

Appendix 10.4

Hydrology, Geology and Hydrogeology

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A10.4 CARBON BALANCE ASSESSMENT

Introduction

- A10.4.1 This report has been prepared by Natural Power Consultants and describes the carbon balance assessment undertaken for Y Bryn Wind Farm (hereafter known as the proposed development) which consists of 18 turbines and ancillary infrastructure¹. This report presents the carbon balance findings for the proposed development and has been produced to assist consultees with their review of the proposed development's impact on peat and to assess the impact in terms of carbon dioxide (CO₂) emissions against the total potential carbon savings attributed to the proposed development.
- A10.4.2 This report should be read in conjunction with the Hydrology, Geology, and Hydrogeology (Chapter 10), Ecology (Chapter 6), Forestry (Chapter 13) and Project Description (Chapter 5) chapters and relevant appendices of the Environmental Statement (ES) which describe the proposed development in more detail and provide important information on the peat resource within the area.

Scope

- A10.4.3 In the UK, Scotland is at the forefront in terms of providing a guidance framework through which the impact of development upon peatlands can be minimised. The carbon balance assessments make use of the carbon calculator tool² which is currently the best method to date to undertake this kind of assessment and is endorsed by the Scottish Environment Protection Agency (SEPA) and the Scottish Government.
- A10.4.4 The carbon balance assessment has been undertaken in accordance with guidance³ Calculating Carbon Losses & Savings from Wind Farms on Scottish Peatlands – Technical Note 2.10.0'. As well as Technical Note 2.10.0⁴, this report has been produced giving consideration to the following guidance documents:
- D.R.Nayak *et al.* Calculating Carbon Budgets of Wind Farms in Scottish Peatlands (2010).
 - Calculating carbon savings from wind farms on Scottish peat lands - A New Approach by Nayak *et al.*, (2010)
 - Smith *et al.* Carbon Implications Of Windfarms Located On Peatlands – Update Of The Scottish Government Carbon Calculator Tool (2011).
 - Scottish Natural Heritage: Carbon rich soil, deep peat and priority peatland habitats map (2016)
 - CCW Guidance Note: Assessing the impact of windfarm developments on peatlands in Wales (Jan 2010).

- NRW Unified Peat Map of Wales in DataMap Wales.⁵
- Natural England Commissioned Report: Investigating the impacts of windfarm development on peatlands in England (Jan 2010).
- Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste. Scottish Renewables (2014).
- Lindsay, R. Peatlands and Carbon: a critical synthesis to inform policy development in peatland conservation and restoration in the context of climate change (2010).
- Scottish Government, SNH and SEPA - Peatland Survey - Guidance on Developments on Peatland – 2017.

- A10.4.5 In addition, advice from the authors of the carbon calculator tool sought for previous assessments has been used again here and the completion of the carbon balance assessments for the proposed development required input from hydrology, peat, ecology and design specialists.
- A10.4.6 Version v1.8.0 of the carbon calculator is currently the latest version of the online tool available (as of 11/12/2023).⁶ The inputs from the online carbon calculator tool run are presented at the end of this Appendix in Annex A (Reference: MXMS-GE1K-64EN v21). As the online tool does not allow any amendments to functionality and cannot be changed, the carbon balance assessment was undertaken subject to the specifications that the tool dictates. The tool does not currently allow users to describe the sources of the input data or the detailed information that is inserted to conduct the analysis. Therefore, Table A10.4.1 presents this source information for the assessment. The data and infrastructure dimensions used have been based on the best data available at the time and, in cases where infrastructure design or construction methods were not yet clear, the worst case values were used to ensure that the assessment presented a worst case scenario in any areas of uncertainty. This carbon balance assessment is based on the data and infrastructure dimensions that reflect the final design of the proposed development, as far as is possible, as provided by Y Bryn Wind Farm Limited (the applicant).
- A10.4.7 It is important to highlight that the assessment used a robust and comprehensive peat depth dataset that was collected during the earlier stages of the design and which provide a fair representation of peat depths across the proposed development area. Working areas and drainage/cable trench areas have also been included within the infrastructure dimensions to attempt to account for any damage/disturbance to peat over and above peat removal within these additional areas hence, some of the infrastructure dimensions may vary slightly to those presented in Chapter 5: Project Description as dimensions also include working and disturbance areas.
- A10.4.8 Therefore, the assessment has used a robust and comprehensive peat depth dataset that was collected in accordance with consultation advice and design work for the proposed development

¹ To note, the proposed battery storage facility isn't included in the assessment as its location will be within the proposed compound and therefore has already been considered in the overall carbon balance assessment. Any carbon balance benefits of its operation, supporting and/or effectively providing "back-up" for the wind farm element or otherwise serving to enable greater decarbonisation of the grid, have not been captured, and so this leads to the assessment here being worst-case.

² Available at: <https://informatics.sepa.org.uk/CarbonCalculator/> [Accessed 15/12/2023]

³ Available at: <http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCguidance2-10-0> [Accessed 15/12/2023]

⁴ Available at: <http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCguidance2-10-0> [Accessed 15/12/2023]

⁵ Available at: <https://datamap.gov.wales/maps/new#/> [Accessed 15/12/2023]

⁶ Available at: <https://informatics.sepa.org.uk/CarbonCalculator/index.jsp> [Accessed 15/12/2023]

and which provides a fair representation of peat depths across the site as well as under the final layout infrastructure, as described in Chapter 10: Hydrology, Geology and Hydrogeology.

Table A10.4.1: Record of source of data

Input	Source of Information
Turbine capacity and lifespan	The applicant Up to 18 turbines, each with a rated output of up to 7.2 MW (minimum scenario 6 MW). Fixed lifespan of the turbines is expected to be up to 50 years.
Capacity factor	Department for Energy Security and Net Zero (DESNZ) Welsh onshore wind average of 2018-2022 data with minimum and maximum average annual values across this period (Energy Trends September 2023, Table 6.1 Renewable electricity capacity and generation, Wales Qtr dataset). A full year's data for 2023 is not yet available. Load factor statistics obtained from: Energy Trends: UK renewables - GOV.UK (www.gov.uk) (accessed on 08/12/2023). It is important to note that the capacity factors used here will not typically reflect the final capacity factor of the proposed development and are much lower than energy yield assessments for this proposed development and candidate turbines indicate. The actual capacity factor would be anticipated to be greater, as modern turbines are more efficient and taller than many of the older turbines on operational wind farms where the BEIS data is derived from.
Fraction of output to backup	The extra capacity that would be needed for back-up power generation is currently estimated at 5% of the rated capacity of wind plant as UK wind power regularly contributes more than 20% of demand (this includes offshore and onshore wind) ⁷ .
Type of peatland	Ecology and Hydrology Departments, Natural Power Consultants Ltd. In the tool, the choice of peatland habitats is limited to acid bog or fen. Information on the proposed development soils has been obtained from UK Soil Observatory (UKSO) ⁸ . The mapper indicates that the dominant soil types are very acid/loamy soils with a wet peaty surface, freely draining acid loamy soils and slowly permeable wet very acid soils with a peaty surface. The quality of the soils has been affected by the existing land use, including productive forestry and associated ridges and furrows as well as artificial drainage ditches to dry the soils. Through a combination of probing and coring it is found that the site is predominantly underlain by soils with a peat content. There is a very limited presence of peat on site, and there is extremely limited presence of peat ≥0.5 m. Where this deepest peat is present, it is situated away from areas of infrastructure and is predominantly confined to the areas of the brown peat found on the upland plateau. Peat depths are also consistently shallow, mostly ≤0.3 m and almost entirely <0.5 m.

