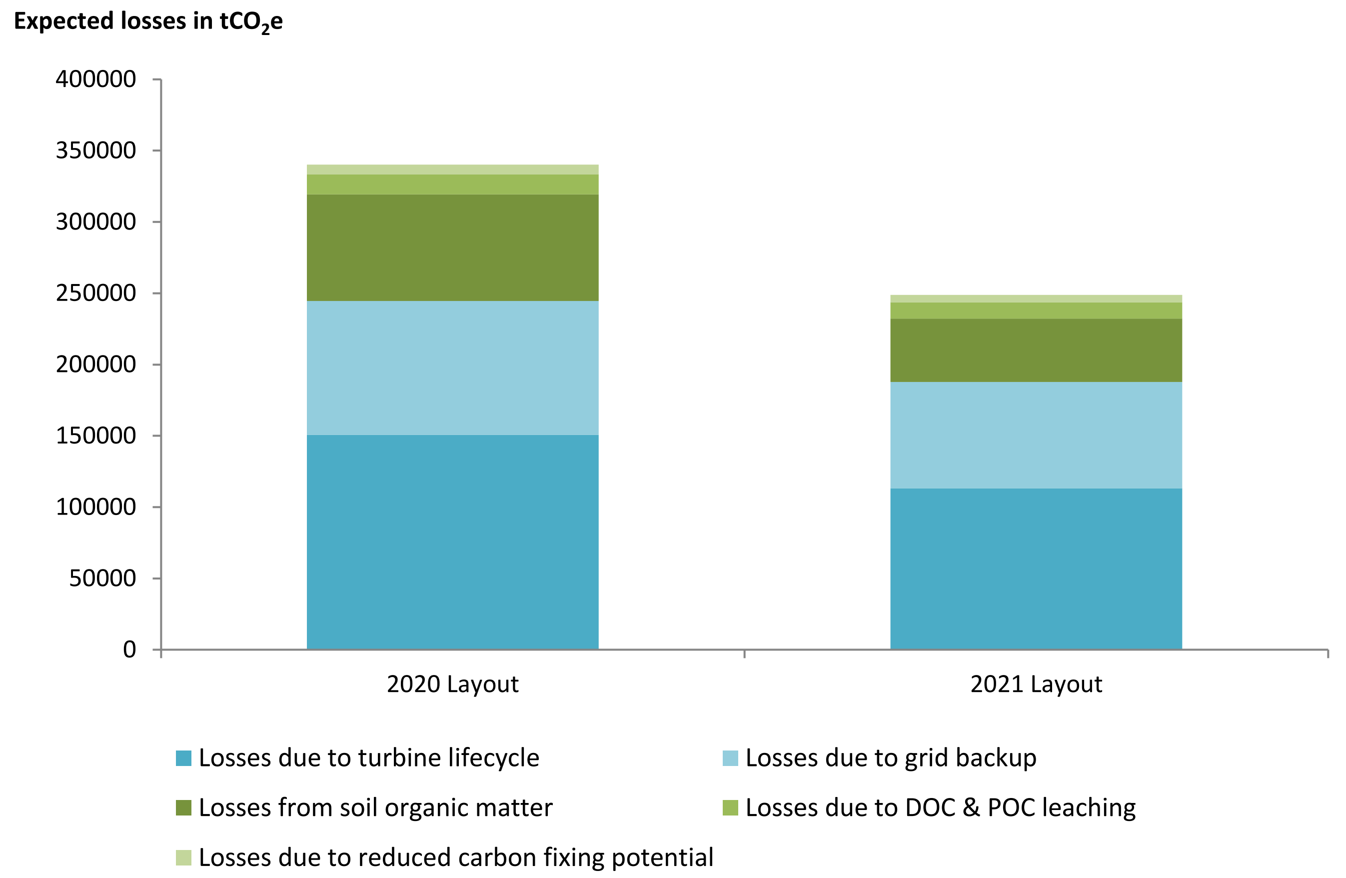
	2020 Layout				2021 Layout			
Emission source	**Estimated emissions (tCO_2e)**			**% of overall emissions (expected scenario)**	**Estimated emissions (tCO_2e)**			**% of overall emissions (expected scenario)**
	Expected	**Minimum**	**Maximum**		**Expected**	**Minimum**	**Maximum**	
Losses due to backup	93,839	93,839	93,839	28%	74,504	74,504	74,504	30 %
Losses due to reduced carbon fixing potential	6,848	2,212	16,116	2%	5,056	1,629	11,894	2%
Losses due to dissolved organic carbon (DOC) & particulate organic carbon (POC) leaching	14,042	1,534	44,847	4%	11,559	1,338	36,048	5%
CO_2 loss from drained peat	23,131	2,896	10,718	7%	20,205	6,859	9,675	8%
Subtotal of emissions during operation	**137,860**	**100,481**	**165,520**	**41%**	**111,324**	**84,330**	**132,121**	**45%**

16.5.3 Table 16.3 shows that the distribution of emissions during the operational phase has not changed significantly. The most significant operational source of emissions is still the requirement for back-up power in the grid, which is assumed to come from a fossil fuel source. Carbon losses due to leaching of carbon and from oxidation of drained peat account for a further 13 %, however, loss of carbon fixing potential from bogs still only contributes 2 % of the total losses.

