Upper Ogmore Wind Farm
Carbon Balance Assessment

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1. EXECUTIVE SUMMARY

1.1 This report has been produced to assist consultees with their review of the proposal's impact on the existing peat body within the proposed site, and to assess the impact in terms of carbon dioxide (CO_2) emissions against the total potential carbon savings attributed to the proposed development.

1.2 The carbon assessment for the proposed development was undertaken using Version 2.8.1 of the Scottish Governments carbon calculator tool. As no tool exists specifically for Welsh wind farms, it is deemed appropriate to use this tool.

1.3 Expected values were determined following detailed site assessment and infrastructure design and were input into the carbon calculator tool.

1.4 The carbon calculator analysis revealed that the expected potential annual energy output of the 7-turbine proposed development is 82,782 MWh yr^{-1}, with minimum and maximum potential outputs at 77,263 MWh yr-1 and 88,301 MWh yr-1.

1.5 The wind farm CO_2 emissions savings over other types of generation (i.e. coal-fired, grid-mix, fossil fuel-mix) is calculated by multiplying the above energy output of the development by the emissions factor of the other types of generation. The figure calculated for the total net emissions of CO_2 lost by the proposed development is then divided by the wind farm CO_2 emissions savings over the other individual types of generation, to reveal the payback time for the proposed development.

1.6 Based on the expected energy output of the development (82,782 MWh yr^{-1}), and the emissions associated with the development, the potential expected tonnes of CO_2 emissions saved per year over coal-fired electricity generation is 74,138 tCO_2; grid-mix generation is 21,396 tCO_2 and fossil-fuel mix is 36,224 tCO_2.

1.7 The conclusion of the carbon calculator reveals that the proposed wind farm will effectively pay back its expected carbon debt from manufacture, construction, impact on habitat and decommissioning within 1.7 years, if it replaces the fossil fuel electricity generation method. Based on the minimum and maximum scenarios, the analysis shows that the payback time for fossil fuel-mix generation ranges between 1.1 and 3.2 years and illustrates that the proposed development will generate 31.8 years' worth of clean energy based on the maximum worst-case value.

1.8 Various conservative assumptions are included in the calculation thereby overestimating the impact to the peat. It is assumed that all peat is removed from the excavation areas of turbine foundations and no benefit is taken from reinstatement. In reality, large areas of the site will be reinstated immediately after construction, including some of the areas above foundations and any borrow pits used.

2. INTRODUCTION

2.1 This report outlines the total carbon balance for the proposed Upper Ogmore Wind Farm (consisting of 7 turbines), including the assumptions made for the calculations that have been undertaken. It has been produced to assist consultees with their review of the proposal's impact on the existing peat body within the proposed site, and to assess the impact in terms of carbon dioxide (CO_2) emissions against the total potential carbon savings attributed to the proposed development.

2.2 Accordingly, the carbon assessment for the proposed development was undertaken using Version 2.8.1 of the carbon calculator tool, produced by the Scottish Government. Where applicable, updated recommended values have been taken for the online tool which replaces this spreadsheet.[1]

2.3 Where relevant, use of the carbon calculator and the associated guidance[2] including 'Calculating Carbon Savings from Wind Farms on Scottish Peatlands – A New Approach' (Nayak *et al.*, revised December 2010) has been adhered to. In addition, the completion of the carbon balance assessment for the proposed development required input from hydrology, ecology and site investigation specialists to feed information into the carbon calculator.

2.4 In the calculation sheet, numbers representing the sources/comments for input values within the Core Input Data sheet of the tool have been placed into the 'Record source of data' column and are explained in Table 1.1 below:

Table 2.1 Source of Data

Number	Input	Source/Comment
1	Lifetime of windfarm	As per planning application
2	Turbine capacity	Site specific modelling
3	Capacity factor	Site specific modelling
4	Extra capacity required for back up	Default value
5	Additional emissions due to reduced thermal efficiency of the reserve generation	Default value
6	Type of peatland	Advised by Engineer
7	Average air temp. at site	Input not required for IPCC method of calculation (refer to 3.23)
8	Average depth of peat at site	Informed by site peat probing 02959D2102; Peat Depth Map

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[1] Available online from: http://informatics.sepa.org.uk/CarbonCalculator/ (last accessed 08/10/18)

[2] Available online from: http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings (last accessed 06/11/2012)