⁷ Available at: <https://www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021> [Accessed 15/12/2023]



Input	Source of Information
	In summary, although the phase 1 and phase 2 peat surveys indicated minimal areas of deep peat within the site boundary, for completeness however, this carbon balance assessment was undertaken.
Average air temp. at the proposed development area	Area specific temperature based on 29 years (1991-2020) data collected from the closest Met office weather station to the proposed development. The Tredegar Climate Station is positioned approximately 33.8 km from the proposed development and at 324 m above ordnance datum, remains at a comparable altitude giving a good idea of temperature and rainfall totals expected at the proposed development area. The expected value is the average annual temperature over the years. The minimum value is the minimum average annual temperature and maximum value is the maximum average annual temperature. https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/qcjjww0udy [Accessed 15/12/2023].
Average depth of peat on the proposed development area	Hydrology Department, Natural Power Consultants Ltd. Informed by peat probe data collection. The average of all the peat probe data collected across the proposed development area during the 100 m grid sampling. It was considered that the 100 m grid data was more appropriately used for this parameter as it covered the whole of the proposed development area whereas the more detailed grid data focussed on infrastructure areas only where deeper peat was encountered as agreed with NRW. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95% confidence intervals of the sample data collected.
Carbon content of dry peat	MATtest results November 2021 – see Annex B at the end of this document Eight peat cores were collected from the proposed development area where the deepest peat depths were found during surveys. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value (11.53), and the minimum(10.13) and maximum values(12.93) represent the lower and upper bound values of the 95% confidence intervals of the sample data collected. These levels were outside the tolerance of the tool (between 19 and 65) therefore 19 was inserted for expected, minimum and maximum scenarios.
Extent of drainage	Hydrology Department, Natural Power Consultants Ltd. Based on proposed development area observation, literature review and previous experience on similar, upland partially forested sites.
Average water table depth	Hydrology Department, Natural Power Consultants Ltd. These values are based on water table depth observations across the proposed development area during site visits, results of dip well monitoring reported by

⁸ UKSO (2018). *UK Soil Observatory map viewer*. [Online]. Available at: <https://mapapps2.bgs.ac.uk/ukso/home.html> [Accessed 15/12/2023]

Input	Source of Information
	Holden <i>et al.</i> 2011 ⁹ , and previous experience on similar upland partially forested sites.
Dry soil bulk density	MAT test Limited results November 2021 – see Annex C at the end of this document Site survey guidance provides details on how dry bulk density is measured and where possible, site-specific dry bulk density values should be used. Density was determined using the eight samples analysed at the laboratory which provided a value for dry soil bulk density. The arithmetic mean was calculated from this data to represent the ‘expected’ value, and the minimum and maximum values represent the lower and upper bound values of the 95% confidence intervals of the sample data collected. However, these values were outside the tolerance of the tool (between 0.05 and 0.3) therefore 0.3 (and 0.29 in minimum scenario) was inserted for expected and maximum scenarios.
Time for regeneration of bog plants	Ecology and Hydrology Departments, Natural Power Consultants Ltd. The period for successful re-vegetation in areas of disturbed peat will be dependent on a wide range of variables. Most importantly protection and stabilisation of bare peat, peat depth, condition and wetness, seed source, slope, altitude, and the degree of grazing and trampling pressure. Vegetation recovery on disturbed peat can be encouraged by protection with suitable vegetated turves and the application of an appropriate nurse seed mix and heather brash / seed as soon as possible following construction. Around infrastructure the local hydrology is usually altered due to the deep excavations. Therefore, unless peat of over 1 m depth is consolidated (which is not considered the case for this site) and high water level maintained, then the result is likely to be a form of wet heath, or potentially a drier heath, rather than bog vegetation. The extent of dwarf-shrub cover will also be heavily influenced by grazing pressure. In this case, the period for appreciable cover of bog plants, assuming suitable conditions are maintained in the peat body, has been estimated to be 10 years (2 years minimum and 20 years maximum). Achieving some cover of wet heath/bog plants within 2 years and complete cover of wet heath/bog vegetation within 20 years. Data is based on that provided in IUCN peatlands restoration review. ¹⁰ However, timescale for successful recovery to a natural assemblage of peatland plant species is dependent on numerous factors including slope, seed source, connectivity to similar habitats, the level of herbivore grazing and the successful stabilisation of the water level in the restoration area. The proposed restoration area is currently forested and so felling method and post-felling management shall also affect restoration. Ditch blocking can result in rapid (1 year), but localised, improvements in water levels but a more precautionary 2 years is used here as minimum timescale for positive change. Although it would be hoped that evidence of peatland vegetation recovery would be detectable within a 10 year period, it may be a prolonged timescale (20 years) before peat stabilisation and biodiversity

⁹ Holden, J., Wallage, Z.E., Lane, S. N. and McDonald, A. T. (2011). Water table dynamics in undisturbed, drained and restored blanket peat. *Journal of Hydrology* **402**, 103-114.

Input	Source of Information
	benefits are realised. The timescales provided are based on the professional experience of the project ecologists.
Carbon accumulation due to Carbon fixation by bog plants	Values have been taken from the guidance notes of the carbon calculator tool that quote published primary literature and Scottish Natural Heritage/NatureScot guidance values.
Area of forestry plantation to be felled	Woodland Chapter 13: Forestry of the ES concludes that the impact of the proposed development on forestry is insignificant with tree felling minimised to areas which are equivalent or similar in size to areas felled by NRW as land manager under normal forest management. Of the total felling area of 119.24 ha, approximately 14.48 ha will be returned to NRW management after construction of the wind farm and will therefore, be available for replanting with forest trees. This is illustrated on Figure 13.7. These areas will be replanted and continue as a normal component of the forest and FRP. Forest design principles, habitat gains and landscaping may require modification of the replanting plan from that in the approved FRP. Any change necessary will be led by NRW requirements. Replanting around infrastructure will be defined after the proposed development is constructed. Forest areas cleared for the purpose of the proposed development which are not required to be kept clear for the operation of the wind farm will be replanted. The resulting net loss of forest land for the wind farm is 104.76 ha and this is entered in the expected scenario. Minimum and maximum scenarios are +/- 10% of the expected value. A commitment has been made for compensatory planting (see Chapter 13) however a precautionary and worst case approach is provided here as the compensatory planting is likely to be offsite.
Coal-fired emission factor	Fixed value of the carbon calculator tool.
Grid mix emission factor	Fixed value of the carbon calculator tool.
Fossil fuel mix emission factor	Fixed value of the carbon calculator tool.
No. of borrow pits and dimensions	Construction Team, Natural Power Consultants Ltd Six borrow pits within proposed development. The total area for all borrow pits is estimated to be 84,235 m ² , therefore area divided by 6 to give average area per borrow pit of 14,093 m ² . Min and max values are +/- 10%.
Average depth of peat removed from turbine foundations, hard	Informed by 100 m grid and detailed peat probe data (i.e. Phase 1 and 2 peat surveys). Over 2400 probes were collected within the proposed development area. These values are derived from interrogation of the peat depth data collected underlying each type of infrastructure

¹⁰ Available at: <https://www.iucn-uk-peatlandprogramme.org/sites/default/files/header-images/Peatland%20Code/Peatland%20Code%20v1.2.%202022.pdf> [Accessed 15/12/2023]

