Document history

Issue	Date	Revision Details
C	30/04/2021	Final

Appendix 4

Carbon Balance

Contents

List of Abbreviations

Abbreviation	Description
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
HMP	Habitat Management Plan
IEMA	Institute of Environmental Management Assessment
SEPA	Scottish Environment Protection Agency

A4.1 INTRODUCTION

A4.1.1 This report has been prepared by Natural Power Consultants Limited (Natural Power) and details the carbon balance assessment undertaken for the Daer Wind Farm (hereafter known as the Proposed Development) which consists of 17 turbines and ancillary infrastructure. 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 (CO_2) emissions against the total potential carbon savings attributed to the Proposed Development.

A4.1.2 This report should be read in conjunction with the Geology, Hydrology and Hydrogeology (Chapter 8), Ecology (Chapter 6), and Project Description (Chapter 3) chapters and relevant appendices of the EIAR which describe the Proposed Development in more detail and provided important information on the peat resource within the area.

A4.1.3 Natural Power has significant experience working on carbon balance assessments, not only in Scotland but across the UK. Members of the Natural Power team have been involved in the development of the carbon calculator tool and provided considerable input to the authors of the tool to refine the analysis further, therefore have an excellent understanding of the tool. Furthermore, the Planning and Environment department at Natural Power is accredited by the Institute of Environmental Management Assessment (IEMA).

A4.2 SCOPE

A4.2.1 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. Carbon balance assessments make use of the carbon calculator tool[1] which is currently the best method to date to undertake this kind of assessment is endorsed by SEPA and the Scottish Government.

A4.2.2 The inputs into the carbon calculator has been undertaken in accordance with guidance 'Calculating Carbon Losses & Savings from Wind Farms on Scottish Peatlands – Technical Note 2.10.0'. As well as Technical Note 2.10.0[2]', 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 (May 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 Wind farms 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 wind farm developments on peatlands in Wales (Jan 2010).
- Natural England Commissioned Report: Investigating the impacts of wind farm 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.

[1] Available online from: https://informatics.sepa.org.uk/CarbonCalculator/index.jsp (last accessed 21/04/2021)

[2] Available online from: http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCguidance2-10-0 (last accessed on 09/09/2020)

A4.3 INPUTS

A4.3.1 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 site investigation specialists.

A4.3.2 Version V1.6.1 of the carbon calculator is currently the latest version of the online tool available (as of 22.04.2021).[3] The inputs from the online carbon calculator tool run are presented in Appendix A4.16 of this report (Reference: ME1T-S2G5-Z22U v2). 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 A4.1 presents the source of the input data for the detailed information that is inserted to conduct the analysis. 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 inputs 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, as far as is possible, as provided by RWE (the Applicant), Natural Power (EIA lead consultant, Ecology, Hydrology, Geotechnical, Design & Advisory Services specialists) and Pell Frischmann.

A4.3.3 It is important to highlight that a comprehensive peat depth dataset was collected during the earlier stages of the design and provide a fair representation of peat depths across the site. 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.

Table A4.1: Record of Source of Data

Input	Source of Information
Turbine capacity and lifespan	RWE. 17 turbines each with a rated output of up to 6.2 MW. Min 5.8 MW and max 6.6 MW reflecting range of turbine models for the tip height proposed. Fixed lifespan of the turbines is expected to be 35 years
Capacity factor	Energy Trends last 5 years average for Scotland (2019-2015). The minimum value used is 23.4 (2016) the lowest from the 5 years, the maximum value was 29.2 (2015) the highest across the 5 year time period and the expected value was calculated as 27.3 an average across the 5 years. https://www.gov.uk/government/statistics/energy-trends-section-6-renewables. (last accessed 12/02/2021)
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% to the National grid.
Type of peatland	Ecology Department. Natural Power Consultants Ltd In the tool, the choice of peatland habitats is limited to acid bog or fen. In this case, acid bog was selected as the ecological surveys identify blanket bog and modified bog habitats as the main peatland habitats within the Proposed Development area. According to the National Soil Map of Scotland[4] within the Proposed Development soils are generally peaty gleys, peaty podzols, peat, brown soils and mineral gleys. The soils are also classified under the NatureScot (2016) Carbon and Peatlands

[3] https://informatics.sepa.org.uk/CarbonCalculator/?ME1T-S2G5-Z22Uv2 (last accessed 21/04/21)

[4] National Soil Map of Scotland, http://map.environment.gov.scot/Soil_maps/?layer=1 (last accessed 08/09/2020)

Input	Source of Information
	Assessment as predominantly Class 3 (vegetation cover does not indicate priority peatland habitat) and Class 5 (vegetation cover does not indicate peatland habitat) with small occurrences of Class 1 (soils which are considered to be of national importance).
Average air temp. at site	Met Office November 2020 The minimum temperature was calculated from the minimum values across this time period (3.82º) and the maximum temperature was calculated from the maximum values across this time period (11.13º). The expected value was calculated as the average of the minimum and maximum values. (7.48º) Temperature based on 29 years (1981-2010) of data collected from the closest weather station to the Proposed Development. The Eskdalemuir (Dumfries and Galloway) Climate Station is positioned approximately 25 km east of the Proposed Development and remains at a comparable altitude giving a good idea of temperature and rainfall totals expected at the Proposed Development Area. https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvdxj13y (last accessed 06/11/2020)
Average depth of peat on site	Hydrology Department, Natural Power Consultants Ltd. Informed by peat probe data collection. The average of all the peat probe data collected across the site during the 100 m grid sampling, 1,373 total probes. 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 probing data focussed on infrastructure areas only. 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.
C content of dry peat	i2 Analytical Ltd results October 2020 – see Appendix A8.15. 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. Values calculated through lab analysis were: expected; 12.43, minimum; 7.3 and maximum; 15, however the tool does not allow you to enter a value below 19. Therefore, values input into the tool were: expected; 19.01, minimum; 19 and maximum; 19.02 (N.B. the tool requires different values for all three entries). This limitation does not reflect the true data that was collected however the values we selected to use were as low as possible to try and be representative of the actual raw data, see section A8.11 of this report for further discussion.
Extent of drainage	Hydrology Department, Natural Power Consultants Ltd. Based on site visits, the results of dipwell monitoring undertaken by Holden et al. 2011, literature review and previous experience on similar, unforested sites. (The main wind farm site not forested, and forestry felling detailed later in the report is as a result of clearance for the access route only.)