Number	Input	Source/Comment
9	C content of dry peat	Default values in online tool
10	Extent of drainage	Typical
11	Average water table depth	Input not required for IPCC method of calculation (refer to 3.23)
12	Dry soil bulk density	Default values in online tool
13	Time for generation of bog plants	Default values
14	Carbon accumulation due to C fixation by bog plants	Default values in online tool
15	Coal-fired emission factor	Default values in online tool
16	Grid mix emission factor	Default values in online tool
17	Fossil fuel mix emission factor	Default values in online tool
18	Foundation & Hard standing areas	Informed by site design
19	Length of floating roads	Informed by site design
20	Road width	Informed by site design
21	Length of excavated roads	Informed by site design
22	Average depth of peat excavated for road	Informed by site peat probing Figure 8.1 in Volume 3; Peat Depth Map
23	Length of rock filled roads	Rock filled roads not proposed for this application
24	Length of cable trenches	Cables to site below peat and so will result in no permanent displacement of peat
25	Additional Peat Excavation	Informed by site design - this includes the area of the substation and temporary construction compound / final energy storage system
26	Restoration of site after decommissioning	Although restoration will occur, this is neglected due to uncertainties

3. CONTRIBUTION TO CLIMATE CHANGE TARGETS: THE CARBON IMPACT OF THE WIND FARM

Wind Farm CO_2 Emission Savings

3.1 The amount of CO_2 emissions produced during energy production varies with the type of fuel used; therefore, the potential CO_2 savings from the proposed development depends on the type of fuel it replaces.

3.2 Wind farm CO_2 emissions savings over other types of generation (i.e. coal-fired, grid-mix, fossil fuel-mix) are calculated by multiplying the energy output of the wind farm development by the emissions factor of the other type of generation. The counterfactual emission factors for different energy generation sources is taken from the latest recommended values in the online calculator tool. The coal-fired and fossil fuel values originate from DUKES data[3]. The grid mix is taken from the list of emission factors used to report on greenhouse gas emissions by UK organisations published by DECC[4].

Table 3.1: Counterfactual emission factors

Fuel mix	Counterfactual emissions factor (t CO_2 MWh^{-1})
Coal-fired plant	0.918
Grid mix	0.28088
Fossil fuel mix	0.460

3.3 The net emissions of CO_2 of the proposed development is calculated by deducting the total CO_2 gains produced by improvement of the site from the total CO_2 emissions lost from construction of, and impacts on peat from, the individual elements of the proposed development (described in the following paragraphs). Then, the net CO_2 emissions lost figure is then divided by the wind farm CO_2 emissions savings over the other individual fuel types calculated, to reveal the payback time. It is considered that coal-fired and grid-mix emissions represent the best and worst-case scenarios respectively, and are reported at the end of each subsection, where applicable.

3.4 The expected potential annual energy output of the proposed development is 82,782 MWh yr-1(based on a 3.6MW turbine model at 37.5 % CF), with minimum and maximum potential outputs at 77,263 MWh yr-1 (3.6MW at 35% CF) and 88,301 MWh yr-1 (3.6 MW at 40% CF).

3.5 The carbon calculator reports the wind farm CO_2 emissions saving compared to those emissions from coal-fired, grid-mix and fossil-fuel electricity generation. Based on the expected annual energy output of the development (82,782 MW yr-1), the potential expected tonnes of CO_2 emissions saved per year over coal-fired electricity generation is 75,994 t CO_2; over grid-mix generation is 23,252 t CO_2 and over fossil-fuel mix is 38,080 t CO_2.

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[3] DBEIS, Digest of United Kingdom statistics 2018, Available online from: https://www.gov.uk/government/statistics/digest-of-uk-energy-statistics-dukes-2018-main-report (Last accessed 09/10/18)

[4] DBEIS, Conversion factors 2018, Available online from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018 (Last accessed 09/10/18)

Emissions due to Turbine Life

3.6 Energy is consumed and associated carbon dioxide (CO_2) emissions are released during manufacture of the turbine components, construction of the site (including site tracks and turbine foundations etc), and during the decommissioning of the development.

3.7 The energy costs of wind farms in Europe have been assessed in detail by a number of reports[5]. The carbon calculator combines findings from these reports to estimate the global direct and indirect use of manufacture, installation, operation, maintenance and decommissioning of wind farms. It estimates that the net lifetime energy use (electricity equivalent) can be determined with the following formula.

$$\text{Emissions } (tCO_2) = (934.35 \times \text{Turbine capacity (MW)}) - 467.55$$

3.8 The carbon calculator reveals an expected emissions figure of 20,411 tonnes of CO_2 (tCO_2) emitted due to the manufacture, construction and decommissioning of the turbines and foundations to be used in the proposed development.

Capacity required due to Back Up

3.9 In order to maintain security of supplies, a second-by-second balance between generation and demand must be maintained by the grid operators. It has been noted that the inherent variable nature of wind energy may affect this balance and therefore, a certain proportion of power is required to stabilise the supply to the customer. The electricity system however, is designed and operated in such a way as to cope with large and small fluctuations in supply and demand. No power station is totally reliable, and demand, although predictable to a degree, is also uncertain. Therefore, the system operator establishes reserves that provide a capability to achieve balance, given the statistics of variations expected over different time scales. The variability of wind generation is but one component of the generation and demand variations that are considered when setting reserve levels.

