VATTENFALL

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Appendix 8.4

Carbon Balance Assessment

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Glossary

Term	Definition
Environmental Impact Assessment	Environmental Impact Assessment (EIA) is a means of carrying out, in a systematic way, an assessment of the likely significant environmental effects from a development.
Environmental Impact Assessment Regulations	The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (EIA Regulations).
Environmental Impact Assessment Report	A document reporting the findings of the EIA and produced in accordance with the EIA Regulations.
The Proposed Development	The South Kyle II Wind Farm Project.
The Proposed Development Area	The area within the “Site boundary” as illustrated on EIAR Volume 2a, Figure 1.1 within which the Proposed Development will be located
Developer	In the event of the Proposed Development being granted Section 36 Consent, this is the Company developing the Project.

List of Abbreviations

Abbreviation	Description
CO_2	Carbon Dioxide
DETS	Derwentside Environmental Testing Services Ltd.
DOC	Dissolved Organic Carbon
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
FLS	Forestry and Land Scotland
ha	Hectare
MW	Mega watt
MWh	Mega watt per hour
MWh yr^{-1}	Mega watt per hour per year
NVC	National Vegetation Classification
POC	Particulate Organic Carbon
SEPA	Scottish Environment Protection Agency
SNH	Scottish Natural Heritage
$tCO_2\ yr^{-1}$	Tonnes of CO_2 per year
Vattenfall	Vattenfall Wind Power Ltd

8.4. Carbon Balance Assessment

8.4.1. This report has been prepared by Natural Power Consultants Ltd. and describes the carbon balance assessment undertaken for South Kyle II Wind Farm (hereafter known as the Proposed Development) which consists of 11 turbines and ancillary infrastructure. This report presents the carbon balance findings for the Proposed Development and has been produced to assist consultees and Scottish Ministers 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.

8.4.2. This report should be read in conjunction with the Geology, Hydrology and Hydrogeology (Volume 1, Chapter 8), Ecology and Biodiversity (Volume 1, Chapter 6), and Project Description (Volume 1, Chapter 3) chapters and relevant appendices of the Environmental Impact Assessment Report (EIAR) which describe the Proposed Development in more detail and provide important information on the peat resource within the area.

8.4.3. The online version of the carbon calculator is the latest version of the tool but is currently unavailable due to technical difficulties with no date confirmed as to when it will be made available online (pers. comms. with Natural Power). As a result, this appendix has made use of the MS Excel based assessment tool, version 2.14.1 (last updated January 2023). A Senior Case Officer at the Energy Consents Unit (email dated 28/01/2025) shared the tool and confirmed that it could be used by developers in lieu of the online tool. Data will be uploaded to the online tool when it becomes available again.

Scope

8.4.4. 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 typically make use of the carbon calculator tool (Scottish Government, 2022), 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

8.4.5. The carbon balance assessment has been undertaken in accordance with guidance[1] ‘Calculating Carbon Losses & Savings from Wind Farms on Scottish Peatlands – Technical Note 2.10.0’[2]. As well as Technical Note 2.10.0, 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 Windfarms Located On Peatlands – Update Of The Scottish Government Carbon Calculator Tool (2011);
- Scottish Natural Heritage (SNH) (now NatureScot): 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);
- 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); and
- Scottish Government, SNH and SEPA - Peatland Survey - Guidance on Developments on Peatland – 2017.

[1] Available online from: http://www.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/17852-1/CSavings/CCguidance2-10-0 (accessed 20/02/2025)

[2] Available online from: https://www.gov.scot/publications/calculating-carbon-savings-wind-farms-scottish-peat-lands-new-approach/pages/13/ (accessed 14/02/2025)

8.4.6. 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, forestry and site investigation specialists.

8.4.7. Version 2.14.1 of the carbon assessment tool is the latest version of the offline tool available (as of 28th April 2024). The tool inputs are presented in Annex B of this report and the sources of the input data and the detailed information that is inserted to conduct the analysis is presented in Table A8.4.1 below. 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 worse-case values were used to ensure that the assessment presented a worse-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 the Developer.

8.4.8. Within the inputs to this assessment, excavation/working areas and drainage/cable trench areas have been included within the infrastructure dimensions to attempt to account for any damage/disturbance to peat over and above actual peat extraction or removal. Hence, some of the infrastructure dimensions within this assessment may vary slightly from those presented in Volume 1, Chapter 3: Project Description, as dimensions within this assessment also include these working and disturbance areas.