16.5.4 Graph 16.1 shows how the emissions are split between sources for both the 2020 Layout and the 2021 Layout. The majority of emissions result from activities largely outside of the control of the Applicant (shown in blue); lifecycle emissions from the turbines can be potentially reduced through consideration at the procurement phase but availability and delivery timescales of appropriate turbines are usually more important factors in selection. The second largest emission source is from back-up power, and this depends on both the grid mix and future grid management policies and is not under the control of the Applicant.

16.5.5 Emissions under the control of the Applicant are shown in green. These include the losses of carbon due to the extraction and drainage of peat and loss of carbon fixing potential. The percentage of emissions under the control of the Applicant have reduced slightly from 28 % to 24 %.

Graph 16-1 - Breakdown of Emission Sources for the Proposed Development (2020 Layout compared to 2021 Layout)



Carbon Balance Assessment – Gains

16.5.6 Table 16.4 shows the estimated carbon gains over the lifetime of the Proposed Development from improvements through restoration, with a comparison between the 2020 Layout and 2021 Layout. This shows the gains resulting from the improvement of degraded bog through off-site habitat restoration; these are only estimated at around -2,000 tCO_2e (the negative sign indicates that the carbon is being removed from the atmosphere) over the lifetime of the Proposed Development because the Carbon Calculator is very cautious about predicting gains from restoration and only estimates the change in balance of CO_2 and methane emissions from raising the water table over the 15 years post-restoration. No gains are assumed from carbon accumulation due to carbon fixation by bog plants in either the restored habitat or the borrow pits.

Table 16.3 - Estimated Carbon Gains During the Construction Phase

	2020 Layout				**2021 Layout**			
Source of gains	**Estimated gains (tCO_2e)**			**% of overall gains (expected scenario)**	**Estimated gains (tCO_2e)**			**% of overall gains (expected scenario)**
	Expected	**Minimum**	**Maximum**		**Expected**	**Minimum**	**Maximum**	
Change in emissions due to improvement of degraded bogs (off-site restoration)	(not previously calculated for the 2020 SEI)				-1,912	-	-4,046	38%
Change in emissions due to restoration of peat from borrow pits	-6,042	-4,841	-6,111	100%	-3,149	-2,630	-3,026	62%
Subtotal of gains	**-6,042**	**-4,841**	**-6,111**	**100%**	**-5,061**	**-2,630**	**-7,072**	**100%**

Comparison with the Baseline

16.5.7 The soil carbon losses from the Proposed Development site are estimated at around 56,000 tonnes of CO_2e (this is the total of losses from drained peat and leached DOCs/POCs in Table 16.3 and excavated peat in Table 16.2). This represents around 1.0 % of the total stored carbon on-site (the estimated stored carbon is set out in Table 16.3 of Chapter 16 of the 2019 EIA Report) and includes anticipated losses from excavated and drained peat and losses due to leaching. This has reduced compared to the 2020 Layout (89,000 tCO_2e and 1.6% of total stored carbon).

Carbon Balance Assessment – Savings

16.5.8 Table 16.5 shows the estimated annual and lifetime CO_2 savings, based on the three different counterfactual emission factors, with a comparison between the 2020 Layout and 2021 Layout. The reduction in number of turbines has reduced the overall output of the Proposed Development so the savings are reduced compared to the 2020 Layout.

Table 16.4 - Estimated Annual and Lifetime Carbon Savings from the Operation of the Proposed Development from the Displacement of Grid Electricity

	2020 Layout			**2021 Layout**		
Counterfactual emission factor	**Estimated savings (tCO_2e per year)**			**Estimated savings (tCO_2e per year)**		
	Expected	**Minimum**	**Maximum**	**Expected**	**Minimum**	**Maximum**
Coal-fired electricity generation	652,287	620,313	685,541	517,884	492,498	544,286
Grid-mix of electricity generation	179,790	170,977	188,956	142,745	135,747	150,022
Fossil fuel - mix of electricity generation	319,054	303,414	335,319	253,313	240,896	266,227

Payback Time and Carbon Intensity

16.5.9 Table 16.6 shows the estimated payback time, if the electricity generated by the Proposed Development is assumed to displace electricity generated by the grid at the current average grid factor and also the carbon intensity of the units produced, with a comparison between the 2020 Layout and 2021 Layout.

Table 16.5 - Estimated Payback time in years and carbon intensity of the units of electricity produced.