3.10 It should also be noted that an individual wind turbine will generate electricity for 70-85% of the time[6], and its electricity output can vary between zero and full output in accordance with the wind speed. However, the combined output of the UK's entire wind power portfolio shows less variability, given the differences in wind speeds over the country as a whole. Whilst the amount of UK wind generation varies, it rarely, if ever, goes completely to zero, nor to full output at the same time throughout the UK.

3.11 The extra capacity needed for back-up power generation is currently estimated to be 5% of the rated capacity of the wind plant if UK wind power contributes more than 20% to the National

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[5] Lenzen, M., Munksgaard, J. (2002). Energy and CO2 life-cycle analyses of wind turbines Review and applications. Renew. Energy. 26, 339-362.

Ardente, F., Beccali, M., Cellura, M. and Brano V.L. (2008). Energy performances and life cycle assessment of an Italian wind farm. Renewable and Sustainable Energy Reviews 12, 200-217.

Vestas (2005). Life cycle assessment of offshore and onshore wind power plants based on Vestas V90-3.0 MW turbines. Vestas Wind Systems A/S Alsvej 21, 8900 Randers, Denmark, https://www.vestas.com/~/media/vestas/about/sustainability/pdfs/lca_v90_june_2006.ashx .

[6] Available online from: https://www.renewableuk.com/page/WindTurbines (last accessed 09/10/18).

Grid[7]. In 2017 Renewable electricity represented 27.9 % of total generation[8]. In future, interconnectivity and an increase in energy storage may reduce this back up requirement.

3.12 This reserve energy represents the additional energy that could have been generated by the conventional generator, but was not specifically due to the need to hold that availability as reserve for wind. The remaining output of the conventional generators will therefore be delivered at lower efficiency as most conventional generators are designed to give maximum efficiency at maximum output. The additional carbon emissions due to backup power generation are therefore created due to the efficiency reduction between full output and reduced output to provide the same total energy. This depends on the type of generator used to provide the backup. Here it is assumed that fossil fuel provides the backup, although the payback time is calculated assuming the different counterfactual cases as before.

3.13 Accordingly, the carbon calculator assumes that backup is provided by a fossil fuel mix of energy generation and reveals an expected lifetime emissions figure of 17,771 tCO_2 due to the back-up.

Loss of Carbon Fixing Potential

3.14 Construction of the development will involve the installation of infrastructure such as turbine foundations, access tracks and hardstandings etc. Where vegetation and/or peat is removed or covered, the vegetation will no longer be able to photosynthesise and therefore, its ability to fix carbon will be lost. In addition, changes to drainage can have an effect on the vegetation of peatlands. Accordingly, the carbon calculator assumes that the carbon-fixing potential is lost from both the area occupied by infrastructure as well as areas affected by drainage.

3.15 The carbon calculator does assume a worst-case scenario of 100% coverage of bog plants in areas where the vegetation is removed through construction or drainage. In order to demonstrate a worst-case scenario of the development's impact on drainage of the carbon fixing potential, the extent of drainage around infrastructure is given as 10 m expected and 5 m and 15 m as minimum and maximum values respectively.

3.16 In accordance with the calculator's methodology, the total emissions attributable to the loss of carbon accumulation by bog plants is equivalent to 832 tCO_2 over the operational period of the wind farm. This emissions figure is based on a development footprint plus the area affected by drainage and assumes 100% mire habitat cover.

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[7] Dale, L., Millborrow, D., Slark, R. and Strbac, G. (2004) Total Cost Estimates for Large-Scale Wind Scenarios in UK, *Energy Policy*, 32, 1949-56. First published in *Power UK*, Issue 109, entitled: 'A shift to wind is not unfeasible'.

[8] DBEIS, Digest of United Kingdom statistics 2018, Available online from: https://www.gov.uk/government/statistics/digest-of-uk-energy-statistics-dukes-2018-main-report (Last accessed 09/10/18)

Loss of Carbon Dioxide from Removed Peat (Direct Loss)

3.17 Peat probing was undertaken at the Upper Ogmore site between 21 and 22 September 2017 by Ramboll. The findings of the surveys have been used to determine the baseline peat depths within the site boundaries. Following an update to the location of T3 further intrusive surveys and peat probing were undertaken between 4 and 10 June 2018 by RSK. The findings of these were used to create a Peat Depth Map; Figure 8.1 in Volume 3. Peat depths vary across the site but are generally quite thin. Thicker peat is found in a localised area close to the site entrance.