8.4.9. In addition, some of the peat excavated volumes reported within this assessment will also differ from those reported within Technical Appendix 8.1 Peat Management Plan (PMP) as this assessment includes those areas where peat and/or peat vegetation may be impacted or damaged/disturbed (e.g. due to working areas or drainage) whereas the PMP investigates only those areas where peat is extracted, stored and then made available for re-use. As such, the peat volumes reported in the carbon balance assessment will be different from those reported in the PMP and are more precautionary.

8.4.10. It is important to note that the tool does not account for the measures that will be implemented to store and re-use excavated peat. Technical Appendix 8.1 identifies that peat will be re-used where possible and will therefore not be lost (and will therefore retain its carbon content). Therefore, the tool has an inherent assumption that all removed and disturbed peat will be lost and will emit carbon as a worst case.

8.4.11. Therefore, this carbon balance assessment has been undertaken to provide an indication (as the tool only provides an indicatively quantitative assessment) of the worst-case net carbon dioxide (CO_2) losses potentially resulting from the Proposed Development. It also considers carbon losses resulting from turbine life and back-up electricity required for wind power and emissions from disturbed peat.

Table 8.4.1: Record of Data Sources

Input	Source of Information
Turbine capacity and lifespan	Up to 11 turbines, each with an expected, and maximum, rated output of 8.4 MW. Fixed lifespan is expected up to 40 years. This information was communicated by the developer.
Capacity factor	Department for Business, Energy & Industrial Strategy (BEIS)[3] Scottish onshore wind average of 2020-2024 data with minimum and maximum average annual values across this period (Energy Trends, Table 6.1 Renewable electricity capacity and generation, Scotland Qtr dataset). Load factor statistics obtained from https://www.gov.uk/government/statistics/energy-trends-section-6-renewables (accessed on 13/02/2025). **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 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% to the National grid.
Type of peatland	In the tool, the choice of peatland habitats is limited to acid bog or fen. Acid bog has been chosen as this is considered to best reflect the peatland characteristic of the site.
Average air temp. at site	Site specific temperature based on 29 years (1991-2020) data collected from the closest **Met Office** weather station to the Proposed Development. The Saughall Climate Station is positioned approximately 30 km north-east of the Proposed Development. The expected value is the average annual temperature over the data collection period. 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/gcuurcfer (accessed 13/02/2025).
Average depth of peat on site	Informed by peat probe data collection. The average of all the peat probe data collected across the site boundary (over 2000 peat probes) during Phase 1. 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 focused 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	Based on laboratory analysis of peat cores collected from site. See Annex A at the end of this document. Five peat cores were collected from the Proposed Development area at turbine locations. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value (37.2), and the minimum (32.05) and maximum values (42.35) represent the lower and upper bound values of the 95% confidence intervals of the sample data collected.
Extent of drainage	No site-specific measurements have been taken so values are based on observations during site visits and previous experience on similar upland forested sites.
Average water table depth	No site-specific measurements have been taken so these values are based on water table depth observations across the site boundary during site visits, as well as the

[3] BEIS existed until 2023 when it was split to form the Department for Business and Trade (DBT), the Department for Energy Security and Net Zero (DESNZ) and the Department for Science, Innovation and Technology (DSIT). Responsibility for national security and investment policy has gone to the Cabinet Office. Department for Business, Energy & Industrial Strategy - GOV.UK [Accessed 28/04/2025]

Input	Source of Information
	water content and von Post results from peat cores taken at turbine locations. The water table across the site was determined as fairly low as the site is forested with multiple drainage furrows as well as drainage ditches along tracks.
Dry soil bulk density	Based on laboratory analysis of peat cores collected from site. See Annex A at the end of this document. Five peat cores were collected from the Proposed Development area at turbine locations. As advised by the authors of the original Excel tool, the arithmetic mean was calculated from this data to represent the 'expected' value (0.14), and the minimum (0.09) and maximum values (0.19) represent the lower and upper bound values of the 95% confidence intervals of the sample data collected.
Time for regeneration of bog plants	This parameter has been estimated to be 15 years (10 years minimum and 20 years maximum) by the project ecologist. 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 a restoration area. Opportunities for habitat management and potential peat restoration have been investigated and are reported in the Outline Biodiversity Enhancement and Restoration Plan (BERP) presented in Chapter 6: Ecology of the EIAR. To present a worst-case scenario for this assessment however, it is assumed that no peat restoration will take place.
Carbon accumulation due to C fixation by bog plants	Values have been taken from the guidance notes of the carbon calculator tool that quote published primary literature and NatureScot guidance values.
Area of forestry plantation to be felled	A total of 210.1 ha will require to be felled to enable the construction and operation of the Proposed Development. However, 131.1 ha will be replanted post-construction of the wind farm, so the expected value for total felling for wind farm and grid is 79.0 ha. Minimum and maximum values are +/- 10% of the expected value. A commitment has been made for compensatory planting (see EIAR Volume 1, Chapter 12) and therefore, after compensatory planting, the resulting net loss of forestry for the proposed development will be 0 ha. However, a precautionary and worst-case approach has been taken that does not account for this, as the compensatory planting may be offsite. The average rate of carbon sequestration in timber parameter has employed the tool guidance note provided in Cannell, 1999)
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	Stone on site will be won from existing onsite quarry for use in construction of turbines and hardstandings, as required.