Counterfactual emission factor	2020 Layout Estimated time to payback (years)			2021 Layout Estimated time to payback (years)		
	Expected	Minimum	Maximum	Expected	Minimum	Maximum
Coal-fired electricity generation	0.5	0.4	0.6	0.5	0.4	0.6
Grid-mix of electricity generation	1.9	1.4	2.3	1.7	1.4	2.1
Fossil fuel - mix of electricity generation	1.0	0.8	1.3	1.0	0.8	1.2
Carbon intensity (kgCO_2e/kWh)	0.016	0.012	0.019	0.014	0.011	0.018

16.5.10 Table 16.6 shows that the 2021 Layout is estimated to have a payback of 1.7 years based on the current grid mix and the carbon intensity of units produced would be significantly lower than the current grid mix (the value of 0.254 kgCO_2e/kWh is currently used in the Carbon Calculator). This is a slight improvement on the 2020 Layout but the range of estimated payback has stayed fairly constant. This is because, although the losses are lower for 2021 Layout, and there is less stored carbon on-site being excavated, or lost through drainage and leaching, there are also fewer units of electricity being generated and therefore the savings are also reduced.

16.6 Assessment of Cumulative Effects

16.6.1 The most significant cumulative effect of the Proposed Development is on the long-term grid electricity carbon factor. As the supply of renewable electricity increases, the overall average national grid carbon factor is predicted to decrease. The cumulative effect of these projects would be to reduce the projected emissions savings of an individual project as each unit of grid electricity would be worth less carbon. This effect will be higher as renewable energy develops further into the future; however, at the same time the exact generation composition of the grid and therefore the carbon emissions per unit of electricity is less predictable.

16.6.2 Although there is a great deal of uncertainty surrounding the future grid factor, the Intergovernmental Analysts Group at the Department for Energy and Climate Change have produced projections which are based on the UK achieving renewable energy targets and successfully implementing the UK Energy Policy. The projections predict an average grid factor over the expected lifetime of the Proposed Development (2024 to 2053) of approximately 0.058 $kgCO_2e/kWh$ (BEIS, 2021). The impact of applying this average grid factor to the Proposed Development would be to reduce the overall average annual saving and therefore increase the expected payback period from 1.7 years to 7.5 years. However, this would not affect the carbon intensity of the project, which is estimated at 0.014 $kgCO_2e/kWh$, which would be well below the projected average for the lifetime of the Proposed Development and would therefore contribute towards this grid decarbonisation.

16.7 Comparison of Effects

16.7.1 The results of the Carbon Calculator for the 2021 Layout show that the Proposed Development is estimated to produce annual carbon savings in the region of 143,000 tonnes of CO_2e per year, and lifetime savings of nearly 4.3 Mt of CO_2e through the displacement of grid electricity. This is in comparison to the annual carbon savings in the region of 180,000 tonnes of CO_2e per year predicted for the 2020 Layout, and lifetime savings of nearly 5.4 Mt of CO_2e. Both layouts used were based on a counterfactual emission factor of 0.254 $kgCO_2e/kWh$, which represents displacing grid electricity at the current average annual grid mix. The lower savings of the 2021 Layout are a function of the reduced number of turbines and therefore generating capacity.

16.7.2 The assessment of the carbon losses and gains from the 2021 Layout has estimated an overall loss of around 244,000 tonnes of CO_2e, mainly due to embodied losses from the manufacture of the turbines and provision of backup power to the grid, in comparison to the 334,000 tonnes of CO_2e predicted for the 2020 Layout. Ecological carbon losses account for 24 % of the total emissions resulting from the 2021 Layout construction and operation, compared to 28 % predicted for the 2020 Layout, indicating that the 2021 Layout has a lower impact on stored carbon on the site.

16.7.3 The estimated payback time of the 2021 Layout, using the Scottish Government Carbon Calculator, is estimated at 1.7 years, with a minimum/maximum range of 1.4 to 2.1 years, compared against the estimated 1.9 years payback time for the 2020 Layout. There are no current guidelines about what payback time constitutes a significant impact, but 1.7 years is around 6 % of the anticipated lifespan of the Proposed Development. Compared to fossil fuel electricity generation projects, which also produce embodied emissions during the construction phase and significant emissions during operation due to combustion of fossil fuels, the Proposed Development has a low carbon footprint and after 1.7 years, the electricity generated is estimated to be carbon neutral and will displace grid electricity generated from fossil fuel sources. The carbon intensity of the electricity produced by the Proposed Development is estimated at 0.014 $kgCO_2e/kWh$. This is below the outcome indicator for the electricity grid intensity of 0.05 kgCO2e/kWh of the carbon intensity required by the Scottish Government in the Climate Change Plan (2018-2032) and therefore the Proposed Development is evaluated to have an overall beneficial effect on climate change mitigation.

16.8 References

Department for Business, Energy & Industrial Strategy. (2021). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. Data tables 1- 19: supporting the toolkit and the guidance. *Available at* *https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal* Accessed on: 07/09/21

Scottish Government (2018). Climate Change Plan. The Third Report on Proposals and Policies 2018-2032.