3.18 In the following calculations, the calculated areas and volume of peat affected by tracks and other infrastructure aim to represent a realistic worst case and assume the following:

- New roads include the running width of 4.5 m, shoulders of 0.25 m each side and additional width of 2.0 m to account for drainage.
- The site is divided into two areas for foundation inputs to represent the two hub height wind turbines being installed. Area 1 includes the three smaller turbines, whilst area 2 includes the four larger turbines. All other infrastructure requirements are the same across the site.
- Excavated area around turbine foundation assumes a 1:2 slope. This is conservative given the shallow depths to bedrock on the site but will allow for working area around the base.
- The area at the surface is limited by the proximity to the track and hardstanding (taken as 12m for the conservative case) as an overlap of these areas would be double counting. This is illustrated in Figure 3.1 displaying the expected values for area 2. Table 3.1 provides a summary of the dimensions used for area 1 and area 2.

Figure 3.1 Area 2 Foundation excavation dimensions

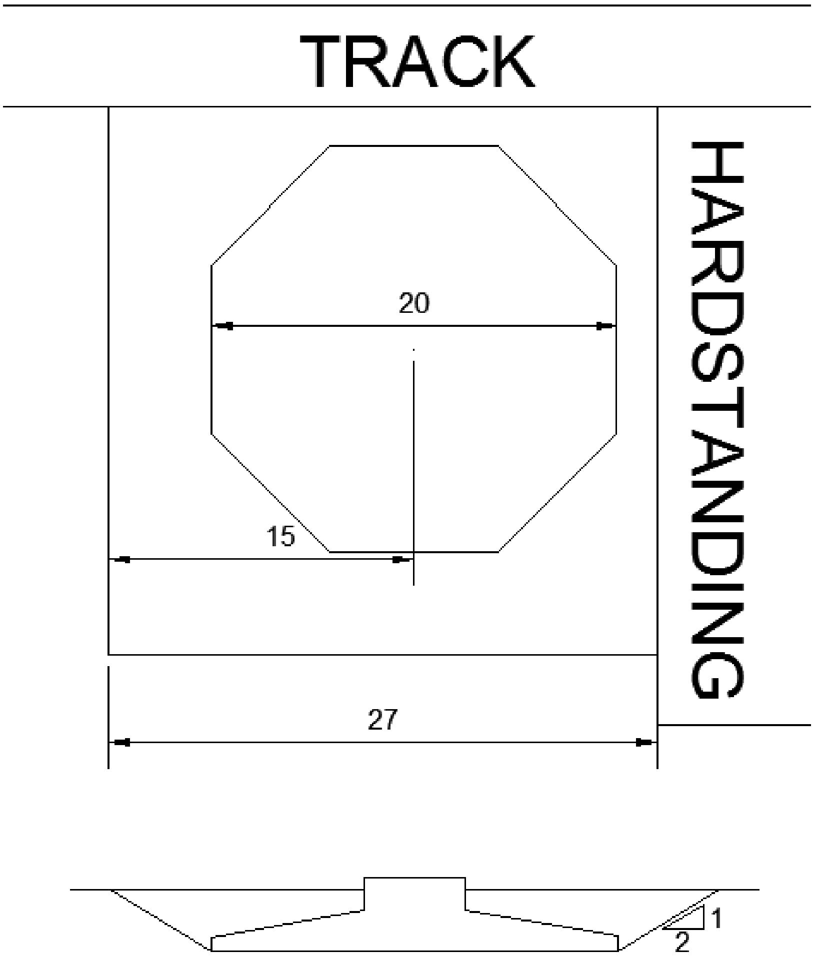

Table 3.1 Foundation excavation dimensions

Turbine Foundations	Area 1			Area 2		
	Expected value	Minimum value	Maximum value	Expected value	Minimum value	Maximum value
Width/length at base (m)	18	16	22	20	18	25
Depth of excavation (m)	3	2.5	3.5	3	2.5	3.5
Half width/length at surface (m)	15	13	18	16	14	19.5
Width/length at surface (m)	27	25	30	28	26	31.5

- Peat volume is modelled with vertical sides at the outer extent of the excavation.
- Borrow pits are excavated to their maximum extent.

3.19 No detailed analysis of peat samples has been performed for the site so values for the carbon content of dry peat (% by weight) and dry soil bulk density (g cm^{-3}) were taken from the latest online calculator tool.

3.20 The carbon calculator applies the full depth of excavation for turbine foundations to estimate peat removal for the turbine foundations and hardstandings. This has been corrected to use only the predicted peat depth at these locations.

3.21 The carbon calculator calculates the total volume of peat removed over the footprint of the wind farm to be 21,188 m^3. The total expected amount of direct CO_2 loss, attributable to peat removal is calculated to be 10,741 tCO_2.