Input	Source of Information
Average water table depth	Hydrology Department, Natural Power Consultants Ltd. Values based on water table depth observations across the site during site visits and the results of dip well monitoring reported by Holden et al. 2011[5], other literature review and previous experience on similar, unforested sites.
Dry soil bulk density	i2 Analytical Ltd results October 2020 – see Appendix A8.15. 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 samples analysed at the laboratory which provided values for dry soil bulk density. -/+ 10% of the amalgamated value has been used as the tool does not allow the same value to be inserted into all three scenarios. Confirmed as acceptable by Energy Consents Unit (ECU).
Time for regeneration of bog plants	Ecology Department. Natural Power Consultants Ltd This has been estimated to be 10 years (7 years minimum and 25 years maximum). The time period for successful regeneration of bog plant species is dependent on numerous factors including relevant seed source, successional rate, the level of herbivore disturbance and the successful stabilisation of the water table in the restoration area. The proposed restoration areas are already vegetated, with bog forming species present. The proposed 6 ha area is active M17 and M18 blanket bog, with drainage ditches dug relatively recently and so it is expected this will restore to its natural state relatively quickly. The proposed 7 ha area is a mosaic of modified bog habitats, which was drained longer ago, and so recolonization by bog plants and restoration to active undamaged bog in this area will take longer. The values provided are based on the professional experience of project ecologists.
Carbon accumulation due to C fixation by bog plants	Values have been inserted from the online tool notes that quote published primary literature and NatureScot guidance values.
Area of forestry plantation to be felled	DGA Forestry LLP Approximately 5.13 ha is required to be felled and 5.13 ha will be restocked as compensatory planting. Therefore it is assumed there will be no net loss of forestry.
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	Geotechnical Department Natural Power Consultants Ltd. Four borrow pits within Proposed Development. Total estimation of expected area = 61,504 m^2 divide by 4 = 15,376. Therefore, length and width = 124 m x 124 m. +/-10% for min and max values, Minimum, 112 m x 112 m, maximum, 135 m x 135 m.
Average depth of peat removed from turbine foundations, hard	Hydrology Department, Natural Power Consultants Ltd. Informed by detailed peat probe data (i.e. Phase 1 and 2 peat surveys). As advised by the authors of the original Excel tool, the arithmetic mean was calculated from

[5] 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
standing and borrow pits	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 & Advisory Services Department Natural Power Consultants Ltd. The foundations will be made from reinforced concrete, delivered to the site. Assume a circular shape with 25 m diameter which is considered representative of a turbine of this size however this is indicative only. The value inputs into tool allow for excavation areas, working areas (4 m) and 10% tolerance for min and max. Dimensions for hardstanding considers the permanent crane hardstanding area, 50 m x 20 m including 5 m working area on all sides apart from side adjoining access track (to avoid double counting) = 60 m x 25 m. +/-10% for min and max values.
Volume of concrete	Pell Frischmann Total concrete volume = 13,450 m^3. 17 turbine foundations, 17 x 750 m^3 = 12,750 m^3. 2 met masts, 250 x 2 = 500 m^3. 1 control building, 1 x 200=200 m^3. +/-10% for min and max values.
Total length of track	Pell Frischmann 18,594 m of existing track length requiring upgrade and 19,071 m of excavated road. 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	Design & Advisory Services Department Natural Power Consultants Ltd. No floating roads were considered in the Carbon Balance Assessment tool to consider the worst case scenario, however it may be proposed to use floating road technique, as discussed in the Peat Management Plan.
Excavated road length	Design & Advisory Services Department Natural Power Consultants Ltd. This value covers 19,071 m of excavated roads. 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.
Excavated road width	Design & Advisory Services Department Natural Power Consultants Ltd. The expected scenario value of 19.9 m is based on 5 m running width, 2.5.m drainage/cable trench on one side (1 m drainage + 1.5 m cable trench) and then 2 m working area either side and 4.2 m batters either side. In some areas, batters would not be needed or working areas and batters may be wider therefore minimum and maximum values of 19.3 m and 20.5 m have been provided respectively -/+ 10% of the expected value. See Paragraph A4.8.5 which shows the calculation for weighted road width which takes into account new access tracks and upgrading of existing access tracks.
Average depth of peat for excavated roads	Informed by 100 m grid and detailed peat probe data collected. 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 A4.8.5 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	Design & Advisory Services Department Natural Power Consultants Ltd. There will be no rock filled roads.
Length of cable trenches	Design & Advisory Services Department 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	Design & Advisory Services and Hydrology Departments Natural Power Consultants Ltd. 41,964 m^3 of additional peat expected to be excavated. This input accounts for the substation, construction compound, met masts, and temporary laydown areas. Calculations are shown in Table A8.2 of this report.
Area of degraded bog to be improved	Ecology Department. Natural Power Consultants Ltd. The development's Environmental Impact Assessment Report (EIAR) predicted a loss or affect to approximately 12 ha of peatland habitat. There are 3 peatland restoration areas proposed in the Habitat management Plan (HMP). Bog restoration area = 5.8 ha, bog restoration search area = 7.2 ha and peatland restoration area = 2.2 ha. The bog restoration search area is an area of modified bog with some visible drainage apparent on aerial photography and so likely good potential for restoration. However it has not yet been subject to a restoration-potential site visit and assessment, Minimum is 8 ha (bog restoration area, plus 2 ha from the search area), Expected is 12 ha (bog restoration plus peatland restoration areas plus half of search area rounded up). Maximum is 16 ha (sum of the total size of the three areas, rounded up). The bog restoration is a form of peatland restoration via ditch blocking. What is referred to as 'peatland restoration' (2.2 ha) is an area of eroding peat where water is running off the hillside and washing peat away into the river, leaving hags and bare eroded peat faces.
Water table depth in degraded bog before and after improvement	Hydrology Department, Natural Power Consultants Ltd. The water table depths are based on field observations and an expectation that drained peat will have a lower water table around ditches as a result of de-watering. Values for after improvement are based on an assumption that rewetting measures (e.g. blocking drainage ditches) would increase water table depth. Consistent with findings of Holden et al. 2011.
Time required for hydrology and habitat of bog to return to its previous state on improvement	Ecology Department. Natural Power Consultants Ltd. The timescales provided are broad as effects of construction of the development have the potential to alter hydrological flows within peatland habitats from hydrological severance which cannot be restored post-construction. Consequently, areas of bog may be permanently affected by the development and will not return to their previous state. These losses have been considered in the development's EIAR and will be compensated in the development's Habitat Management Plan (HMP). Where hydrological severance does not occur then timescales are dependent on the restoration methods implemented at the time of construction, the vegetation available for restoration purposes and the level of previous destruction disturbance.

Input	Source of Information
	Based on figures in IUCN Peatland Restoration review.[6] Blocking techniques can achieve water table and biodiversity gains after the first year; minimum figure of 2 years therefore adopted as bog will not be significantly degraded by the end of construction. Most known gains accrue by around 5 years, but some gains are thought to accrue as late as c. 20 years after enhancement. 10 years taken as a cautious midpoint given that gains may well be front-loaded. The figures provided are based on the professional opinion of the project's ecologist and hydrologist.
Area of borrow pits to be restored	Geotechnical Department Natural Power Consultants Ltd. Same values used as area of borrow pits excavated.
Water table depth in borrow pits before and after improvement	Hydrology Department. Natural Power Consultants Ltd. The water table depths are based on field observations and an expectation that drained peat will have a lower water table around ditches as a result of de-watering. The values represent the target for water table depths at the restored surface in borrow pits to be restored to similar water table depths of the site prior to commencement of groundwork.
Time required for hydrology and habitat of borrow pits to return to its previous state on restoration (years)	Ecology Department. Natural Power Consultants Ltd This has been estimated to be 10 years (7 years minimum and 25 years maximum). The time period for successful regeneration of bog plant species is dependent on numerous factors including relevant seed source, successional rate, the level of herbivore disturbance and the successful stabilisation of the water table in the restoration area. The proposed restoration area is already vegetated, albeit with none bog-forming species, and so the rate of recolonisation (if variables area controlled sufficient) will be great than that of an area of bare peat. The values provided are based on the professional experience of project ecologists.
Water table depth around foundations and hardstandings before and after restoration	Hydrology Department. Natural Power Consultants Ltd. 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.
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 3, 2 and 5 years used. Based on professional judgement.
Will the hydrology of the site 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 site be restored on decommissioning?	Ecology Department. Natural Power Consultants Ltd No. At the moment, upon decommissioning, restoration of habitats is not guaranteed. There are no plans to reintroduce species using nurse crops or fertilisation, therefore a worst case scenario of "no restoration" has been input into the carbon calculator tool.