Input	Source of Information
standing and borrow pits	As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95% confidence intervals of the sample data collected.
No. of foundations/ hardstandings and dimensions	Design Team, Natural Power Consultants Ltd The foundations will be made from reinforced concrete, delivered to the proposed development Area. Assume a circular shape with 33 m diameter for those turbines at 250 m tip, 31 m for those 230 m to tip, and 29 m for those 206 m to tip. These are considered representative of turbines of these sizes however this is indicative only. An average value (dependent on number of turbines at each size) of 30.5 m is used. The value inserted into the tool allow for excavation areas, working areas (10 m) and min and max are based on 29 m foundation and 33 m foundation respectively. Dimensions for hardstanding considers the permanent crane hardstanding area, 40 m x 35 m in the expected scenario and +/-10% for min and max values. Working area not included as they included in temporary laydown area.
Volume of concrete	Construction Team, Natural Power Consultants Ltd 18 turbine foundations, $18 \times 1200 \text{ m}^3 = 21,600 \text{ m}^3$, 2 meteorological mast = $2 \times 200 = 400 \text{ m}^3$ and substation 120 m^3 in the expected scenario. +/- 10% for min and max values and substation 90 m^3 min, 400 m^3 max.
Total length of track	Construction Team, Natural Power Consultants Ltd Total track length is 21,514 m comprised of 8,934 m of new excavated road and 12,580 m of existing track requiring upgrade. The minimum and maximum scenarios are +/- 10% of the expected value as the tool does not allow the same value to be inserted into all three scenarios.
Length of floating roads	Construction Team, Natural Power Consultants Ltd No floating road required.
Excavated road length	Construction Team, Natural Power Consultants Ltd As the tool does not allow specific inputs for upgraded tracks, this value includes the 8,934 m of proposed 'new' track as well as the 12,580 m of tracks to be 'upgraded' and the values for excavated road widths and peat depths for both are weighted according to the different lengths for new and upgraded tracks. +/- 10% of the expected value as the tool does not allow the same value to be inserted into all three scenarios.
Excavated road width	Construction Team, Natural Power Consultants Ltd See Paragraph A10.4.31 which shows the calculation for weighted road width which takes into account new access tracks and upgrading of existing access tracks.
Average peat depths for excavated roads	Hydrology Department, Natural Power Consultants Ltd. Informed by Phase 1 peat probe data and the targeted Phase 2 data collected.

Input	Source of Information
	As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value, and the minimum and maximum values provided represent the lower and upper bound values of the 95% confidence intervals of the sample data collected. See also Paragraph A10.4.37 which shows the calculation for weighted road peat depth which takes into account new access tracks and upgrading of existing access tracks.
Length of rock filled roads	Construction Team, Natural Power Consultants Ltd There will be no rock filled roads.
Length of cable trenches	Construction Team, Natural Power Consultants Ltd It is assumed that all cables will follow tracks and an allowance for cable trenches has been made when calculating excavated road widths.
Additional peat excavated	Construction Team, Natural Power Consultants Ltd $32,066 \text{ m}^3$ of additional peat will be excavated. This input accounts for the substation, 4 construction compounds, 18 laydown areas and 2 meteorological mast crane hardstandings. External transformers are not included as they would be covered by turbine/crane hardstanding excavations. Calculations are shown in Table A10.4.3 of this Appendix.
Area of degraded bog to be improved	Ecology Team, Natural Power Consultants Ltd No peatland restoration is proposed for this site. Whilst there is an area of currently forested peatland which will be restored to wet woodland, including ditch blocking, as part of Habitat Management Plan (HMP), no carbon gains have been included as improvement of degraded bog for these works within this assessment as a worst case.
Area of felled plantation to be improved	Ecology Team, Natural Power Consultants Ltd The outline HMP proposes areas (approx. 14.48 ha) of plantation that shall be felled for construction of the wind farm and which could be replanted, but which instead shall remain as open habitat. There is also wet woodland restoration which will including the blocking of existing ditches to re-wet the ground and pond creation measures. Minimum and maximum values are +/- 10% of the expected value.
Area of borrow pits to be restored	Geotech Team, Natural Power Consultants Ltd Due to the shallow nature of peat within the borrow pit areas, zero values have been inserted to assume worst case scenario with no peat restoration within the borrow pits,
Water table depth around foundations and hardstandings before and after restoration	Hydrology Department. Natural Power Consultants Ltd. The foundations and hardstandings are situated in areas that avoid deep peat.. The 'before restoration' water table depth is based on the scenario whereby drainage is not removed but left in situ. It assumes that the drainage left in place would cause some draw down on the existing water table. The 'after restoration' water depths are based on backfilling of the drainage which would bring the water table depth up to, and likely higher, than previous levels before construction.

Input	Source of Information
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	Hydrology Department. Natural Power Consultants Ltd. Values of 2, 1 and 5 years used. Based on professional judgement.
Will the hydrology of the proposed development Area be restored on decommissioning	Hydrology Department. Natural Power Consultants Ltd. Yes. During the construction and commissioning of the wind farm, drainage ditches will be blocked and therefore the water table will increase. Upon the decommissioning of the wind farm, best practice principles will be adopted.
Will the habitat of the proposed development Area be restored on decommissioning?	Hydrology Department. Natural Power Consultants Ltd. No. At the moment it is assumed that upon decommissioning, restoration of habitats will not be undertaken. There are no plans to control grazing or reintroduce species using nurse crops or fertilisation, therefore a worst case scenario of “no restoration” has been inputted into the carbon calculator tool.

Source: Natural Power

A10.4.9 The following paragraphs and tables report on the results of the carbon calculator calculations that are present within the online tool. For further clarification of the calculations, the reader will need to view the online submission (Reference: MXMS GE1K 64EN V.21).

Wind Farm CO₂ Emission Savings

A10.4.10 The amount of CO₂ emissions produced during energy production varies with the type of fuel used; therefore, the potential CO₂ savings from the proposed development depends on the type of fuel it replaces. The wind farm CO₂ emission savings over other types of generation (i.e. coal-fired, grid-mix, fossil fuel-mix) is calculated by multiplying the energy output of the wind farm development by the emissions factor of the other type of generation.

A10.4.11 Based on an expected 7.2 MW turbine model scenario, the expected potential annual energy output of the proposed development (for the purposes of this model, see the note in respect of capacity factors in table above) is 317,883 MWh yr⁻¹ (15,894,144 MWh over 50 years), with minimum and maximum potential outputs at 240,304 MWh yr⁻¹ and 363,295 MWh yr⁻¹ respectively.

A10.4.12 Based on the expected annual energy output of the proposed development (317,883 MWh yr⁻¹), the potential expected emissions saved over coal-fired electricity generation is 318,519 tonnes of CO₂ per year (tCO₂ yr⁻¹); and over grid-mix generation is 61,472 tCO₂ yr⁻¹ and over fossil-fuel mix generation is 137,325 tCO₂ yr⁻¹.

Emissions due to Turbine Life

A10.4.13 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.

A10.4.14 The carbon calculator includes a module for assessing the carbon emissions due to turbine life. Nayak *et al.*, (2010) explain that the turbine life calculation within the carbon calculator is based on generic data as it does not accommodate a site-specific full life-cycle analysis. Therefore, the turbine life emissions for the proposed development are estimated utilising an equation for ≥1 MW turbines that has been derived from data from numerous European sites, and which shows a significant relationship across the European sites examined.

A10.4.15 The carbon calculator reveals an expected emissions figure of 119,666 tonnes of CO₂ (tCO₂) equivalent (equiv.) emitted due to the manufacture, construction and decommissioning of the turbines. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for turbine life is expected to take approximately 10 months.

Capacity Required due to Back Up

A10.4.16 In order to maintain security of energy supply, 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 timescales. The variability of wind generation is but one component of the generation and demand variations that are considered when setting reserve levels.

A10.4.17 It should also be noted that an individual wind turbine will generally generate electricity for 70-85% of the time, 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.

A10.4.18 The extra capacity that would be needed for back-up power generation is currently estimated to be approximately 5% of the rated capacity of the wind plant as UK wind power contributes more than 20% to the National Grid. The carbon calculator assumes that all back-up power generation will be via fossil fuels or grid-mix which does not account for any back-up energy generation from renewable sources directly or from renewable energy that has been stored in batteries. As such, the emissions figure required from back-up power generation for the proposed development is considered to be conservative as the calculator assumes a very worst case scenario.