Loss of Carbon Dioxide from Drained Areas left in Situ (Indirect Loss)

3.22 Carbon is also lost from peat habitats through drainage that occurs in the peat around the proposed development's infrastructure. The carbon calculator tool and associated guidance refers to this CO_2 loss as an "indirect loss". The extent of the site affected by drainage is calculated assuming an expected, minimum and maximum extent of drainage around each drainage feature e.g. turbine foundation, tracks etc. Although the extent of drainage is heavily dependent on topography, the analysis itself assumes relatively level terrain.

3.23 The carbon calculator tool calculates the area surrounding the wind farm infrastructure that is within the extent of drainage (10 m) and derives the CO_2 emissions resulting from this process. The total expected CO_2 loss from drained peat is 11,078 tCO_2. There are two calculations methods available. The IPCC default methodology[9] has been used which produces more conservative results than a site-specific calculation.

Loss of Carbon Dioxide from DOC and POC loss

3.24 Additional CO_2 emissions from organic matter can occur as carbon dioxide and methane can leach out of peat that is restored to conditions where the water table depth is higher after restoration than before restoration and is a further consideration of the carbon calculator. Dissolved Organic Carbon (DOC) is defined as the organic matter that is able to pass through a filter (range in size between 0.7 and 0.22 μm). Conversely, Particulate Organic Carbon (POC) is that carbon that is too large and is filtered out of a sample.

3.25 Only restored drained land has been included in the calculations within the carbon calculator for DOC and POC, because if the land is not restored then the carbon has already been lost for excavated peat.

3.26 The carbon calculator calculates that there will be no CO_2 lost due to DOC and POC leaching over the operational life of the wind farm.

Total Loss of Carbon Dioxide from Impact on Peat

3.27 The following calculations on total loss of CO_2 from the impact on peat have been based on a number of key assumptions (some of which are built into the tool itself), specifically in relation

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[9] IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol 3, table 5-13

to peat in order to demonstrate a worst-case scenario using on-site data with input from ecology and hydrology specialists. In summary, these assumptions are:

- 100% of the area potentially affected by the wind farm is covered in peat forming mire habitat;
- The terrain is relatively flat with no existing drainage;
- Infrastructure dimensions for foundations, tracks and hardstandings include working areas;
- 100% of the carbon stored in the excavated peat will be lost as carbon dioxide and not reinstated on site;
- 10 m expected average extent of drainage to demonstrate a conservative expected scenario.

3.28 The combined expected impact of the development on peat over the operational lifetime of the development is therefore calculated as:

Table 3.2 CO_2 Losses from impact on peat

	CO_2 from plants		CO_2 loss from removed peat		CO_2loss from drained peat
Loss tCO_2=	832 tCO_2	+	14,867 tCO_2	+	11,078 tCO_2
Total Loss tCO_2=			26,777 tCO_2		

4. CARBON GAIN DUE TO SITE IMPROVEMENT AND RESTORATION

4.1 Restoration of areas within the site can reverse emissions and act as carbon storage, reducing the total CO_2 emissions as a result of the development. For simplification however, no gains from restoration have been accounted for. Hydrology is a complex issue and it is difficult to determine the level of water increase across the site.

5. OVERALL CARBON BALANCE OF THE PROPOSED WIND FARM

5.1 The total emissions savings of CO_2 of the proposed development is calculated by comparing the emissions from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity, grid-mix or fossil fuel-mix. The results are summarised in table 5.1.

Table 5.1: Summary of the emission savings associated with the Proposed Upper Ogmore Wind Farm

	TOTAL EMISSIONS SAVINGS (tCO_2 eq)		
	Expected	Minimum	Maximum
Coal-fired electricity generation	2,594,827	2,438,415	2,723,858
Grid-mix electricity generation	748,855	715,508	754,821
Fossil fuel-mix electricity generation	1,267,832	1,199,886	1,308,396

5.2 The carbon calculator reports the wind farm CO_2 emissions saving compared to those emissions from coal-fired, grid-mix and fossil-fuel electricity generation. Based on the expected annual energy output of the development (82,782 MW yr-1), and the emissions associated with the development, the potential expected tonnes of CO_2 emissions saved per year over coal-fired electricity generation is 74,138 tCO_2; grid-mix generation is 21,396 tCO_2 and fossil-fuel mix is 36,224 tCO_2. Given that the total estimated CO_2 emissions for Bridgend local authority area was 822,500 t CO_2 in 2016[10], the expected potential CO_2 emissions savings from the wind farm could account for the equivalent of 9.0%, 2.6 % and 4.4% of the total annual CO_2 emissions estimate for Bridgend when compared against coal-fired, grid-mix and fossil-fuel mix electricity generation.