Source: Natural Power Consultants

A4.4 WIND FARM CO_2 EMISSION SAVINGS

A4.4.1 The amount of CO_2 emissions produced during energy production varies with the type of fuel used; therefore, the potential CO_2 savings from the Proposed Development depends on the type of fuel it replaces. The wind farm CO_2 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.

A4.4.2 Based on an averaged 6.2 MW turbine model scenario, the expected potential annual energy output of the Proposed Development is 252,062 MWh yr^{-1} (8,822,170 MWh over 35 years), with minimum and maximum potential outputs at 202,114 MWh yr^{-1} and 286,999 MWh yr^{-1} (see explanatory in footnote for calculation[7]).

A4.4.3 Based on the expected annual energy output of the Proposed Development (252,062 MWh yr-1), the potential expected emissions saved over; coal-fired electricity generation[8],is 231,897 tonnes of CO_2 per year (tCO_2 yr^{-1}); and over grid-mix generation[9] is 63,918tCO_2 yr^{-1} and over fossil-fuel mix generation[10] is 113,428 tCO_2 yr^{-1}.

A4.5 EMISSIONS DUE TO TURBINE LIFE

A4.5.1 Energy is consumed and associated carbon dioxide (CO_2) emissions are released during manufacture of the turbine components, construction of the site (including site tracks and turbine foundations etc.), and during the decommissioning of the development.

A4.5.2 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.

A4.5.3 The carbon calculator reveals an expected emissions figure of 94,782 tonnes of CO_2 (tCO_2) 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.

A4.6 CAPACITY REQUIRED DUE TO BACK UP

A4.6.1 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

6 Available online from: https://www.iucn-uk-peatlandprogramme.org/resources/commission-inquiry/work-commission-2011/peatland-restoration (last accessed 16/02021)

7 6.2 MW turbine model x 17 turbines x 0.273 capacity factor x 8760 (hours) = 252,062 $MWhyr^{-1}$

8 Based on assumption that coal fired plant emission factor (t CO_2 MWh^{-1}) is 0.92 (value used in last carbon calculator online tool that Natural Power had accessed).

9 Based on assumption that grid-mix emission factor (t CO_2 MWh^{-1}) is 0.25358 (value used in last carbon calculator online tool that Natural Power had accessed).

10 Based on assumption that fossil-mix emission factor (t CO_2 MWh^{-1}) is 0.45 (value used in last carbon calculator online tool that Natural Power had accessed).

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.

A4.6.2 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.

A4.6.3 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.

A4.6.4 The carbon calculator assumes that backup is provided by a fossil fuel mix of energy generation and reveals an expected emissions figure 72,710 tCO_2 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 7.7 months.

A4.7 LOSS OF CARBON FIXING POTENTIAL

A4.7.1 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 influence 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 5 m expected and 1 m and 15 m as minimum and maximum values respectively.

A4.7.2 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 not an accurate representation of the site's total habitat characteristics.

A4.7.3 Habitat loss calculations for the development have been recalculated based on the revised infrastructure and are discussed in Chapter 6 of the EIAR. The table in the Appendix A8.17, table A8.5 provides a summary of total effects to habitats as a results of the Proposed Development which shows that while blanket bog is the most extensive habitat within the Proposed Development, this has largely been avoided for the siting of infrastructure during the design process and not all of the habitats effected are peatland habitats.

A4.7.4 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 other types of habitats do exist on site and will also be lost. Furthermore, another input required for the assessment is the time required for regeneration of bog plants. This has been estimated to be 10 years (7 years minimum and 25 years maximum) as described in Table A8.1. This, in part, is based on the observation of the quality of the bog vegetation on site. 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.

A4.7.5 The carbon calculator reveals that the expected total emissions attributable to the loss of carbon accumulation by bog plants in equivalent 4,555 tCO_2 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 0.5 months. However, as previously described above, it is important to recognise that 100% bog/mire habitat cover is not an accurate description of the site's characteristics.

A4.8 LOSS OF CARBON DIOXIDE FROM REMOVED PEAT (DIRECT LOSS)

A4.8.1 The 2017 Peatland Survey Guidance 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). Peat soil is an organic soil which contains more than 60 per cent of organic matter and exceeds 50 centimetres in thickness.

A4.8.2 The peat depth data are taken from the low resolution peat study using a 100 m grid sample and the more detailed peat depth probing undertaken on the site. Overall, 4,341 peat depth measurements were taken across the Proposed Development to inform peat depths across the site. 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.

A4.8.3 Peat survey methodology was conducted in accordance with the guidance documentation 'Guidance on Developments on Peatland – Peatland Surveys 2017'[11]. The results from the detailed peat probe surveys are shown in Table 8.3.1 of Technical Appendix 8.3 Peat Management Plan. An interpolation of the results shows that the highest proportion (57 %) of recorded peat depths fell within the <0.5 m range, with the next highest proportion (26 %) within the ≥0.5 – <1.0 m range. The areas of deep peat (greater than 0.5 m) are largely located in the upper plateau areas across the Proposed Development, particularly across the east of the Proposed Development Area. To obtain site-specific information relating to the characteristics of the peat/soil, peat core samples were also collected and were logged in accordance with the Von Post Scale of Humification

A4.8.4 Carbon content of dry peat (% by weight) and dry soil bulk density (g cm^{-3}) were analysed in a laboratory (see Appendix A8.15 for results) and the expected (average values across all samples), minimum and maximum values should be inserted in the carbon calculator. As advised by the authors of the tool, it is acceptable to input minimum and maximum values of +/- 10-% into the tool, which is what should be inserted for dry soil bulk density. As explained in Table A8.1, the values based on laboratory results for carbon content of dry peat were too low for the tool, therefore minimum accepted values of 19 was inserted for minimum, 19.01 for expected and 19.02 for maximum (the tool only accepts different values for each scenario).

A4.8.5 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 tracks. However, under advice provided by the authors of the calculator, instead of simply reporting the length and width of new (excavated tracks), the widening/upgrading of existing access tracks (all excavated) has been accounted for in this assessment by calculating the weighted average width of tracks along the total length of new and upgraded 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:

  [19,071 m (expected length of new track) x 19.9 m (expected width)]

  + [18,594 (expected length of upgraded track) x 6.8 m (expected width of upgrade)

  = 505,952.1 m^2

  Then; 505,952.1 m^2 / 37,665 (total expected length of tracks) = 13.43 m expected weighted average width

[11] Available online from: https://www.gov.scot/Resource/0051/00517174.pdf (last accessed 09/09/2020)

The calculations for expected weighted peat depths were as follows:

[19,071 m (expected length of new track) x 0.6m (expected average peat depth)]

+ [18,594 (expected length of upgraded track) x 0.28 m (expected average depth for upgraded tracks)

= 2,358.2 m^2

Then; 16,648.92 m^2 / 37,665 (expected total length of tracks) = 0.44 m expected weighted average peat depth.