A10.4.19 The carbon calculator assumes that backup is provided by a fossil fuel mix of energy generation and reveals an expected emissions figure of 122,612 tCO₂ equiv. due to the back-up. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for back-up is expected to take approximately 11 months.

Loss of Carbon Fixing Potential

- A10.4.20 Construction of the proposed 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 working areas used to install the infrastructure and areas affected by drainage. In order to demonstrate a worst-case scenario of the proposed development's impact on carbon fixing potential through drainage, the extent of drainage around infrastructure is given as 3.5 m expected and 2 m and 5 m as minimum and maximum values respectively. These values are considered to be reasonable as there is little peat present where infrastructure is located and little water held in the superficial soils.
- A10.4.21 The carbon calculator also assumes that the footprint of the wind farm has 100% coverage of bog plants that are still accumulating carbon for those areas where vegetation is either removed during construction or compromised due to disturbance or drainage. This assumption is considered to be very much a worst-case scenario as 100% bog habitat cover is self-evidently not an accurate representation of the proposed development area's total habitat characteristics.
- A10.4.22 The distribution and quality of soils across the Y Bryn site boundary is dependent upon land use, geology, topography and hydrological regime of the area. Information on the proposed development soils has been obtained from UK Soil Observatory (UKSO)¹¹. The mapper indicates that the dominant soil types are very acid/loamy soils with a wet peaty surface, freely draining acid loamy soils and slowly permeable wet very acid soils with a peaty surface. The quality of the soils has been affected by the existing land use, including productive forestry and associated ridges and furrows as well as artificial drainage ditches to dry the soils.
- A10.4.23 Habitat loss calculations for the development have been calculated based on the revised infrastructure and are discussed in Chapter: 6 Ecology of the ES. The wind farm is located predominantly within two areas of productive forestry and thus 'coniferous woodland – plantation' was the Phase 1 habitat type that was recorded across the majority of the survey area. Areas of broadleaved or mixed woodland are also present, along steep inaccessible slopes above watercourses or woodland naturally regenerating within unmanaged or unplanted areas. Linear strips and patches of open ground exist within the north and south sections usually adjacent to forestry tracks and/or within forestry rides, some of which are managed by annual cutting of the vegetation. Phase 1 habitats within these open areas include marsh/marshy grassland and wet and dry dwarf shrub heath. No habitat classified as blanket bog, raised bog or modified bog were recorded in the surveyed area.
- A10.4.24 Table 6.13 within Chapter 6 demonstrates 243.7 ha of potential peat habitat as being present. This is 'worst case' as it assumes for example, all broadleaved woodland is wet (bog) woodland and assumes all marshy grassland is on peatland, which is known not to be the case. This is from a

total surveyed area of 2,282.2 ha. Using this approach, potential peat habitats comprise 10.7 % of all habitats recorded. The habitat loss calculations reveal that, of the maximum 243.7 ha of potential peatland habitat present, there will only be 7.4 ha lost or disturbed to the proposed development. This equates to 3 % of the potential peat habitat on site and less than 0.5 % of all habitats recorded on site. The tool assumes that 100% of habitats lost or disturbed will be peat habitats, but this has been shown not to be the case.

- A10.4.25 It is therefore considered that the carbon calculator's assumption that 100% of the land lost through construction or drainage of the proposed development is covered in bog plants or peatland vegetation is considered to be highly precautionary in this instance as limited bog plants exist on site and many other types of habitats do exist on site. Furthermore, another input required for the assessment is the time required for regeneration of bog plants. This has been estimated to be 10 years (2 years minimum and 20 years maximum) as described in Table A10.4.1. This, in part, is based on the observation of the quality of the bog vegetation on proposed development area. In addition, any indirect damage which may result from the construction would be dealt with sensitively using best practice techniques to support rapid regeneration of vegetation.
- A10.4.26 The carbon calculator reveals that the expected total emissions attributable to the loss of carbon accumulation by bog plants is equivalent to 4,083 tCO₂ equiv. over the operational period of the wind farm. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for loss of carbon fixing potential is expected to be less than a month. However, as previously described above, it is important to recognise that 100% bog/mire habitat cover is not an accurate description of the proposed development area's characteristics.

Loss of Carbon Dioxide from Removed Peat (Direct Loss)

- A10.4.27 The 2017 Peatland Survey Guidance¹² states that peat is defined as the partially decomposed remains of plants and soil organisms which have accumulated at the surface of the soil profile. Peat accumulates where the rate of input of organic material from the surface exceeds the rate of decomposition and 'turn-over' of this new material. A peat layer does not include a mineral fraction (hence being differentiated from topsoil).
- A10.4.28 Peat is a soft to very soft, highly compressible, highly porous organic material that can consist of up to 90 – 95% water, with 5 – 10% solid material¹³. Unmodified peat consists of two layers; a surface acrotelm which is usually 10 – 30 cm thick, highly permeable and receptive to rainfall. Decomposition of organic matter within the acrotelm occurs aerobically and rapidly. The acrotelm generally has a high proportion of fibrous material and often forms a crust in dry conditions.
- A10.4.29 A second layer > 30 cm thick, or catotelm, lies beneath the acrotelm and forms a stable colloidal substance which is generally impermeable. As a result, the catotelm usually remains saturated with little groundwater flow. Peat is thixotropic, meaning that the viscosity of the material decreases when stress is applied. The thixotropic nature of peat may be considered less important where the peat has been modified through artificial drainage or natural erosion and is drier but will be significant when the peat body is saturated.

¹¹ UKSO (2018). *UK Soil Observatory map viewer*. [Online]. Available at: <https://mapapps2.bgs.ac.uk/ukso/home.html> [Accessed 15/12/2023]

¹² Available at: <https://www.gov.scot/publications/peatland-survey-guidance/> [Accessed 15/12/2023]

¹³ Warburton *et al.* (2004) Hydrological controls of surficial mass movements in peat.

A10.4.30 Due to soils mapping, in particular the Unified Peat Map of Wales¹⁴, suggesting the distribution of peat and peaty soils underlying the proposed development, a Phase 1 peat depth survey, followed by Phase 2 detailed probing and coring has been carried out to thoroughly understand the peat and its locality within Y Bryn site boundary.

A10.4.31 The peat depth data at the proposed development are taken from the peat study using a 100 m grid sample and the more detailed peat depth probing undertaken on the site. Overall, 2,493 peat depth measurements were taken across the proposed development to inform peat depths across the proposed development area. As advised by the authors of the tool, the arithmetic mean was calculated from this data to represent the ‘expected’ value, and the minimum and maximum values provided represent the lower and upper bound values of the 95% confidence intervals of the sample data collected.

A10.4.32 Peat survey data has been collected in line with the recommended statutory approach, comprising of initial phase 1 (100 m grid) surveys, followed by more detailed Phase 2 (targeted) surveys. The results of the phase 1 surveys were used to inform preliminary design, before refinement following completion of the Phase 2 surveys. The detailed Phase 2 surveys were undertaken in October and November 2021 and June 2023 and concentrated to areas where it was possible that there was a peat depth >0.3 m (based on desk study and phase 1 surveys). The resolution of the peat surveys was a 20 m grid across turbines and crane pads, and every 20 m along each side of existing access roads.

A10.4.33 Owing to the underlying geology, there is a presence of superficial clay across the site. In many areas the clay was easily penetrable by the probes used to measure the peat depth, and therefore the depths recorded during the 100 m grid survey were the depth of the soil column rather than just peat. During phase 2 peat surveys in areas where measured depths were consistently ≥0.3 m, in line with NRW guidance, soil cores were taken at 52 locations to characterise the soil column. This allowed the actual peat soil depth to be measured relative to total probed depth. Probed depths surrounding the soil core have been corrected based on that core and the results presented in Chapter 10: Hydrology, Geology and Hydrogeology. Table 10.11 are the corrected peat soil depths.