5.3 Table 5.2 and Figure 5.1 below outline the overall carbon payback time for the 7 turbines and associated infrastructure described in the preceding paragraphs. The net emissions of CO_2 of the proposed development is calculated by deducting the total CO_2 gains produced by improvement of the site from the total CO_2 emissions lost from construction of, and impacts on peat from, the individual elements of the proposed development (described in the following paragraphs). Then, the net CO_2 emissions lost figure is divided by the wind farm CO_2 emissions savings over the other individual fuel types calculated, to reveal the payback time. It is considered that fossil fuel-mix emissions represent the most likely scenario.

Table 5.2: Summary of the carbon payback time associated with the Proposed Upper Ogmore Wind Farm

	EMISSIONS PAYBACK TIME (YEARS)		
	Expected	Minimum	Maximum
Coal-fired electricity generation	0.9	0.5	1.6
Grid-mix electricity generation	2.8	1.8	5.2
Fossil fuel-mix electricity generation	1.7	1.1	3.2

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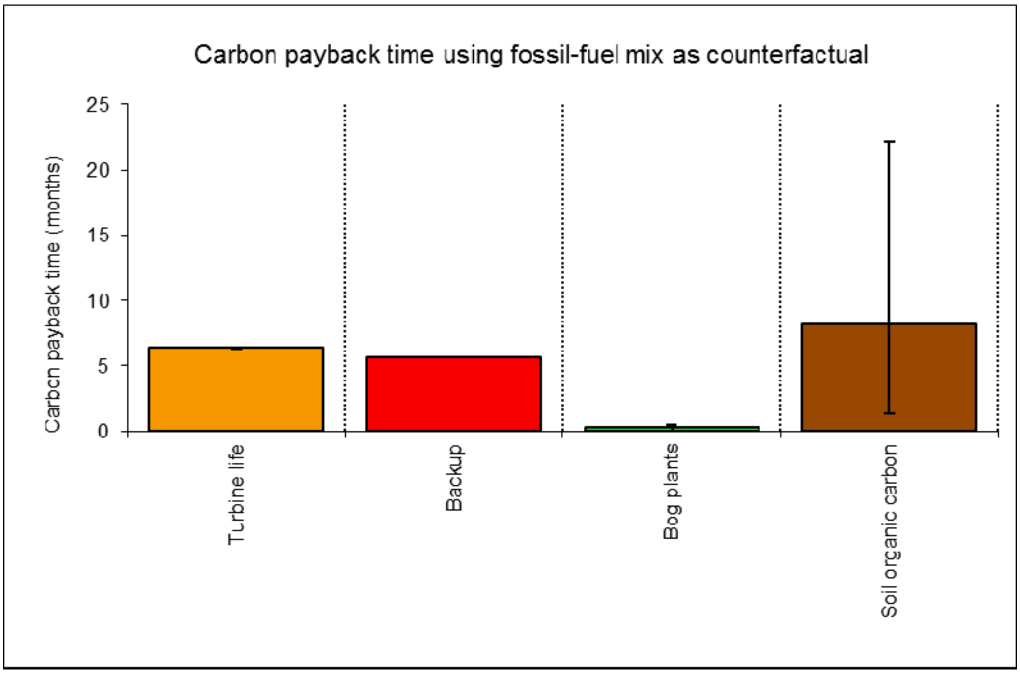
[10] 2005 to 2016 UK local and regional CO2 emissions, Available online from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/720677/2005-16_UK_local_and_regional_CO2_emissions.xlsx - Last accessed 09/10/18

Figure 5.1: Carbon payback time using fossil fuel mix as the counterfactual forProposed Upper Ogmore Wind Farm



5.4 The conclusion of the model reveals that the proposed wind farm will likely effectively pay back its expected carbon debt from manufacture, construction, impact on habitat and decommissioning within 1.7 years, if it replaces the fossil fuel electricity generation method. Based on the minimum and maximum scenarios, the analysis shows that the payback time for fossil fuel-mix generation ranges between 1.1 and 3.2 years and illustrates that the proposed development is likely to generate 31.8 years' worth of clean energy based on the maximum worst-case value.

