

Carbon Balance Report

Mynydd Maen Wind Farm

Ref 04412-6385505

Revision History

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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 wind farm site, and to assess the impact in terms of carbon dioxide (CO₂) emissions against the total potential carbon savings attributed to the proposed Mynydd Maen Wind Farm, hereafter referred to as the 'proposed wind farm'.
- 1.2 The carbon assessment for the proposed wind farm was undertaken using Version 2.8.1 of the Scottish Governments carbon calculator tool which is produced based on carbon calculator tool v1.7.0. 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 13turbine proposed wind farm is 192,851 MWh yr⁻¹, with minimum and maximum potential outputs at 161,960 MWh yr⁻¹ and 223,740 MWh yr⁻¹.
- 1.5 The wind farm CO₂ 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 CO₂ lost by the proposed wind farm is then divided by the wind farm CO₂ emissions savings over the other individual types of generation, to reveal the payback time for the proposed wind farm.
- 1.6 Based on the expected energy output of the proposed wind farm (192,851 MWh yr⁻¹), and the emissions associated with the proposed wind farm, the potential expected tonnes of CO₂ emissions saved per year over coal-fired electricity generation is 193,237 tCO₂; grid-mix generation is 37,294 tCO₂ and fossil-fuel mix is 83,312 tCO₂.
- 1.7 The conclusion of the carbon calculator reveals that the proposed wind farm would effectively pay back its expected carbon debt from manufacture, construction, impact on habitat and decommissioning within 1.3 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 0.9 and 3.1 years and illustrates that the proposed wind farm would generate 31.9 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 would be reinstated immediately after construction, including some of the areas above foundations and any borrow pits used. In addition, it is assumed that all excavations do not overlap other excavations. However, in reality excavations for turbine foundations, access tracks and hardstandings overlap each other resulting in a smaller excavation footprint.

2 Introduction

- 2.1 This Technical Appendix of the Environmental Statement (ES) evaluates the effects of the proposed wind farm (consisting of 13 turbines) on climate change and carbon balance, 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 (CO₂) emissions against the total potential carbon savings attributed to the proposed wind farm.
- 2.2 Accordingly, the carbon assessment for the proposed wind farm 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 from the online tool V1.7.0 which replaces this spreadsheet¹.
- 2.3 Where relevant, use of the carbon calculator and the associated guidance² 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 wind farm 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 2.1 below:

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	Met office website (Input not required for IPCC method of calculation though)
8	Average depth of peat at site	Informed by 04412-RES-STE-DR-PT-004; Peat Depth Plan

Table 2.1 Source Data

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¹ Available online from: <u>http://informatics.sepa.org.uk/CarbonCalculator/</u> (last accessed 24/01/2024) ² Available online from: <u>http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-</u> <u>sources/19185/17852-1/CSavings</u> (last accessed 24/01/2024)

Number	Input	Source/Comment
9	C content of dry peat	Default values in Windfarm Carbon Calculator Web tool guidance ³
10	Extent of drainage	Typical
11	Average water table depth	Input not required for IPCC method of calculation (refer to paragraph 3.22)
12	Dry soil bulk density	Default values in Windfarm Carbon Calculator Web tool guidance
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 04412-RES-STE-DR-PT-004; Peat Depth Plan
23	Length of rock filled roads	Rock filled roads not proposed for this application
24	Length of cable trenches	Allowance included in access tracks width.
25	Additional Peat Excavation	Informed by site design - this includes the area of the substation and temporary construction compound
26	Restoration of site after decommissioning	Although restoration will occur, this is neglected due to uncertainties

³ Available online from:

https://informatics.sepa.org.uk/CarbonCalculator/assets/Carbon_calculator_User_Guidance.pdf (last accessed 24/01/2024)

3 Contribution to Climate Change Targets: The Carbon Impact of the Wind Farm

Wind Farm CO₂ Emission Savings

- 3.1 The amount of CO₂ emissions produced during energy production varies with the type of fuel used; therefore, the potential CO₂ savings from the proposed wind farm depends on the type of fuel it replaces.
- 3.2 Wind farm CO₂ emissions savings over other types of generation (i.e. coal-fired, grid-mix, fossil fuelmix) 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 are taken from the online tool as were shown on the date visited (24th January 2024). Values for both coal-fired and fossil fuel-mix emission factors are confirmed from DUKES data for the UK which is published annually. The value for the grid-mix emission factor has been confirmed from the report on greenhouse gas emissions by UK organisations published by BEIS.