- The expected values for excavated new roads width discussed above include the running width Proposed access tracks have been assumed to accommodate a 5 m running width, and additional width to account for drainage/cable trench (2.5 m) on one side, (1 m drainage + 1.5 m cable trench) and then 2 m working area either side + 4.2m batters either side (Taken from 25 m interval spacing dataset for batters) giving a total running width of 19.9 m. In some areas, batters would not be needed or smaller than noted in expected scenario above (minimum scenario) or cable trench/working areas and batters may be wider (maximum scenario), therefore minimum and maximum values of 19.3 m and 20.5 m have been provided respectively.
- The expected values for upgrading of access roads widths discussed above include additional track width of 1.3 m on one side and drainage/cable trench (1.5 m) on one side, and a working area of 2 m on one side and batters of 2 m on one side providing an expected additional width of 6.8 m. In some areas, batters would not be needed (minimum scenario) or cable trench/working areas and batters may be wider (maximum scenario), therefore the minimum and maximum values of 6.5 m and 11 m have been provided respectively.
- Working areas, and excavation areas have been included around turbine foundations and we assume a circular shape of 25 m diameter however this is indicative only, (indicative dimensions of 29 m diameter, which includes an additional working area of 4 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/laydown/installation areas have also been included in the calculations around the hardstandings (an indicative dimension of 50 m x 20 m for hardstandings + 5 m working area = 60 m x 25 m, to avoid double counting the edge by the road).
- No floating roads have been considered so that the assessment can consider the worst case scenario.

A4.8.6 Some of these assumptions above will differ from those used to calculate peat extraction volumes within the Peat Management Plan (PMP). The working areas presented within this carbon balance assessment represent those areas where peat and/or peat vegetation may be removed or damaged/disturbed whereas the PMP investigates only those areas where peat is extracted and stored, then available for re-use. As such, the peat data reported in the carbon calculator inputs are considered to be precautionary and considered to be highly worst case. In fact, latest guidance states that peat depth measurements of less than 0.5 m are not categorised as peat (rather peat soils), and deep peat deposits are considered being >0.5 m in depth. Accordingly, in line with this guidance, the PMP excludes measurements of less than 0.5 m from the peat extraction volume calculations. However, this assessment uses these data as a worst case.

A4.8.7 The carbon calculator also requires information relating to other ancillary infrastructure not explicitly accounted for above, namely the substation and construction compound. 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 A4.2: Additional peat excavated calculations

Additional Peat Excavated			
	Expected	Minimum	Maximum
Substation (m^2)	6,600	5,346	7,986
Substations Average Peat Depth (m)	0.53	0.45	0.55
Construction Compound Area (m^2)	6,600	5,346	7,986
Construction Area Average Peat Depth (m)	0.53	0.25	0.8
Met Masts (m^2)	450	365	545
Met Masts Area Average Peat Depth (m)	0.62	0.1	0.95
Laydown Areas (m^2)	65,450	53,015	79,195
Laydown Areas Average Peat Depth (m)	0.53	0.49	0.57
Total Area of Peat Removed (m^2)	79,100	64,072	95,712
Total Volume of Peat Removed (m^3)	41,964	29,756	56,440

Source: Natural Power Consultants

A4.8.8 The carbon calculator calculates the total expected area of land lost due to the wind farm construction as 68.624 ha (does not include drained peat areas) and expected volume of peat removed over the footprint of the wind farm is expected to be 302,232.51 m^3. 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.

A4.8.9 The CO_2 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. The total expected amount of CO_2 loss, attributable to peat removal only, that is reported within the online submission is calculated to be 16,657 tCO_2 equivalent.

A4.9 LOSS OF CARBON DIOXIDE FROM DRAINED AREAS LEFT IN SITU (INDIRECT LOSS)

A4.9.1 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 CO_2 loss as an "indirect loss". The extent of the site 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 site and also topography. The carbon calculator, however, assumes no existing drainage on site and flat terrain which is not representative of the actual site characteristics. Therefore, results using this parameter should only be considered as indicative at best.

A4.9.2 Hydrological and site investigation specialists visually noted and recorded water table depths during surveys which informed the site design evolution. Extent of drainage is a reasonable estimation based on knowledge of the site (topography etc.), experience at similar sites and expert judgement. As such, a recommended average extent around the drainage feature of 5 m was considered as an appropriate expected average for the calculation. Values of 1 m and 15 m were inserted as inputs to represent best and worst case scenarios respectively.

A4.9.3 The total expected CO_2 loss from removed peat and from drained peat reported within the online tool submission is 16,657 tCO_2 equivalent.

A4.10 LOSS OF CARBON DIOXIDE FROM DOC AND POC LOSS

A4.10.1 Additional CO_2 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 CO_2.

A4.10.2 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).

A4.10.3 The carbon calculator calculates that there will be an expected 0.08 tCO_2 equivalent. lost due to DOC and POC leaching over the operational life of the wind farm.

A4.11 TOTAL LOSS OF CARBON DIOXIDE FROM IMPACT ON PEAT

A4.11.1 The following calculations on total loss of CO_2 from the impact on peat have been based on a number of key assumptions (some of which are built into the tool itself), specifically in relation 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;
- For some parameters (e.g. C content of peat, dry bulk density), the online tool assumes values will be entered within a restricted range. If the data values that have been collected from site do not fall within these ranges, then the end user is forced to insert the closest value that the tool permits. In the case of this assessment, the real data values for C content of peat (expected = 12.43, minimum = 7.3 and maximum = 15) were far lower than is allowed to be inserted in the tool which results in the tool misrepresenting this parameter. **As such, it is considered that the results that rely on the values for these parameters (i.e. loss of carbon dioxide for impacts on peat) are therefore misrepresented by the tool.**
- 5 m metre expected average extent of drainage to demonstrate a conservative expected scenario and 15 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 micrositing to further reduce impacts on peat.

A4.11.2 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 (values not available due to no access to online tool):

Table A4.3: Total loss of CO_2 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
	4,555	16,657	0.08
Total loss tonnes of CO_2 equivalent	21,212		

Source: Online Tool Reference: ME1T-S2G5-Z22U v2

A4.12 LOSS OF CARBON FIXING DUE TO FOREST FELLING

A4.12.1 Whilst there is no forestry on the ground where wind turbines are proposed, there is commercial forestry along the proposed access from the public road. There would be a woodland area of 5.13 ha felled to accommodate the Proposed Development (see also Chapter 12 for further detail on felling proposals). In accordance with the guidance for the carbon calculator the ‘area of felled plantation to be improved' is inserted as 0 ha into the carbon calculator tool as 5.13 ha of replanting and compensatory planting will be undertaken, therefore no net loss of forestry.

A4.13 CARBON GAIN DUE TO SITE IMPROVEMENT AND RESTORATION

A4.13.1 Restoration of areas within the site can reverse emissions and act as carbon storage, reducing the total CO_2 emissions as a result of the Proposed Development. The carbon calculator considers 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.

A4.13.2 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.