Table A10.4.2: Total number of soil depths in each category from Phase 1 and 2 surveys

Total Soil Depth (m)	Results	% of Points
<0.3	2192	87.9
≥0.3 - <0.4	112	4.5
≥0.4 - <1	180	7.2
≥1 - <1.5	7	0.3
≥1.5 - <2	0	0
≥2	2	0.1
Total	2493	100

Source: Hydrology Team, Natural Power Consultants Ltd

A10.4.34 Table 10.4.2 shows that the majority (~88%) of recorded depths fell within the <0.3 m range, with 5% recorded depths within the ≥0.3 - <0.4 m, the next highest proportion (~7.2%) within the ≥0.4 - <1 m range. Taking into account the results of the cores, the areas of deeper peat soils (≥0.3 m) as shown on Figure 10.4 in Volume 2 of the ES are restricted to the plateau between Nant-y-glo and Nant Sychbant (primarily between T9 and T10), parts of the north slope of Mynydd Margam (primarily around the access track to T16), the plateau around Brynallwyn (north-east of T12), and a small area in the north section south of the main access track for T1 – T5. Any other areas of deep peat were localised to within the vicinity of small valleys or watercourses across the Y Bryn site boundary and well away from areas of infrastructure associated with the proposed development. The area of deepest peat identified was the plateau between Nant-y-glo and Nant Sychban however although this is relatively near proposed infrastructure this has been avoided.

A10.4.35 To obtain site-specific information relating to the characteristics of the peat/soil, peat core samples were also collected using a Russian peat core and were retained for laboratory and geochemical analysis.

A10.4.36 Carbon content of dry peat (% by weight) and dry soil bulk density (g cm⁻³) were analysed in a laboratory (see Annex B and C). The expected, minimum and maximum values for carbon content of dry peat were outside the tolerances of the carbon balance tool so the minimum ranges of the tool were used.

A10.4.37 The excavated peat volumes calculated and reported within the assessment accommodate realistic working areas with the assumption built into the model that all peat in working areas is excavated and lost. Within this assessment, in order to represent a worst case scenario the following working areas and assumptions have been incorporated into the analysis:

- The carbon calculator does not accommodate inputs for upgrading tracks and only allows inputs for new excavated tracks. However, under advice provided by the authors of the calculator, instead of simply reporting the length and width of new tracks (excavated tracks), the widening/upgrading of existing access tracks has been accounted for in this assessment by calculating the weighted average width of tracks along the total length of new and upgraded

¹⁴ Welsh Government (2015). Unified Peat Map of Wales. Available at: <https://datamap.gov.wales/maps/new/#/> [Accessed 15/12/2023]

tracks. The same approach has been applied for calculating the weighted peat depths for access tracks.

For example, the calculations for expected weighted track widths were as follows:

$[8,934 \text{ m (expected length of new track)} \times 17.5 \text{ m (expected width)}]$
 $+ [12,580 \text{ m (expected length of upgraded track)} \times 6.5 \text{ m (expected width of upgrade)}]$
 $= 238,115 \text{ m}^2$

Then; $238,115 \text{ m}^2 / 21,514 \text{ (total expected length of tracks)} = 11.07 \text{ m}$ expected weighted average width.

The calculations for expected weighted peat depths were as follows:

$[8,934 \text{ m (expected length of new track)} \times 0.24 \text{ m (expected average peat depth)}]$
 $+ [12,580 \text{ m (expected length of upgraded track)} \times 0.20 \text{ m (expected average depth for upgraded tracks)}]$
 $= 4,660 \text{ m}^2$

Then; $4,660 \text{ m}^2 / 21,514 \text{ (expected total length of tracks)} = 0.22 \text{ m}$ expected weighted average peat depth.

- An expected value for excavated new roads width of 17.5 m is based on 7 m running width (expected running width is 6 m, however precautionary value of 7 m inserted to account for widening on corners), 2.5 m drainage/cable trench on one side and then 8 m allowance for cut/fill working areas. In some areas, cut/fill working areas may be narrower or wider therefore, the minimum and maximum values for running width of 6 m and 9 m have been used respectively.
- An expected value for upgrades to existing tracks of 6.5 m is based on an increase by 2 m in running width, 2.5 m for cable trench on one side and then 2 m allowance for cut/fill working areas in the expected scenario (6.5 m), and then as cut/fill working areas may be narrower or wider, the minimum (5.5 m) and maximum (8.5 m) values have been provided.
- Working areas, excavation areas and batters have been included around turbine foundations and the average length and width included for the range of turbines sizes considered (indicative average dimensions of 30.5 m x 30.5 m, with an additional excavation area of 10 m). Minimum and maximum values allow +/- 10% tolerance to account for changes in these areas that may be required. In most cases, the turbine foundation footprint and working areas will overlap with the hardstandings/working areas/laydown areas. As such, the minimum dimensions included within this assessment for turbine foundations should be considered very worst case as there is an element of double counting.
- Working areas have also been included in the calculations around the temporary laydown areas (1 side assumed to be next to a road with no additional working area).

A10.4.38 The carbon calculator requires information relating to other ancillary infrastructure not explicitly accounted for above, namely the substation, construction compound, anemometer mast etc. The following table utilises the expected dimensions of the additional infrastructure and peat depths used to calculate the total area and total volume of excavations.

Table A10.4.3: Additional peat excavated calculations

	Additional Peat Excavated		
	Expected	Minimum	Maximum
Substation (m²)	12,800	11,520	14,080
Substations Average Peat Depth (m)	0.2	0.2	0.2
Laydown Areas (m²)	115,500	102,900	126,000
Laydown Areas Average Peat Depth (m)	0.20	0.18	0.23
Construction Compound (m²)	45,760	41,360	50,160
Construction Compound Average Peat Depth (m)	0.14	0.11	0.18
Meteorological mast hardstanding (m²)	4,400	4,500	6,000
Meteorological mast hardstanding Average Peat Depth (m)	0.35	0.14	0.54
Total Area of Peat Removed (m²)	178,460	160,280	196,240
Total Volume of Peat Removed (m³)	32,066	25,376	44,065

Source: Natural Power

A10.4.39 Sheet 5, Table 5a of the carbon calculator calculates the total expected area of land lost due to the wind farm construction as 55.6 ha and expected volume of peat removed over the footprint of the wind farm is expected to be 111,367 m³. Total volumes and areas have been stated within the results of the tool, these values are not rounded which conveys a false accuracy and it should be borne in mind that these values are only highly indicative as not all of the volume and areas reported as removed will be peat habitat.

A10.4.40 The CO₂ release associated with the volume of peat excavated assumes a worst-case scenario that 100% of the peat is lost. However, this is not the case as the peat will be reused as part of peat reinstatement and restoration and the fact that this is a very low peat site, the total expected amount of CO₂ loss, attributable to peat removal only, (i.e. CO₂ emissions from peat that is excavated for the wind farm only, no impacts from drainage of peat) that is reported within the online submission is calculated to be -49,341 tCO₂ equivalent. This reduces the overall payback of the construction of the wind farm by 4 months.