 Table 3.1: Counterfactual emissions factors

Fuel mix	Counterfactual emissions factor (tCO ₂ MWh ⁻¹)
Coal-fired plant	0.945
Grid mix	0.207
Fossil fuel mix	0.424

- 3.3 The net CO₂ emissions of the proposed wind farm are calculated by deducting the total CO₂ gains produced by improvement of the site from the total CO₂ emissions lost from construction of, and impacts on peat from, the individual elements of the proposed wind farm (described in the following paragraphs). The net CO₂ emissions lost figure is then divided by the wind farm CO₂ 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 wind farm is 192,851 MWh yr⁻¹(based on a 4.3 MW turbine model at 39.36 % CF), with minimum and maximum potential outputs at 161,960 MWh yr⁻¹ (4.3 MW at 33.05 % CF) and 223,740 MWh yr⁻¹ (4.3 MW at 45.66 % CF).
- 3.5 The carbon calculator reports the wind farm CO₂ 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 (192,851 MWh yr⁻¹), the potential expected tonnes of CO₂ emissions saved per year over coal-fired electricity generation is 182,244 tCO₂; over grid-mix generation is 39,920 tCO₂ and over fossil-fuel mix is 81,769 tCO₂.

Emissions due to Turbine Life

- 3.6 Energy is consumed and associated carbon dioxide (CO₂) 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 reports⁴. 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.

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

3.8 The carbon calculator reveals an expected emissions figure of 47,806 tonnes of CO₂ (tCO₂) emitted due to the manufacture, construction and decommissioning of the turbines and foundations to be used in the proposed wind farm.

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 would generate electricity for 70-80 % of the time⁵, 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 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 would therefore be delivered at lower

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.

Life Cycle Assessment of Electricity Production from an onshore V117-4.2 MW Wind Plant.

https://www.vestas.com/content/dam/vestas-com/global/en/sustainability/reports-andratings/lcas/LCA%20of%20Electricity%20Production%20from%20an%20onshore%20V11742MW%20Wind%20Plan tFinal.pdf.coredownload.inline.pdf.

⁴ Lenzen, M., Munksgaard, J. (2002). Energy and CO₂ life-cycle analyses of wind turbines Review and applications. Renew. Energy. 26, 339-362.

⁵Available online from: <u>https://www.edfenergy.com/energywise/all-you-need-to-know-about-wind-power</u> (last accessed 01/09/23).

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.

3.12 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 36,359 tCO₂ due to the back-up.

Loss of Carbon Fixing Potential

- 3.13 Construction of the proposed wind farm would 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 would no longer be able to photosynthesise and therefore, its ability to fix carbon would be lost. In addition, changes to drainage may 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.
- 3.14 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.
- 3.15 In accordance with the calculator's methodology, the total emissions attributable to the loss of carbon accumulation by bog plants is equivalent to 1,582 tCO₂ over the operational period of the proposed wind farm. This emissions figure is based on a development footprint plus the area affected by drainage and assumes 100 % mire habitat cover.

Loss of Carbon Dioxide from Removed Peat (Direct Loss)

- 3.16 Peat probing was undertaken at the site in November 2021 by SLR Consulting Ltd. The findings of the surveys have been used to determine the baseline peat depths within the site. Following this, phase two peat probing which focused on the proposed infrastructure (tracks, hardstandings, etc.) and the proposed turbine locations were undertaken in March 2023 by SLR Consulting Ltd. The findings of these were used to create a Peat Depth Plan (Figure 9.3 in Volume 3). Peat depths vary across the site but are generally quite thin.
- 3.17 In the following calculations, the calculated areas and volume of peat affected by tracks and other infrastructure aim to represent a worst case and assume the following:

New roads include the running width of 5 m, shoulders of 0.25 m each side and additional width of 5 m to account for drainage and cable trenches.

No overlaps of infrastructure's excavations are considered, and each element's excavation footprint have been assessed individually.

Excavated area around turbine foundation assumes a 1:2 slope. This is conservative given the shallow depths to bedrock on the site but would allow for working area around the base.