ANNEX A: CORE INPUT DATA

Input data	Expected values		Possible range of values			
	Enter expected value here	Record source of data	Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	7		7		7	
Lifetime of windfarm (years)	35	1	35	1	35	1
Performance						
Power rating of turbines (turbine capacity) (MW)	3.6	2	3.6	2	3.6	2
Capacity factor	Direct input of capacity factor		Direct input of capacity factor		Direct input of capacity factor	
Enter estimated capacity factor (percentage efficiency)	37.5	3	35.0	3	40.0	3
Backup						
Extra capacity required for backup (%)	5	4	5	4	5	4
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	5	10	5	10	5
Carbon dioxide emissions from turbine life - (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	6	Acid bog	6	Acid bog	6
Average annual air temperature at site (^oC)		7		7		7
Average depth of peat at site (m)	0.30	8	0.20	8	0.40	8
C Content of dry peat (% by weight)	55.5	9	49	9	62	9
Average extent of drainage around drainage features at site (m)	10.00	10	5.00	10	15.00	10
Average water table depth at site (m)		11		11		11
Dry soil bulk density (g cm^{-3})	0.35	12	0.25	12	0.45	12
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	6	13	5	13	10	13
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	14	0.12	14	0.31	14
Forestry Plantation Characteristics						
Method used to calculate CO_2 loss from forest felling	Enter simple data		Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	0		0		0	
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	0.00		0.00		0.00	
Counterfactual emission factors						
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.918	15	0.918	15	0.918	15
Grid-mix emission factor (t CO_2 MWh^{-1})	0.28088	16	0.28088	16	0.28088	16
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.46	17	0.46	17	0.46	17
Borrow pits						
Number of borrow pits	2		0		2	
Average length of pits (m)	140		0		140	
Average width of pits (m)	140		0		140	
Average depth of peat removed from pit (m)	0.20		0.00		0.40	
Foundations and hard-standing area associated with each turbine		18		18		18
Method used to calculate CO_2 loss from foundations and hard-standing	Enter detailed information		Enter detailed information		Enter detailed information	
Please enter construction data in sheet: Construction input data						
Average depth of peat removed from turbine foundations (m)	0.20		0.10		0.40	
Average depth of peat removed from hard-standing (m)	0.20		0.10		0.40	
Access tracks						
Total length of access track (m)	4300	19	4085	19	4515	19
Existing track length (m)	0		0		0	
Length of access track that is floating road (m)	185	19	0	19	185	19
Floating road width (m)	7	20	7	20	7	20
Floating road depth (m)	0.20		0.00		0.30	
Length of floating road that is drained (m)						
Average depth of drains associated with floating roads (m)						
Length of access track that is excavated road (m)	4115	21	4085	21	4330	21
Excavated road width (m)	7	20	7	20	7	20
Average depth of peat excavated for road (m)	0.30	22	0.20	22	0.40	22
Length of access track that is rock filled road (m)	0	23	0	23	0	23
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)	0.00		0.00		0.00	
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)		24		24		24
Average depth of peat cut for cable trenches (m)						
Additional peat excavated (not already accounted for above)						
Volume of additional peat excavated (m^3)	1440	25	1440	25	1600	25
Area of additional peat excavated (m^2)	7200.0	25	7200.0	25	8000.0	25
Peat Landslide Hazard						
Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments						
Improvement of C sequestration at site by blocking drains, restoration of habitat etc		26		26		26
Improvement of degraded bog						
Area of degraded bog to be improved (ha)						
Water table depth in degraded bog before improvement (m)						
Water table depth in degraded bog after improvement (m)						
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)						
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)						
Water table depth in felled area before improvement (m)						
Water table depth in felled area after improvement (m)						
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)						
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)						
Water table depth in borrow pit before restoration (m)						
Water table depth in borrow pit after restoration (m)						
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)						
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)						
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)						
Water table depth around foundations and hardstanding after restoration (m)						
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)						
Restoration of site after decomissioning						
Will the hydrology of the site be restored on decommissioning?	No		No		No	
Will you attempt to block any gullies that have formed due to the windfarm?	No		No		No	
Will you attempt to block all artificial ditches and facilitate rewetting?	No		No		No	
Will the habitat of the site be restored on decommissioning?	No		No		No	
Will you control grazing on degraded areas?	No		No		No	
Will you manage areas to favour reintroduction of species	No		No		No	