A4.13.3 The EIAR predicted a loss or effect to approximately 12 ha of peatland habitat. To compensate for these effects from construction and operation of the development area an area of at least 8 ha will be targeted for restoration (minimum value).

A4.13.4 This assessment accommodates for expected improvements to degraded bog, of which a minimum of 8 ha is proposed for bog restoration for the Proposed Development (see Table A4.1) and expected value of 12 ha and maximum value of 16 ha.

A4.13.5 The results report -777 tCO_2 equivalent.in carbon gains from the restoration measures in the expected scenario and -9,584 tCO_2 equivalent. 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.

A4.14 CARBON BALANCE SUMMARY

A4.14.1 Table A4.4 below reveals the carbon losses and carbon gains for each of the above parameters for the Proposed Development.

Table A4.4: Expected CO_2 losses and gains

Carbon Balance Input Parameter	Expected Results
1. Wind farm CO_2 emission saving over …	
Coal fired electricity generation (tCO_2yr^{-1})	231,897
Grid mix of electricity generation (tCO_2yr^{-1})	63,918
Fossil fuel mix of electricity generation (tCO_2yr^{-1})	113,428
Energy output from wind farm over lifetime (MWh)	8,822,170
CO_2 losses due to wind farm (tCO_2 eq.)	
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	94,782
3. Losses due to backup	72,710
4. Losses due to carbon fixing potential	4,555
5. Losses from soil organic matter	16,657
6. Losses due to DOC & POC leaching	0
7. Losses due to felling forestry	0
Total losses (tCO_2 eq.)	188,704
Total CO2 gains due to improvement of site (tCO_2 eq.)	
8a. Gains due to improvement of degraded bogs	0
8b. Gains due to improvement of felled forestry	0
8c. Gains due to restoration of peat from borrow pits	0
8d. Gains due to removal of drainage from foundations and hardstandings	-777
Total gains (tCO_2 eq.)	-777
Net CO2 emissions (tCO_2 eq.)	187,928

Source: *Online Tool Reference: ME1T-S2G5-Z22U v2: Payback Time and CO_2 emissions page.*

A4.14.2 The net emissions of CO_2 of the Proposed Development are calculated by deducting the total CO_2 gains produced by improvement and restoration of the Proposed Development Area from the total CO_2 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 A4.4 reveals the net CO_2 emissions.

A4.14.3 The wind farm CO_2 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.

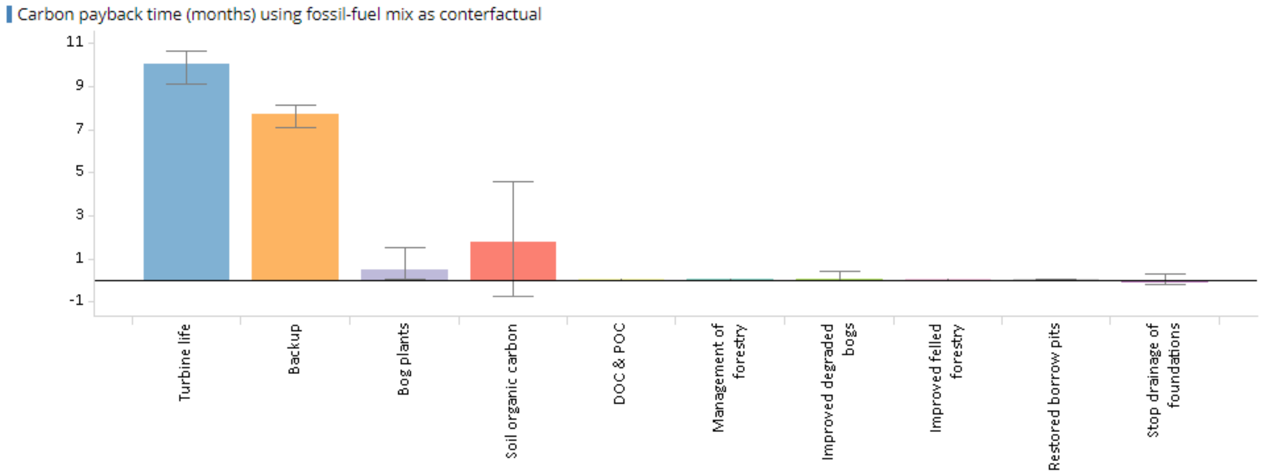
A4.14.4 The carbon payback time for the wind farm is calculated by comparing the net loss of CO_2 from the site due to wind farm development with the carbon savings achieved by the wind farm while displacing electricity generated from coal-fired generation, grid-mix generation or fossil-fuel mix electricity generation. Diagrams 1 and 2 below illustrate the payback times for the alternative proposed development in years.

Diagram 1: Carbon payback time for the Proposed Development

RESULTS	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO2 eq.)	187,928	145,303	241,418
Carbon Payback Time			
...coal-fired electricity generation (years)	0.8	0.6	1.3
...grid-mix of electricity generation (years)	2.9	2.0	4.7
...fossil fuel-mix of electricity generation (years)	1.7	1.1	2.7

Source: *Online Tool Reference: ME1T-S2G5-Z22U v2*

Diagram 2: Carbon payback time for different elements of the assessment



Source: *Online Tool Reference: ME1T-S2G5-Z22U v2*

A4.14.5 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 within 1.7 years, if it replaced 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 1.1 to 2.7 years respectively.

A4.14.6 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.

A4.14.7 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* ".

A4.14.8 In this context, the results of this assessment reveal that the net impact of the Proposed Development at Daer will be positive overall, as over the 35-year lifespan of the Proposed Development, it is expected to generate 33 years' worth of clean energy if it replaced fossil fuel electricity generation. In addition, over the expected **33 years that**

the wind farm is likely to be generating carbon-free electricity, this could result in expected **CO_2 emission savings over 3,743,124 tonnes**[12] of CO_2 when replacing fossil fuel electricity generation. As the negative payback period represents approximately 6% of the operational period and the positive contribution 94% it is possible to conclude that the positive contribution is statistically significant. The proposed development therefore illustrates a significantly positive net impact in terms of its contribution towards the reduction of greenhouse gas emissions from energy production.

A4.15 LABORATORY RESULTS

4041 mCERTS

Environmental Science

Sam Wainwright
Natural Power Consultants Limited
The Green House, Forrest Estate
St John's Town of Dalry
Castle Douglas
DG7 3XS

t: 01644430008

e: samw@naturalpower.com

i2 Analytical Ltd.
7 Woodshots Meadow,
Croxley Green
Business Park,
Watford,
Herts,
WD18 8YS

t: 01923 225404
f: 01923 237404
e: reception@i2analytical.com

Analytical Report Number : 20-33535

Project / Site name:	Daer Windfarm	**Samples received on:**	02/10/2020
Your job number:		**Sample instructed/ Analysis started on:**	02/10/2020
Your order number:	E55526	**Analysis completed by:**	13/10/2020
Report Issue Number:	1	**Report issued on:**	13/10/2020
Samples Analysed:	4 soil samples		

Ashleigh Cunningham

Signed:

Ashleigh Cunningham
Customer Service

For & on behalf of i2 Analytical Ltd.

Standard Geotechnical, Asbestos and Chemical Testing Laboratory located at: ul. Pionierów 39, 41 -711 Ruda Śląska, Poland.