Table 3.1. Foundation excavation dimensions

	Expected value	Minimum value	Maximum value
Turbine Foundations			
Length at surface (m)	28	25	30
Width at surface (m)	28	25	30
Length at bottom (m)	18	16	22
Width at bottom (m)	18	16	22

Peat volume is modelled with vertical sides at the outer extent of the excavation.

Borrow pits are excavated to their maximum extent.

- 3.18 No detailed analysis of peat samples has been performed for the site so value for the carbon content of dry peat (% by weight) was taken from the latest online calculator tool and value of dry soil bulk density (g cm⁻³) was taken from the user guidance of Windfarm Carbon Calculator Web Tool.
- 3.19 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.
- 3.20 The carbon calculator calculates the total volume of peat removed over the footprint of the proposed wind farm to be 54,108.8 m³. The total expected amount of direct CO_2 loss, attributable to peat removal is calculated to be 13,485 tCO₂.

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

- 3.21 Carbon is also lost from peat habitats through drainage that occurs in the peat around the proposed wind farm's infrastructure. The carbon calculator tool and associated guidance refers to this CO₂ 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 foundations, tracks etc. Although the extent of drainage is heavily dependent on topography, the analysis itself assumes relatively level terrain.
- 3.22 The carbon calculator tool calculates the area surrounding the proposed wind farm infrastructure that is within the extent of drainage (10 m) and derives the CO₂ emissions resulting from this process. The total expected CO₂ loss from drained peat is 8,920 tCO₂. There are two calculation methods available.

The IPCC default methodology⁶ has been used in this assessment which produces more conservative results than a site-specific calculation.

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

- 3.23 Additional CO₂ 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 (ranging in size between 0.7 and 0.22 μm). Conversely, Particulate Organic Carbon (POC) is carbon that is larger and so is filtered out of a sample.
- 3.24 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 in excavated peat.
- 3.25 The carbon calculator calculates that there would be no CO_2 lost due to DOC and POC leaching over the operational life of the proposed wind farm.

Total Loss of Carbon Dioxide from Impact on Peat

- 3.26 The following calculations of the total loss of CO₂ 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 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 proposed 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 would be lost as CO₂ and not reinstated on-site;
 - 10 m expected average extent of drainage to demonstrate a conservative expected scenario.
- 3.27 The combined expected impact of the proposed wind farm on peat over the operational lifetime is therefore calculated as:

Table 3.2 CO₂ Losses impact on peat

	CO2 from plants	+	CO ₂ loss from removed peat	+	CO ₂ loss from drained peat
Loss tCO ₂ =	1,582 tCO ₂	+	13,485 tCO ₂	+	8,920 tCO ₂

⁶ IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol 3, table 5-13

Total Loss	23,987 tCO ₂
tCO ₂ =	23,967 1002

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 CO₂ emissions as a result of the proposed wind farm. 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 CO₂ of the proposed wind farm is calculated by comparing the emissions from the site due to the proposed wind farm with the carbon-savings achieved by the proposed wind farm while displacing electricity generated from coal-fired capacity, grid-mix or fossil fuel-mix. The results are summarised in Table 5.1.

	TOTAL EMISSIONS	SAVINGS (tCO2 eq)	
	Expected	Minimum	Maximum
Coal-fired electricity generation	6,270,405	5,271,006	7,185,811
Grid-mix electricity generation	1,289,055	1,087,579	1,406,606
Fossil fuel-mix electricity generation	2,753,761	2,317,665	3,105,912

Table 5.1: Summary of the emission savings associated with the proposed Mynydd Maen Wind Farm

- 5.2 The carbon calculator reports the wind farm CO₂ 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 proposed wind farm (192,851 MW yr⁻¹), and the emissions associated with it, the potential expected tonnes of CO₂ emissions saved per year over coal-fired electricity generation is 179,154 tCO₂; grid-mix generation is 36,830 tCO₂ and fossil-fuel mix is 78,679 tCO₂. Given that the total estimated CO₂ emissions for the Caerphilly local authority area was 643,500 tCO₂ in 2020⁷, the expected potential CO₂ emissions savings from the proposed wind farm could account for the equivalent of 27.8 %, 5.7 % and 12.2 % of the total annual CO₂ emissions estimate for Caerphilly 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 proposed 13 turbines and associated infrastructure described in the preceding paragraphs. The net CO₂ emissions of the proposed wind farm are calculated by deducting the total CO₂ gains produced by improvement of the site from the total CO₂ emissions lost from construction of, and impacts on peat from, the individual elements of the proposed wind farm (described in the following paragraphs). Then, the net CO₂ emissions lost figure is divided by the proposed wind farm CO₂ 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.