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

- A10.4.41 Carbon is also lost from peat habitats through drainage that occurs in the peat around the proposed development’s infrastructure. The carbon calculator and associated guidance refers to this CO₂ loss as an “indirect loss”. The extent of the proposed development Area affected by drainage assumes an expected, minimum and maximum extent of drainage around each drainage feature e.g. turbine foundation, tracks etc. It is important to bear in mind that the extent of drainage is dependent on existing drainage conditions on proposed development area and also topography. The carbon calculator, however, assumes no existing drainage on proposed development area and flat terrain which is not representative of the actual proposed development area characteristics. Therefore, results using this parameter should only be considered as indicative at best.
- A10.4.42 Hydrological and site investigation specialists visually noted and recorded water table depths during surveys which informed the proposed development Area design evolution. Extent of drainage is a reasonable estimation based on knowledge of the proposed development Area (topography etc.), experience at similar sites and expert judgement. As such, a recommended average extent around the drainage feature of 3.5 m was considered as an appropriate expected average for the calculation. Values of 2 m and 5 m were inserted as inputs to represent best and worst case scenarios respectively.
- A10.4.43 Page 5, Table 5 of the carbon calculator calculates the total expected CO₂ loss from removed peat and from drained peat. This reports that the CO₂ loss from drained peat is 0 tCO₂ equiv., as in Table 5d of the tool assumes that the emissions from drained and undrained peat have the same proportion over the emissions period (i.e. CO₂ emissions of drained soil and undrained soil are the same (Table 5e) and therefore the net emissions due to drainage is 0 tCO₂ equiv.
- Loss of Carbon Dioxide from DOC and POC loss**
- A10.4.44 Additional CO₂ emissions from organic matter can occur as carbon dioxide and methane, which 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 generally between 0.7 and 0.22 µm). Conversely, Particulate Organic Carbon (POC) is the fraction of soil carbon that is larger in particle size. The assessment tool assumes that 100% of the losses due to leaching DOC and POC from restored drained and improved land are eventually lost as gaseous CO₂.
- A10.4.45 Only restored drained and improved land has been included in the calculations within the carbon calculator for DOC and POC, because if the land is not restored or improved, then the carbon loss has already been accounted for in the calculations for excavated and drained peat (i.e. the carbon assessment assumes that if land is not restored then 100% of the carbon will be lost from the removed or drained volume of soil).
- A10.4.46 The carbon calculator calculates that there will be an expected 3 tCO₂ equiv. lost due to DOC and POC leaching over the operational life of the wind farm.

Total Loss of Carbon Dioxide from Impact on Peat

- A10.4.47 The following calculations on 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 (unrealistic) 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/laydown areas;
 - 100% of the carbon stored in the excavated peat will be lost as carbon dioxide and not reinstated on site;
 - 3.5 m metre expected average extent of drainage to demonstrate a conservative expected scenario and 5 m worst case scenario;
 - The average extent of drainage assumes that the depth of peat affected by drainage is equal to the depth of peat removed;
 - The peat depth data used to inform the volumes of peat removed assume that all recorded depths are in peat; and
 - The model assumes no micro-siting to further reduce impacts on peat.
- A10.4.48 The combined expected impact of the development on peat and vegetation over the operational lifetime of the development for the proposed layout is calculated as:

Table A10.4.4: Total loss of CO₂ from impact on peat

	CO ₂ loss from plants +	CO ₂ loss from removed peat+ CO ₂ loss from drained peat (i.e. soil organic matter loss)	+CO ₂ DOC & POC loss
	4,083	-49,341	3
Total loss CO ₂ equivalent		-45,255	

Source: Online Tool Reference MXMS GE1K 64EN V.18

- A10.4.49 Based on the calculated emissions for fossil fuel-mix generation, the payback time for loss of soil organic carbon is actually a carbon gain which reduces the overall payback of the construction of the wind farm by over 4 months.
- Loss of Carbon Fixing due to Forest Felling**
- A10.4.50 Of the total felling area of 119.24 ha, approximately 14.48 ha will be returned to NRW management after construction of the wind farm and will therefore, be available for replanting with forest trees. These areas will be replanted and continue as a normal component of the forest and forest resource plans (FRP). Forest design principles, habitat gains and landscaping may require

modification of the replanting plan from that in the approved FRP. Any change necessary will be led by NRW requirements.

A10.4.51 Forest areas cleared for the purpose of the proposed development which are not required to be kept clear for the operation of the wind farm will be replanted. The resulting net loss of forest land for the wind farm is 104.76 ha. However, a commitment has been made for compensatory planning (see Chapter 13), and a precautionary and worst case approach is provided here as the compensatory planting is likely to be offsite.

A10.4.52 In accordance with the guidance for the carbon calculator¹⁵ the net forestry felled is inserted as 104.76ha into the carbon calculator tool as 14.48 ha of replanting will be undertaken.

A10.4.53 The carbon calculator calculates that there will be an expected 69,142 tCO₂ equiv. lost due to felling of productive forestry over the operational life of the wind farm. Based on the calculated emissions savings for fossil fuel-mix generation, the payback time for loss of carbon fixing potential is expected to be approximately six months.

Carbon Gain Due to Site Improvement and Restoration

A10.4.54 Restoration of areas within a proposed site can reverse emissions and act as carbon storage, reducing the total CO₂ emissions as a result of the proposed development. The carbon calculator takes into account reductions for emissions resulting from the improvement of degraded bog, as well as the restoration of borrow pits and early removal of drainage from turbine foundations.

A10.4.55 The drainage associated with the hardstandings and foundations will have an expected draw down on the water table during the construction period until such a time when they are removed/backfilled. This restoration work will where possible, intend to raise the water table depth above that which is already present before construction. All construction ditches and drainage on site will be blocked to minimise indirect habitat damage and loss through drainage. In cases where peat is excavated during the construction, it will be translocated or appropriately stored and used for reinstatement to best practice techniques.

A10.4.56 Although improvements will be made as part of the HMP where some ditch blocking will take place, a precautionary approach has been undertaken that assumes no restoration of degraded bog takes place. Similarly, a precautionary approach for borrow pit restoration is also assumed due to the very shallow nature of peat found within the borrow pit areas.

A10.4.57 An area close to the turbine development area in the Margam forestry section was identified during baseline surveys as having soils with a high content of peat. It is proposed that the HMP includes an aim to establish wet woodland in this area, this being the most appropriate wetland habitat given the isolated location of this area within the forest. This would be undertaken in line with the existing felling plan, so that once the appropriate area is cleared of timber, it is not replanted with conifers.

A10.4.58 As part of this prescription, the existing ditches within this area would be blocked to re-wet the ground, where possible. In addition, the outline HMP proposes areas of plantation that shall be felled for construction of the wind farm and which could be replanted, but which instead shall remain

as open habitat preventing soils from drying out further. Pond creation will also allow the natural retention of water to take place and this area will be kept free of conifer regeneration to encourage the creation of marshy grassland habitat (which includes some mire habitats).

A10.4.59 The results report -3,002 tCO₂ equiv. in carbon gains from the restoration measures in the expected scenario and -4,243 tCO₂ equiv. in carbon gains from restoration in the maximum (best case) scenario. It is important to note that the minimum scenario does not show any carbon gains accrued from improvements of the site as the tool has assumed that no improvement has occurred which is considered to be an unrealistic scenario.

Carbon Balance Summary

A10.4.60 Table A10.4.5 reveals the carbon losses and carbon gains for each of the above parameters for the proposed development.

Table A10.4.5: Expected CO₂ losses and gains

Carbon Balance Input Parameter	Expected Results
1. Windfarm CO₂ emission saving over ...	
Coal fired electricity generation (tCO ₂ yr ⁻¹)	318,519
Grid mix of electricity generation (tCO ₂ yr ⁻¹)	61,472
Fossil fuel mix of electricity generation (tCO ₂ yr ⁻¹)	137,325
Energy output from windfarm over lifetime (MWh)	15,894,144
Total CO₂ losses due to wind farm (tCO₂ eq.)	
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	119,666
3. Losses due to backup	122,612
4. Losses due to reduced carbon fixing potential	4,083
5. Losses from soil organic matter	-49,341
6. Losses due to DOC & POC leaching	3
7. Losses due to felling forestry	69,142
Total losses (tCO₂ eq.)	266,165
Total CO₂ gains due to improvement of site (tCO₂ eq.)	
8a. Change in emissions due to improvement of degraded bogs	0
8b. Change in emissions due to improvement of felled forestry	-3,002
8c. Change in emissions due to restoration of peat from borrow pits	0
8d. Change in emissions due to removal of drainage from foundations and hardstandings	-511

¹⁵ Available at: <http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCalcGuidance> [Accessed 15/12/2023]

Carbon Balance Input Parameter	Expected Results
Total change in emissions due to improvements (tCO ₂ eq.)	-3,513
Net CO ₂ emissions (tCO ₂ eq.)	262,652

Source: Online Tool Reference Online Tool Reference MXMS GE1K 64EN v21: Payback Time and CO₂ emissions page.