Accredited tests are defined within the report, opinions and interpretations expressed herein are outside the scope of accreditation.

Standard sample disposal times, unless otherwise agreed with the laboratory, are :

soils - 4 weeks from reporting
leachates - 2 weeks from reporting
waters - 2 weeks from reporting
asbestos - 6 months from reporting

Excel copies of reports are only valid when accompanied by this PDF certificate.

Any assessments of compliance with specifications are based on actual analytical results with no contribution from uncertainty of measurement. Application of uncertainty of measurement would provide a range within which the true result lies. An estimate of measurement uncertainty can be provided on request.

Iss No 20-33535-1 Daer Windfarm

This certificate should not be reproduced, except in full, without the express permission of the laboratory.
The results included within the report relate only to the sample(s) submitted for testing.

Page 1 of 4

[12] Calculation is 33 years x 113,428 tCO_2 (as shown in Table A4.4 and online submission)

Analytical Report Number: 20-33535

Project / Site name: Daer Windfarm
Your Order No: E55526

Lab Sample Number				1638889	1638890	1638891	1638892	
Sample Reference				T4	T31	T35	T36	
Sample Number				None Supplied	None Supplied	None Supplied	None Supplied	
Depth (m)				0.40	0.60	0.50	1.10	
Date Sampled				08/09/2020	08/09/2020	08/09/2020	08/09/2020	
Time Taken				None Supplied	None Supplied	None Supplied	None Supplied	
Analytical Parameter (Soil Analysis)	**Units**	**Limit of detection**	**Accreditation Status**					
Stone Content	%	0.1	NONE	< 0.1	< 0.1	< 0.1	< 0.1	
Moisture Content	%	N/A	NONE	66	91	80	82	
Total mass of sample received	kg	0.001	NONE	1.0	1.0	0.70	0.70	

General Inorganics

pH - Automated	pH Units	N/A	MCERTS	U/S*	U/S*	U/S*	3.7	
Total Organic Carbon (TOC)	%	0.1	MCERTS	13	15	15	7.3	

*U/S - Unsuitable for analysis, samples absorbed all water used for extraction.

Analytical Report Number : 20-33535

Project / Site name: Daer Windfarm

* These descriptions are only intended to act as a cross check if sample identities are questioned. The major constituent of the sample is intended to act with respect to MCERTS validation. The laboratory is accredited for sand, clay and loam (MCERTS) soil types. Data for unaccredited types of solid should be interpreted with care.

Stone content of a sample is calculated as the % weight of the stones not passing a 10 mm sieve. Results are not corrected for stone content.

Lab Sample Number	Sample Reference	Sample Number	Depth (m)	Sample Description *
1638889	T4	None Supplied	0.40	Brown loam with vegetation.
1638890	T31	None Supplied	0.60	Brown loam with vegetation.
1638891	T35	None Supplied	0.50	Brown loam and clay with vegetation.
1638892	T36	None Supplied	1.10	Brown loam and clay with vegetation.

4041

Analytical Report Number : 20-33535

Project / Site name: Daer Windfarm

Water matrix abbreviations: Surface Water (SW) Potable Water (PW) Ground Water (GW) Process Water (PrW)

Analytical Test Name	Analytical Method Description	Analytical Method Reference	Method number	Wet / Dry Analysis	Accreditation Status
Moisture Content	Moisture content, determined gravimetrically. (30 oC)	In house method.	L019-UK/PL	W	NONE
pH in soil (automated)	Determination of pH in soil by addition of water followed by automated electrometric measurement.	In house method.	L099-PL	D	MCERTS
Stones content of soil	Standard preparation for all samples unless otherwise detailed. Gravimetric determination of stone > 10 mm as % dry weight.	In-house method based on British Standard Methods and MCERTS requirements.	L019-UK/PL	D	NONE
Total organic carbon (Automated) in soil	Determination of organic matter in soil by oxidising with potassium dichromate followed by titration with iron (II) sulphate.	In house method.	L009-PL	D	MCERTS

For method numbers ending in 'UK' analysis have been carried out in our laboratory in the United Kingdom.
For method numbers ending in 'PL' analysis have been carried out in our laboratory in Poland.
Soil analytical results are expressed on a dry weight basis. Where analysis is carried out on as-received the results obtained are multiplied by a moisture correction factor that is determined gravimetrically using the moisture content which is carried out at a maximum of 30oC.

Iss No 20-33535-1 Daer Windfarm

Page 4 of 4

SUMMARY REPORT

Summary of Density by Linear Measurement Test Results

Tested in Accordance with: BS EN ISO 17892-2: 2014: Clause 5.1

i2 Analytical Ltd
Unit 8 Harrowden Road
Brackmills Industrial Estate
Northampton NN4 7EB

4041

Client: Natural Power Consultants Limited
Client Address: The Green House, Forrest Estate, St John's Town of Dalry, Castle Douglas, DG7 3XS
Contact: Sam Wainwright
Site Address: Daer WF

Client Reference: 13484UKC
Job Number: 20-16433
Date Sampled: Not Given
Date Received: 23/06/2020
Date Tested: 30/07/2020
Sampled By: Client - CH & EM

Testing carried out at i2 Analytical Limited, ul. Pionierow 39, 41-711 Ruda Slaska, Poland

Test results

Laboratory Reference	Hole No.	Sample Reference	Sample Depth Top (m)	Sample Depth Base (m)	Type	Description	Remarks	Bulk density (Mg/m3)	Dry density (Mg/m3)	WC (%)
1545953	1016	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.00	0.23	333
1545956	1045	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.00	0.23	332
1545945	1381 Track	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.01	0.22	354
1545950	265 Track	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		0.98	0.32	210
1545948	643	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.01	0.21	387
1545946	836	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.02	0.17	491
1545954	T24 1376	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		0.98	0.40	144
1545952	T31 1319	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		0.99	0.31	220
1545949	T33 1164	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.04	0.14	646
1545955	T36	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.00	0.30	238

Note: WC - Water Content

Comments:

Signed:

Marcin Szulc
PL Deputy Geotechnical Laboratory Manager
for and on behalf of i2 Analytical Ltd

Page 1 of 1

Date Reported: 09/10/2020

GF 166.12

UKAS TESTING 4041

SUMMARY REPORT

Summary of Density by Linear Measurement Test Results

Tested in Accordance with: BS EN ISO 17892-2: 2014: Clause 5.1

i2 Analytical Ltd
Unit 8 Harrowden Road
Brackmills Industrial Estate
Northampton NN4 7EB

i2 Analytical Environmental Science

Client: Natural Power Consultants Limited
Client Address: The Green House, Forrest Estate, St John's Town of Dalry, Castle Douglas, DG7 3XS
Contact: Sam Wainwright
Site Address: Daer WF

Client Reference: 13484UKC
Job Number: 20-16433
Date Sampled: Not Given
Date Received: 23/06/2020
Date Tested: 30/07/2020
Sampled By: Client - CH & EM

Testing carried out at i2 Analytical Limited, ul. Pionierow 39, 41-711 Ruda Slaska, Poland

Test results

Laboratory Reference	Hole No.	Sample: Reference	Depth Top (m)	Depth Base (m)	Type	Description	Remarks	Bulk density (Mg/m3)	Dry density (Mg/m3)	WC (%)
1545957	T4	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.04	0.14	641
1545947	T7 1444	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		1.03	0.16	533
1545951	T8 1220	Not Given	Not Given	Not Given	D	Dark brown TOPSOIL with organic		0.99	0.31	217

Note: WC - Water Content

Comments:

Opinions and interpretations expressed herein are outside of the scope of the UKAS Accreditation. This report may not be reproduced other than in full without the prior written approval of the issuing laboratory. The results included within the report relate only to the sample(s) submitted for testing.