Lookup tab

Choice of methodology for calculating emission factors	IPCC default

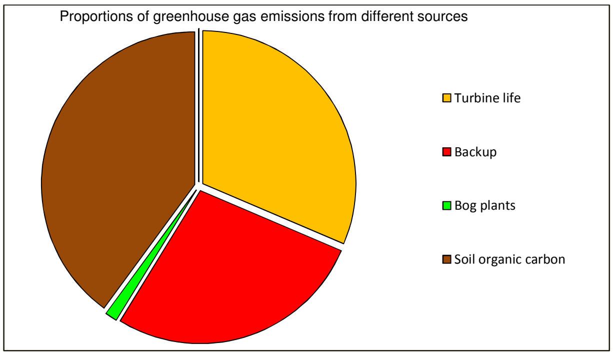
ANNEX B: CONSTRUCTION INPUT DATA

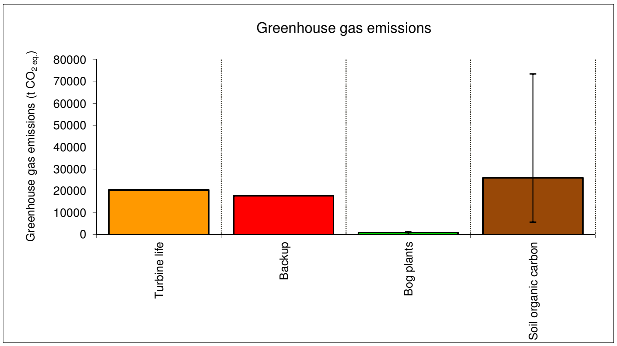
Input data	Expected values		Possible range of values			
	Enter expected value here ↓	Record source of data	Enter minimum value here ↓	Record source of data	Enter maximum value here ↓	Record source of data
Construction design **Note - total number of turbines already specified:**	**7**		**7**		**7**	
AREA 1						
Number of turbines in this area	3		3		3	
Turbine foundations						
Depth of peat removed when constructing foundations (m)	0.2		0.1		0.4	
Approximate geometric shape of hole dug when constructing foundations	Rectangular		Rectangular		Rectangular	
Length at surface (m)	27		25		30	
Width at surface (m)	27		25		30	
Length at bottom (m)	18		16		22	
Width at bottom (m)	18		16		22	
Hardstanding						
Depth of peat removed when constructing hardstanding (m)	0.2		0.1		0.4	
Approximate geometric shape of hole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular	
Length at surface (m)	41.5		36.5		41.5	
Width at surface (m)	26.5		21.5		26.5	
Length at bottom (m)	45.5		40.5		45.5	
Width at bottom (m)	30.5		25.5		30.5	
Piling						
Is piling used?	No		No		No	
Volume of Concrete						
Volume of concrete used (m^3)	350		300		400	
AREA 2						
Number of turbines in this area	4		4		4	
Turbine foundations						
Depth of hole dug when constructing foundations (m)	0.2		0.1		0.4	
Approximate geometric shape of hole dug when constructing foundations	Rectangular		Rectangular		Rectangular	
Length at surface (m)	28		26		31.5	
Width at surface (m)	28		26		31.5	
Length at bottom (m)	20		18		25	
Width at bottom (m)	20		18		25	
Hardstanding						
Depth of hole dug when constructing hardstanding (m)	0.2		0.1		0.4	
Approximate geometric shape of hole dug when constructing hardstanding	Rectangular		Rectangular		Rectangular	
Length at surface (m)	41.5		36.5		41.5	
Width at surface (m)	26.5		21.5		26.5	
Length at bottom (m)	45.5		40.5		45.5	
Width at bottom (m)	30.5		25.5		30.5	
Piling						
Is piling used?	No		No		No	
Volume of Concrete						
Volume of concrete used (m^3)	450		400		500	

ANNEX C: PAYBACK TIME AND C0$_2$ EMISSIONS

	Exp.	*Min.*	*Max.*
1. Windfarm CO_2 emission saving over…			
…coal-fired electricity generation (tCO_2 yr^{-1})	75994	70928	81060
…grid-mix of electricity generation (tCO_2 yr^{-1})	23252	21702	24802
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	38080	35541	40618
Energy output from windfarm over lifetime (MWh)	2897370	2704212	3090528
Total CO_2 losses due to wind farm (t CO_2 eq.)			
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	20411	20394	20428
3. Losses due to backup	17771	17771	17771
4. Losses due to reduced carbon fixing potential	832	181	1553
5. Losses from soil organic matter	25945	5705	73495
6. Losses due to DOC & POC leaching	0	0	0
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	64958	44051	113247
8. Total CO_2 gains due to improvement of site (t CO_2 eq.)			
8a. Gains due to improvement of degraded bogs	0	0	0
8b. Gains due to improvement of felled forestry	0	0	0
8c. Gains due to restoration of peat from borrow pits	0	0	0
8d. Gains due to removal of drainage from foundations & hardstanding	0	0	0
Total gains	0	0	0
Net Windfarm CO_2 emission saving over…			
…coal-fired electricity generation (tCO_2)	2594827	2438415	2723858
…grid-mix of electricity generation (tCO_2)	748855	715508	754821
…fossil fuel - mix of electricity generation (tCO_2)	1267832	1199886	1308396
…coal-fired electricity generation (tCO_2 yr^{-1})	74138	69669	77825
…grid-mix of electricity generation (tCO_2 yr^{-1})	21396	20443	21566
…fossil fuel - mix of electricity generation (tCO_2 yr^{-1})	36224	34282	37383

RESULTS	*Exp.*	*Min.*	*Max.*
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**64958**	**44051**	**113247**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.9	0.5	1.6
…grid-mix of electricity generation (years)	2.8	1.8	5.2
…fossil fuel - mix of electricity generation (years)	**1.7**	**1.1**	**3.2**
Ratio of soil carbon loss to gain by restoration (TARGET ratio (Natural Resources Wales) < 1.0)	**0.0**	**0.0**	**0.0**
Ratio of C emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	**6**	**4**	**10**





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