A10.4.61 The net emissions of CO₂ of the proposed development is calculated by deducting the total CO₂ gains produced by improvement and restoration of the site from the total CO₂ emissions from manufacture of, construction of, and impacts on peat from, the individual elements of the alternative proposed development (described in the preceding paragraphs). Table A10.4.5 reveals the net CO₂ emissions.

A10.4.62 The wind farm CO₂ emissions savings of the proposed development over other types of generation (i.e. coal-fired, grid-mix, fossil fuel-mix) is calculated by multiplying the energy output of the proposed development by the emissions factor of the other type of generation. However, this parameter only takes into consideration the energy output of the proposed development and does not take into account any of the carbon losses or gains that are produced from manufacture of, construction of, and impacts on peat from, the individual elements of the proposed development. The parameter that takes all of this into account is the carbon payback time and it is this value that evidences the carbon balance of the proposed development.

A10.4.63 The carbon payback time for the wind farm is calculated by comparing the net loss of CO₂ from the site due to wind farm development with the carbon savings achieved by the wind farm while displacing electricity generated from coal-fired generation, grid-mix generation or fossil-fuel mix electricity generation.

Figures A10.1 and A10.2 illustrate the payback times for the alternative proposed development in years and months (respectively).

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO ₂ eq.)	262,652	199,538	291,838
Carbon Payback Time			
...coal-fired electricity generation (years)	0.8	0.5	1.2
...grid-mix of electricity generation (years)	4.3	2.8	6.3
...fossil fuel-mix of electricity generation (years)	1.9	1.3	2.8

Figure A10.1: Overall carbon payback time using fossil fuel mix as counterfactual

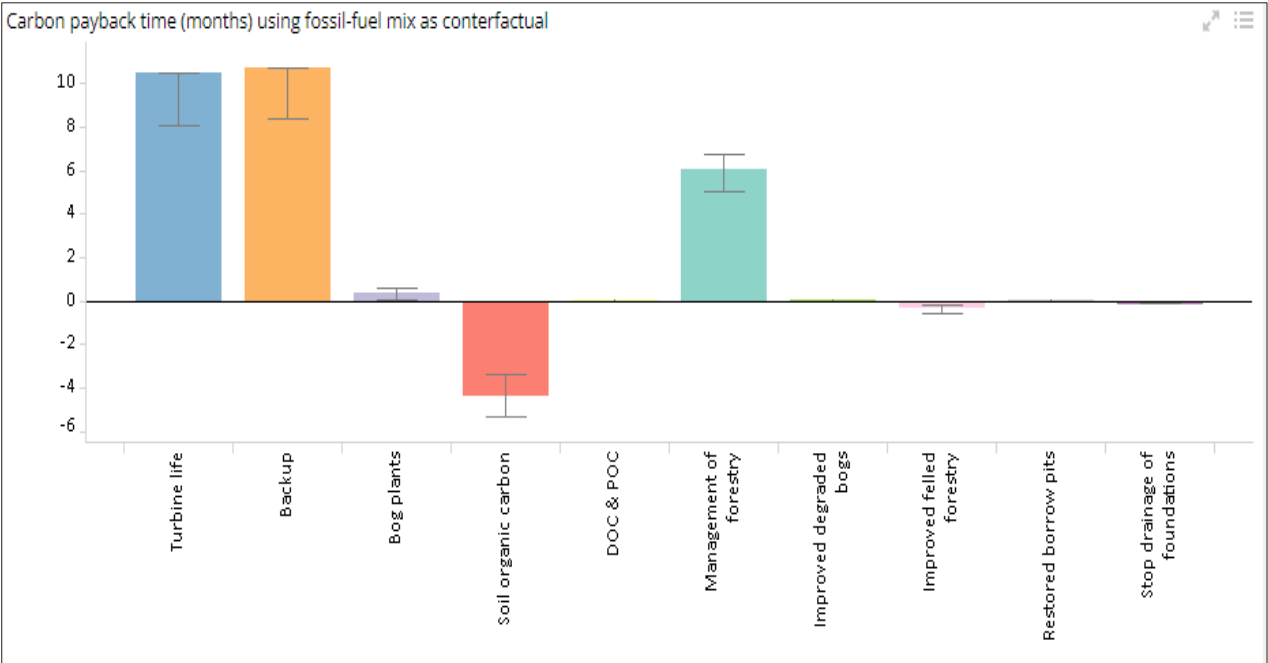


Figure A10.2: Carbon payback time of different elements using fossil fuel mix as counterfactual

A10.4.64 The results from the carbon calculator reveal that the proposed development would have effectively paid back its expected carbon debt from manufacture, construction, impact on habitat and decommissioning 1.9 years if it replaced with the fossil fuel electricity generation method. Based on the minimum and maximum scenarios however, the analysis shows that the payback time for fossil fuel-mix generation ranges between 1.3 to 2.8 years respectively.

A10.4.65 The Institute of Environmental Management and Assessment (IEMA) has identified the online carbon calculator tool for wind farm carbon assessments. This tool provides a consistent and the most comprehensive method for carbon assessment for wind farm developments on peat lands to date. However, the online tool does not define what level of impact on peat is considered to be a 'significant effect' as the existing carbon balance literature using this carbon assessment tool does not state this requirement.

A10.4.66 In this regard, IEMA conclude that:

‘...when evaluating significance, all new Green House Gas (GHG) emissions contribute to a significant negative environmental effect; however; some projects will replace existing development that have higher GHG profiles. The significance of a project’s emissions should therefore be based on its net impact, which may be positive or negative.’.

A10.4.67 In this context, the results of this assessment reveal that the net impact of the proposed development will be positive overall, as over the 50-year lifespan, it is expected to generate over 48 years’ worth of clean energy if it replaced fossil fuel electricity generation. In addition, over the expected 50 years that the wind farm is likely to be generating carbon-free electricity, this could result in expected CO₂ emission savings of over 6,591,600 tonnes¹⁶ of CO₂ when replacing fossil fuel electricity generation. This illustrates a positive net impact through contributing significantly towards the reduction of greenhouse gas emissions from energy production.

¹⁶ Calculation is 48 years x 137,325 tCO₂ (as shown in Table A10.4.5 and online submission).