Signed:

Marcin Szulc
PL Deputy Geotechnical Laboratory Manager
for and on behalf of i2 Analytical Ltd

Page 1 of 1

Date Reported: 09/10/2020

GF 166.12

UKAS TESTING 4041

SUMMARY REPORT

Summary of Density by Linear Measurement Test Results

Tested in Accordance with: BS EN ISO 17892-2: 2014: Clause 5.1

i2 Analytical Ltd
Unit 8 Harrowden Road
Brackmills Industrial Estate
Northampton NN4 7EB

i2 Analytical Environmental Science

Client: Natural Power Consultants Limited
Client Address: The Green House, Forrest Estate, St John's Town of Dalry, Castle Douglas, DG7 3XS
Contact: Sam Wainwright
Site Address: Daer Windfarm

Client Reference: 20-33535
Job Number: 20-33535
Date Sampled: 08/09/2020
Date Received: 02/10/2020
Date Tested: 15/10/2020
Sampled By: Not Given

Testing carried out at i2 Analytical Limited, ul. Pionierow 39, 41-711 Ruda Slaska, Poland

Test results

Laboratory Reference	Hole No.	Sample: Reference	Depth Top (m)	Depth Base (m)	Type	Description	Remarks	Bulk density (Mg/m3)	Dry density (Mg/m3)	WC (%)
1638892	T36	Not Given	1.10	Not Given	T	Black PEAT		1.01	0.18	458

Note: WC - Water Content

Comments:

Opinions and interpretations expressed herein are outside of the scope of the UKAS Accreditation. This report may not be reproduced other than in full without the prior written approval of the issuing laboratory. The results included within the report relate only to the sample(s) submitted for testing.

Signed:

Aleksandra Jurochnik
PL Technical Reviewer
for and on behalf of i2 Analytical Ltd

Page 1 of 1

Date Reported: 19/10/2020

GF 166.12

A4.16 CARBON CALCULATOR INPUT DATA

21/04/2021 Reference: ME1T-S2G5-Z22U v2

Carbon Calculator v1.6.1
Daer Location: 55.342018 -3.601934
Natural Power

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	17	17	17	Technical Appendix 4.0, Table A4.1
Duration of consent (years)	35	35	35	Technical Appendix 4.0, Table A4.1
Performance				
Power rating of 1 turbine (MW)	6.2	5.8	6.6	Technical Appendix 4.0, Table A4.1
Capacity factor	27.3	23.4	29.2	Technical Appendix 4.0, Table A4.1
Backup				
Fraction of output to backup (%)	5	5	5	Technical Appendix 4.0, Table A4.1
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	Technical Appendix 4.0, Table A4.1
Average annual air temperature at site (°C)	7.48	3.82	11.13	Technical Appendix 4.0, Table A4.1
Average depth of peat at site (m)	0.63	0.6	0.66	Technical Appendix 4.0, Table A4.1
C Content of dry peat (% by weight)	19.01	19	19.02	Technical Appendix 4.0, Table A4.1
Average extent of drainage around drainage features at site (m)	5	1	15	Technical Appendix 4.0, Table A4.1
Average water table depth at site (m)	0.3	0.1	0.4	Technical Appendix 4.0, Table A4.1

1/5

21/04/2021 Reference: ME1T-S2G5-Z22U v2

Input data	Expected value	Minimum value	Maximum value	Source of data
Dry soil bulk density (g cm^{-3})	0.24	0.19	0.29	Technical Appendix 4.0, Table A4.1
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	10	7	25	Technical Appendix 4.0, Table A4.1
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25	0.12	0.31	Technical Appendix 4.0, Table A4.1
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	Technical Appendix 4.0, Table A4.1
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	3.6	3.5	3.7	Technical Appendix 4.0, Table A4.1
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	0.92	0.92	0.92	
Grid-mix emission factor (t CO2 MWh^{-1})	0.25358	0.25358	0.25358	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.45	0.45	0.45	
Borrow pits				
Number of borrow pits	4	4	4	Technical Appendix 4.0, Table A4.1
Average length of pits (m)	124	112	135	Technical Appendix 4.0, Table A4.1
Average width of pits (m)	124	112	135	Technical Appendix 4.0, Table A4.1
Average depth of peat removed from pit (m)	0.27	0.19	0.34	Technical Appendix 4.0, Table A4.1
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	29	26	32	Technical Appendix 4.0, Table A4.1
Average width of turbine foundations (m)	29	26	32	Technical Appendix 4.0, Table A4.1
Average depth of peat removed from turbine foundations(m)	0.53	0.49	0.57	Technical Appendix 4.0, Table A4.1
Average length of hard-standing (m)	60	54	66	Technical Appendix 4.0, Table A4.1
Average width of hard-standing (m)	25	22.5	27.5	Technical Appendix 4.0, Table A4.1

2/5

21/04/2021 Reference: ME1T-S2G5-Z22U v2

Input data	Expected value	Minimum value	Maximum value	Source of data
Average depth of peat removed from hard-standing (m)	0.53	0.49	0.57	Technical Appendix 4.0, Table A4.1
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	13450	12105	14795	Technical Appendix 4.0, Table A4.1
Access tracks				
Total length of access track (m)	37665	33899	41432	Technical Appendix 4.0, Table A4.1
Existing track length (m)	0	0	0	Technical Appendix 4.0, Table A4.1
Length of access track that is floating road (m)	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	
Length of access track that is excavated road (m)	37665	33899	41432	Technical Appendix 4.0, Table A4.1
Excavated road width (m)	13.43	12.68	16.01	Technical Appendix 4.0, Table A4.1
Average depth of peat excavated for road (m)	0.44	0.4	0.48	Technical Appendix 4.0, Table A4.1
Length of access track that is rock filled road (m)	0	0	0	
Rock filled road width (m)	0	0	0	
Rock filled road depth (m)	0	0	0	
Length of rock filled road that is drained (m)	0	0	0	
Average depth of drains associated with rock filled roads (m)	0	0	0	
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	Technical Appendix 4.0, Table A4.1
Average depth of peat cut for cable trenches (m)	0	0	0	Technical Appendix 4.0, Table A4.1
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	41964	29756	56440	Technical Appendix 4.0, Table A4.1
Area of additional peat excavated (m^2)	79100	64072	95712	Technical Appendix 4.0, Table A4.1
Peat Landslide Hazard				