 ⁷ 2005 to 2016 UK local and regional CO2 emissions, Available online from: <u>https://www.infobasecymru.net/IAS/themes/environmentandsustainability/environment/tabular?viewId=5</u>
 <u>18&geoId=1&subsetId</u> - Last accessed 04/09/23

Table 5.2: Summary of	the carbon	payback tim	e associated	with	the proposed	Mynydd Maen	Wind
Farm							

	EMISSIONS PAYBA	CK TIME (YEARS)	
	Expected	Minimum	Maximum
Coal-fired electricity generation	0.6	0.4	1.4
Grid-mix electricity generation	2.7	1.9	6.4
Fossil fuel-mix electricity generation	1.3	0.9	3.1

Figure 5.1: Carbon payback time using fossil fuel mix as the counterfactual for Proposed Mynydd Maen Wind Farm



Carbon payback time using fossil-fuel mix as counterfactual

5.4 The conclusion of the model reveals that the proposed wind farm would likely effectively pay back its expected carbon debt from manufacture, construction, impact on habitat and decommissioning within 1.3 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 0.9 and 3.1 years and illustrates that the proposed wind farm is likely to generate 31.9 years' worth of clean energy based on the maximum worst-case value.

Annex A: Core Input Data

Inter any or any o		Expected values	Record source	Enter minimum value here	Record source	Enter maximum value here	R s
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	Dimensions	12		12		12	Г
	ifetime of windfarm (years)		1		1		
			2	4.3	2	4.3	
	Japacity lactor		_				
	Backup						
	additional emissions due to reduced thermal efficiency of the						
	Carbon dioxide emissions from turbine life -	1	J				
	3g. manufacture, construction, decommissioning)						L
		Acid bog 🔽	6	Acid bog 🔻	6	Acid bog 🔻	H
	werage annual air temperature at site (°C)	10.94	7	7.44	7	12.8	
Anome of the set of t	Content of dry peat (% by weight)	53.23		19.57	9	64.28	
Dyy allow lawy gray 0.13 10 0.07 10 5 10 0.07 The regule of Constrained of Lapid allow law of Lapid a		10.00		5.00		15.00	
The negative for segmention of big sints that restortion Consequention for segmention of big sints that restortion (a) 25 - 4 - 4 - 4 - 4 - 4 - 4 - 4 - 4 - 4 -	Dry soil bulk density (g cm ⁻³)	0.13		0.07		0.29	
Construction and it for 1/2 / 1000 100 100 100 100 100 100 Marced relation for the factor of the factor	ime required for regeneration of bog plants after restoration	7	13	5	13	10	T
Lath II (1) Lath II (2) Lath II (2) <thlath (2)<="" ii="" th=""> <thlath (2)<="" ii="" th=""></thlath></thlath>	Carbon accumulation due to C fixation by bog plants in undrained						
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Function on the data material scale and back back back back back back back back	verage width of pits (m)	78		0		78	
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standing peaks enter construction data in sheet: Construction input data Average droch of peak removed from tachine foundations (m) 23 201 201 20 Average droch of peak removed from tachine foundations (m) 0.33 0 0.19 0.5 0.0 Average droch of peak removed from tachine foundations (m) 0.25 0 0.55 0.0 Total length of access tack including junctions as tack kinght(m) 0.008 19 0.055 0.0 <td>Nethod used to calculate CO2 loss from foundations and hard-</td> <td>Enter detailed information</td> <td></td> <td>Enter detailed information</td> <td></td> <td>Enter detailed information</td> <td>ſ</td>	Nethod used to calculate CO2 loss from foundations and hard-	Enter detailed information		Enter detailed information		Enter detailed information	ſ
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Annex B: Construction Input Data