ANNEX A: Carbon Calculator Input Data

Carbon Calculator v1.7.0
Y Bryn Wind Farm Location: 51.7722 -3.2455
Y Bryn Wind Farm Limited

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
<u>Dimensions</u>				
No. of turbines	18	18	18	Appendix 10.4 Table 10.4.1
Duration of consent (years)	50	50	50	Appendix 10.4 Table 10.4.1
<u>Performance</u>				
Power rating of 1 turbine (MW)	7.2	6	7.2	Appendix 10.4 Table 10.4.1
Capacity factor	28	25.4	32	Appendix 10.4 Table 10.4.1
<u>Backup</u>				
Fraction of output to backup (%)	5	5	5	Appendix 10.4 Table 10.4.1
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life (tCO2 MW ⁻¹) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	Chapter 10 Table 10.14
Average annual air temperature at site (°C)	9.22	5.74	12.7	Appendix 10.4 Table 10.4.1
Average depth of peat at site (m)	0.29	0.27	0.31	Appendix 10.4 Table 10.4.1
C Content of dry peat (% by weight)	19	19	20	Appendix 10.4 Table 10.4.1
Average extent of drainage around drainage features at site (m)	3.5	2	5	Appendix 10.4 Table 10.4.1
Average water table depth at site (m)	0.7	0.5	0.9	Appendix 10.4 Table 10.4.1
Dry soil bulk density (g cm ⁻³)	0.3	0.29	0.3	Appendix 10.4 Table 10.4.1
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	10	2	20	Appendix 10.4 Table 1
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha ⁻¹ yr ⁻¹)	0.25	0.12	0.31	Appendix 10.4 Table 1
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	104.76	94.28	115.23	Appendix 10.4 Table 10.4.1
Average rate of carbon sequestration in timber (tC ha ⁻¹ yr ⁻¹)	3.6	3.5	3.7	Appendix 10.4 Table 10.4.1
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh ⁻¹)	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh ⁻¹)	0.19338	0.19338	0.19338	
Fossil fuel-mix emission factor (t CO2 MWh ⁻¹)	0.432	0.432	0.432	
Borrow pits				

Input data	Expected value	Minimum value	Maximum value	Source of data
Number of borrow pits	6	6	6	Appendix 10.4 Table 10.4.1
Average length of pits (m)	140.39	126.35	154.43	Appendix 10.4 Table 10.4.1
Average width of pits (m)	100	100	100	Appendix 10.4 Table 10.4.1
Average depth of peat removed from pit (m)	0.19	0.17	0.2	Appendix 10.4 Table 10.4.1
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	40.5	39	43	Appendix 10.4 Table 10.4.1
Average width of turbine foundations (m)	40.5	39	43	Appendix 10.4 Table 10.4.1
Average depth of peat removed from turbine foundations(m)	0.19	0.18	0.21	Appendix 10.4 Table 10.4.1
Average length of hard-standing (m)	40	36	44	Appendix 10.4 Table 10.4.1
Average width of hard-standing (m)	35	31.5	38.5	Appendix 10.4 Table 10.4.1
Average depth of peat removed from hard-standing (m)	0.21	0.2	0.22	Appendix 10.4 Table 10.4.1
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m ³)	22120	19800	24600	Appendix 10.4 Table 10.4.1
Access tracks				
Total length of access track (m)	21514	19363	23665	Appendix 10.4 Table 10.4.1
Existing track length (m)	0	0	0	Appendix 10.4 Table 10.4.1
<u>Length of access track that is floating road (m)</u>	0	0	0	
Floating road width (m)	0	0	0	
Floating road depth (m)	0	0	0	
Length of floating road that is drained (m)	0	0	0	
Average depth of drains associated with floating roads (m)	0	0	0	
<u>Length of access track that is excavated road (m)</u>	21514	19363	23665	Appendix 10.4 Table 10.4.1
Excavated road width (m)	11.07	10.07	13.07	Appendix 10.4 Table 10.4.1
Average depth of peat excavated for road (m)	0.22	0.2	0.24	Appendix 10.4 Table 10.4.1
<u>Length of access track that is rock filled road (m)</u>	0	0	0	
Rock filled road width (m)	0	0	0	
Rock filled road depth (m)	0	0	0	
Length of rock filled road that is drained (m)	0	0	0	
Average depth of drains associated with rock filled roads (m)	0	0	0	
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	Appendix 10.4 Table 10.4.1
Average depth of peat cut for cable trenches (m)	0	0	0	Appendix 10.4 Table 10.4.1
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m ³)	32066	25376	44065	Appendix 10.4 Table 10.4.1
Area of additional peat excavated (m ²)	178460	160280	196240	Appendix 10.4 Table 10.4.1

Input data	Expected value	Minimum value	Maximum value	Source of data
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed
Improvement of C sequestration at site by blocking drains, restoration of habitat etc				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	0	0	0	Appendix 10.4 Table 10.4.1
Water table depth in degraded bog before improvement (m)	0	0	0	
Water table depth in degraded bog after improvement (m)	0	0	0	
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	0	0	0	
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	0	0	0	
<u>Improvement of felled plantation land</u>				
Area of felled plantation to be improved (ha)	14.48	13.03	15.9	Appendix 10.4 Table 10.4.1
Water table depth in felled area before improvement (m)	0.7	0.5	0.9	Appendix 10.4 Table 10.4.1
Water table depth in felled area after improvement (m)	0.5	0.4	0.7	Appendix 10.4 Table 10.4.1
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	10	5	15	Appendix 10.4 Table 10.4.1
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	50	50	50	Appendix 10.4 Table 10.4.1
<u>Restoration of peat removed from borrow pits</u>				
Area of borrow pits to be restored (ha)	0	0	0	Appendix 10.4 Table 10.4.1
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	0	0	0	
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	0	0	0	
<u>Early removal of drainage from foundations and hardstanding</u>				
Water table depth around foundations and hardstanding before restoration (m)	0.7	0.5	0.9	Appendix 10.4 Table 10.4.1
Water table depth around foundations and hardstanding after restoration (m)	0.6	0.4	0.8	Appendix 10.4 Table 10.4.1
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	2	1	5	Appendix 10.4 Table 10.4.1
Restoration of site after decommissioning				
<u>Will the hydrology of the site be restored on decommissioning?</u>	Yes	Yes	Yes	

Input data	Expected value	Minimum value	Maximum value	Source of data
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	Appendix 10.4 Table 10.4.1
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	Appendix 10.4 Table 10.4.1
<u>Will the habitat of the site be restored on decommissioning?</u>	No	No	No	
Will you control grazing on degraded areas?	No	No	No	Appendix 10.4 Table 10.4.1
Will you manage areas to favour reintroduction of species	No	No	No	Appendix 10.4 Table 10.4.1
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

ANNEX B: Laboratory Results – Carbon Content



Summary of Chemical Analysis

Soil Samples

Our Ref 21-23753
Client Ref 21/1298
Contract Title Y Bryn

Test	Method	LOD	Units	Lab No	1930778	1930779	1930780	1930781	1930782	1930783	1930784	1930785	1930786	1930787	1930788
				Sample ID	TP899	TP1664	TP1350	TP1570	TP1274	TP1544	TP1026	TP1122	TP1431	TP602	TP982
				Depth											
				Other ID											
				Sample Type	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
				Sampling Date	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
				Sampling Time	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
Inorganics															
Loss on Ignition at 440oC	DETSC 2003#	0.01	%											70	
Carbon, Total	DETSC 2084*	0.5	%	11	12	12	8.9	22	15	16	11	10	23	9.9	
Total Organic Carbon	DETSC 2002	0.1	%	12	12	12	9.4	12	14	11	12	10	> 15	7.4	

Key: * -not accredited. # -MCERTS (accreditation only applies if report carries the MCERTS logo). n/s -not supplied.

ANNEX C: Laboratory Results – Dry Soil Bulk Density

THE NATURAL POWER CONSULTANTS
Y BRYN



TRIAL PIT	SAMPLE	DEPTH (m)	MOISTURE CONTENT (%)	BULK DENSITY (Mg/m ³)	DRY DENSITY (Mg/m ³)
TP	602	-	430	1.09	0.21
TP	899	-	73	1.27	0.73
TP	982	-	61	1.32	0.82
TP	1026	-	144	1.21	0.50
TP	1122	-	140	1.28	0.53
TP	1274	-	231	1.01	0.31
TP	1350	-	79	1.31	0.73
TP	1431	-	83	1.40	0.77
TP	1544	-	126	1.14	0.50
TP	1570	-	134	1.28	0.55
TP	1664	-	58	1.18	0.75

Tested in accordance with BS1377 Part 2 : 1990
Bulk Density : Linear Measurement

SUMMARY OF MOISTURE CONTENT
AND DENSITY TEST RESULTS