3/5

21/04/2021 Reference: ME1T-S2G5-Z22U v2

Input data	Expected value	Minimum value	Maximum value	Source of data
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed
Improvement of C sequestration at site by blocking drains, restoration of habitat etc				
Improvement of degraded bog				
Area of degraded bog to be improved (ha)	12	8	16	Technical Appendix 4.0, Table A4.1
Water table depth in degraded bog before improvement (m)	0.5	0.4	1	Technical Appendix 4.0, Table A4.1
Water table depth in degraded bog after improvement (m)	0.4	0.3	0.7	Technical Appendix 4.0, Table A4.1
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10	2	20	Technical Appendix 4.0, Table A4.1
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	10	2	20	Technical Appendix 4.0, Table A4.1
Improvement of felled plantation land				
Area of felled plantation to be improved (ha)	0	0	0	Technical Appendix 4.0, Table A4.1
Water table depth in felled area before improvement (m)	0	0	0	
Water table depth in felled area after improvement (m)	0	0	0	
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	0	0	0	
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	0	0	0	
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	1.5	1.3	1.8	Technical Appendix 4.0, Table A4.1
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0.4	0.2	0.5	Technical Appendix 4.0, Table A4.1
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0.3	0.1	0.4	Technical Appendix 4.0, Table A4.1
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	10	7	25	Technical Appendix 4.0, Table A4.1
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	10	7	25	Technical Appendix 4.0, Table A4.1

4/5

21/04/2021 Reference: ME1T-S2G5-Z22U v2

Input data	Expected value	Minimum value	Maximum value	Source of data
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.4	0.2	0.5	Technical Appendix 4.0, Table A4.1
Water table depth around foundations and hardstanding after restoration (m)	0.3	0.1	0.4	Technical Appendix 4.0, Table A4.1
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	3	2	5	Technical Appendix 4.0, Table A4.1
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you attempt to block any gullies that have formed due to the windfarm?	Yes	Yes	Yes	Technical Appendix 4.0, Table A4.1
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes	Yes	Yes	Technical Appendix 4.0, Table A4.1
Will the habitat of the site be restored on decommissioning?	No	No	No	
Will you control grazing on degraded areas?	No	No	No	Technical Appendix 4.0, Table A4.1
Will you manage areas to favour reintroduction of species	No	No	No	Technical Appendix 4.0, Table A4.1
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

5/5

A4.17 SUMMARY OF TOTAL EFFECTS TO HABITATS

Table A4.5: Summary of total effects to habitats

Phase 1 Habitat type	NVC Community	Area in Proposed Development Area (ha)	Area lost to Proposed Development (ha)	Peatland Habitat Y/N
A1.1.1 Semi-natural broadleaved woodland	W7: *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland	0.8	0.05	N
A1.1.2 Plantation broadleaved woodland	W7: *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland	2.3	0.1	N
A1.1.2 Plantation broadleaved woodland	W11: *Quercus petraea-Betula pubescens- Oxalis acetosella* woodland OR None			N
A1.2.2 Plantation coniferous woodland	No	118.3	4.1	N
A1.3.2 Plantation mixed woodland	No	4.3	0.1	N
A2 Scrub	W7: *Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum*	1.9	0.1	N
A2 Scrub	W11: *Quercus petraea-Betula pubescens- Oxalis acetosella*; W4 *Betula pubescens-Molinia caerulea* woodlands OR None			N
A3.1 Broadleaved parkland	No	0.6	0.04	N
A4.2 Recently felled coniferous woodland	No	26.0	1.4	N
B1.1 Unimproved acid grassland	U5: *Nardus stricta-Galium saxatile*; U6: *Juncus squarrosus-Festuca ovina* grasslands	215.0	0.7	N
B1.2 Semi-improved acid grassland	U2: *Deschampsia flexuosa*; U4: *Festuca ovina-Agrostis capillaris-Galium saxatile* grasslands	56.1	0.5	N

Phase 1 Habitat type	NVC Community	Area in Proposed Development Area (ha)	Area lost to Proposed Development (ha)	Peatland Habitat Y/N
B2 Neutral grassland	MG5: *Cynosurus cristatus-Centaurea nigra* grassland	17.0	0	N
B2 Neutral grassland	MG9: *Holcus lanatus-Deschampsia cespitosa* grassland; MG10: *Holcus lanatus-Juncus effusus* rush-pasture	3.4	0.03	N
B3 Calcareous grassland	CG10: *Festuca ovina-Agrostis capillaris* grassland	26.7	0	N
B4 Improved grassland	MG6: *Lolium perenne-Cynosurus cristatus* grassland; MG7: *Lolium perenne* leys	15.9	0.3	N
B5 Marshy grassland	M23: *Juncus effusus/ acutiflorus-Galium palustre* mire	348.7	1.9	N
B5 Marshy grassland	M27: *Filipendula ulmaria-Angelica sylvestris* mire			N
B5 Marshy grassland	MG9: *Holcus lanatus-Deschampsia cespitosa* grassland; MG10: *Holcus lanatus-Juncus effusus* rush-pasture; M25: *Molinia caerulea-Potentilla erecta* mire			N
B6 Poor semi-improved grassland	MG6: *Lolium perenne-Cynosurus cristatus* grassland	11.9	0.06	N
C1 Bracken	U20: *Pteridium aquilinum-Galium saxatile* community	1.2	0.3	N
C3.2 Tall herb and fen: non-ruderal	No	1.4	0.01	N
D1.1 Acid dry dwarf shrub heath	H10: *Calluna vulgaris-Erica cinerea*; H12: *Calluna vulgaris-Vaccinium myrtillis*; H21: *Vaccinium myrtillis-Racomitrium lanuginosum* heaths	3.2	0	N
D2/D5 Wet dwarf shrub heath/acid grassland mosaic	M15: *Scirpus cespitosus-Erica tetralix* wet heath	23.8	0.06	N
E1.6.1 Blanket bog	M17: *Scirpus cespitosus-Eriophorum vaginatum*; M18: *Erica tetralix-Sphagnum papillosum*; M19: *Calluna vulgaris- Eriophorum vaginatum* blanket mires; M2: *Sphagnum cupsidatum/recurvum*; M3: *Eriophorum angustifolium* bog pools	610.3	3.9	Y
E1.7 Wet modified bog	M15: *Scirpus cespitosus-Erica tetralix* wet heath; M17: *Scirpus cespitosus-Eriophorum vaginatum* blanket mire; M25: *Molinia caerulea-Potentilla erecta* mire (when on peat >0.5 m deep)	355.3	3.3	Y
E1.8 Dry modified bog	M19: *Calluna vulgaris-Eriophorum vaginatum*; M20: *Eriophorum vaginatum* blanket mires	137.6	1.1	Y
E2.1 Acid/neutral flush/spring	M4: *Carex rostrata-Sphagnum recurvum* mire	29.2	0.01	N
E2.1 Acid/neutral flush/spring	M6: *Carex echinata-Sphagnum recurvum auriculatum* mire			N
E2.1 Acid/neutral flush/spring	M29: *Hypericum eloides-Potamogeton polygonifolius* spring			N
E2.2 Basic flush/spring	M11: *Carex demissa-Saxifraga aizoides* mire	55.9	0	N
E2.2 Basic flush/spring	M10: *Carex dioica-Pinguicula vulgaris* mire			N
E2.2 Basic flush/spring	M37: *Cratoneuron commutatum-Festuca rubra* spring			N
E2.3 Bryophyte dominated flush and spring	M32: *Philonutus fontana-Saxifraga stellaris* spring	0.3	0	N
F1 Swamp	S10: *Equisetum fluvitale*; S12: *Typha latifolia*; S19: *Eleocharis palustre* swamps	0*	0	N

Source: Natural Power