	Expected values	Expected values			Possible range of values				
		Record			Record				
Input data	Enter expected value here	source	Enter minimum value here	source	Enter maximum value here	Record source			
		of data		of data		of data			
Construction design	▼	_	*	_	•				
Note - total number of turbines already specified:	13		13		13				
AREA 1	10				10				
Number of turbines in this area	13		13		13				
Turbine foundations									
Depth of peat removed when constructing foundations (m)	0.3		0.2		0.5				
Approximate geometric shape of hole dug when constructing	Rectangular 🗸 🗸		Rectangular 🗸 🗸		Rectangular 🛛 🗸 🗸				
foundations									
Length at surface (m)	28		25		30				
Width at surface (m) Length at bottom (m)	28 18		25 16		30 22				
Width at bottom (m)	18		16		22				
Hardstanding	10		10		<i>LL</i>				
Depth of peat removed when constructing hardstanding (m)	0.3		0.2		0.5				
Approximate geometric shape of hole dug when constructing	Rectangular		Rectangular		Rectangular				
hardstanding	, and the second s				gam.				
Length at surface (m)	52		47		57				
Width at surface (m)	34.5		32		37				
Length at bottom (m)	56		51		61				
Width at bottom (m)	38.5		36		41				
Piling	No 🔻		No		No 🔻				
Is piling used?	NO V				NO				
Volume of Concrete	5200		4550		5850				
Volume of concrete used (m ³)	3200		4330		3830				
AREA 2									
Number of turbines in this area									
Turbine foundations									
Depth of hole dug when constructing foundations (m)			_						
Approximate geometric shape of hole dug when constructing foundations	▼		▼		▼				
Length at surface (m)									
Width at surface (m)									
Length at bottom (m)									
Width at bottom (m)									
Hardstanding									
Depth of hole dug when constructing hardstanding (m)									
Approximate geometric shape of hole dug when constructing			-		-				
hardstanding									
Length at surface (m)									
Width at surface (m)									
Length at bottom (m)									
Width at bottom (m) Piling									
Is piling used?	-		-		-				
Volume of Concrete									
Volume of concrete used (m ³)									

Annex C: Payback Time and CO₂ Emissions

	Exp.	Min.	Max.
1. Windfarm CO ₂ emission saving over…			
coal-fired electricity generation (tCO ₂ yr ⁻¹)		153052	211434
grid-mix of electricity generation (tCO ₂ yr ⁻¹)	39920	33526	46314
fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)		68671	94866
Energy output from windfarm over lifetime (MWh)	6749796	5668600	7830900
Total CO ₂ losses due to wind farm (t CO ₂ eq.)			
Losses due to turbine life (eg. manufacture,	47806	47599	48012
construction, decomissioning)			
3. Losses due to backup		36359	36359
Losses due to reduced carbon fixing potential		393	2918
5. Losses from soil organic matter		1470	127100
6. Losses due to DOC & POC leaching		0	0
7. Losses due to felling forestry		0	0
Total losses of carbon dioxide	108152	85821	214390
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
8c. Gains due to restoration of peat from borrow pits	0	0	0
8d. Gains due to removal of drainage from foundations	0	0	0
& hardstanding	Ů	0	0
Total gains	0	0	0
Net Windfarm CO ₂ emission saving over…			
coal-fired electricity generation (tCO ₂)	6270405	5271006	718581
grid-mix of electricity generation (tCO ₂)	1289055	1087579	140660
fossil fuel - mix of electricity generation (tCO ₂)	2753761	2317665	310591
coal-fired electricity generation (tCO ₂ yr ⁻¹)	179154	150600	205309
grid-mix of electricity generation (tCO ₂ yr ⁻¹)		31074	40189
fossil fuel - mix of electricity generation (tCO ₂ yr ⁻¹)		66219	88740
RESULTS			
	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO _{2 eq} .)			
	108152	85821	214390
Carbon Payback Time			
coal-fired electricity generation (years)	0.6	0.4	1.4
grid-mix of electricity generation (years)	2.7	1.9	6.4
fossil fuel - mix of electricity generation (years)		0.9	3.1
Ratio of soil carbon loss to gain by restoration	0.0	0.0	0.0
(TARGET ratio (Natural Resources Wales) < 1.0)	0.0	0.0	0.0
Ratio of C emissions to power generation (g / kWh)			