Input	Source of Information
Average depths of peat removed from infrastructure	Detailed construction information for each turbine and hardstanding has been included within the tool. Informed by 100 m grid and multiple detailed surveys peat probe data within the 100 m micrositing allowance areas. Over 1000 probes were collected for turbine and hardstandings data with some overlap due to the adjacent nature of the infrastructure. These values are derived from interrogation of the peat depth data collected underlying each type of infrastructure including micrositing areas. 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	Turbine dimension inputs in the maximum scenario are based on a 19.8 m diameter foundation with maximum working areas of up to 12.5 m at the surface and bottom of the excavation. Expected and minimum scenarios employ the same size foundation diameter with smaller working areas (10 m, 5 m). The Excel tool uses square foundations, so equivalent square areas are 30 m, 25 m and 32 m squares. Dimensions for the worst-case candidate turbine hardstandings are based on the footprints shown in EIAR Volume 2a, Figure 3.3 (~ 7,400 m^2 each). The actual crane pad and hardstanding areas as shown in Figure 3.3 are less than 7,400 m^2 however, to represent a worst case, working areas and variations in the final size of hardstandings have been accommodated into each scenario such that maximum and minimum areas are 9,000 m^2 and 6,500 m^2. The hardstanding infrastructure will overlap the foundation in places so there is also an element of double counting here.
Volume of concrete	Based on approximately 830 m^3 for each turbine base, plus some allowance for substation and transformer elements if they are external to the turbine on the turbine foundation. Minimum and maximum scenarios are +/- 10% of expected scenario.
Total length of track	Total expected track length is approximately 11.5 km and is comprised of 7,310 m of new excavated road and 4,223 m of existing track requiring widening. Minimum and maximum scenarios are -/+ 10% of the expected value to accommodate any changes to design through micrositing.
Length of floating roads	No floating roads are proposed.
Excavated road length	As the tool does not allow specific inputs for widening of existing tracks, this value includes the 7,310 m of proposed 'new' track as well as 4,223 m of existing road to be widened and the values for excavated road widths and peat depths for both are weighted according to the different lengths for new and upgraded tracks (as advised by the authors of the tool). See Paragraph 8.4.35 for further details. It is also important to note that the calculations are based on worst case that the full 4,223 m length of existing track will need widening however topographic surveys undertaken pre-construction may indicate a smaller requirement.
Excavated road width	See Paragraph 8.4.15 which shows the calculation for weighted road width which takes into account new access tracks and widening of existing access tracks.
Average peat depths for excavated roads	Informed by probes collected from Phase 1 peat probe data and multiple targeted detailed Phase 2 surveys.

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 8.4.35 which shows the calculation for weighted road peat depth which takes into account new access tracks and widening of existing tracks.
Length of rock filled roads	There will be no rock filled roads.
Length of cable trenches	It is assumed that all cables will follow new tracks or existing tracks and an allowance for cable trenches (and drainage ditches) has been made when calculating excavated road widths.
Additional peat excavated	Approximately 20,340 m^3 of additional peat will be excavated in the expected scenario. This input accounts for the substation, BESS and control building and the construction compound. External transformers/electrical cubicles are not included as they would be covered by turbine/crane hardstanding excavations. Calculations are shown in Table 8.4.2 of this report.
Area of degraded bog to be improved	Peatland restoration measures and area are proposed as described in Chapter 8: Hydrology, Hydrogeology and Soils and Appendix 8.1 Outline Management Plan.
Area of borrow pits to be restored	Not applicable – no borrow pits are planned for the Proposed Development.
Water table depth around foundations and hardstandings before and after restoration	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)	Values of 3, 2 and 5 years used to reflect the expected, minimum and maximum scenarios respectively. Based on site observations and professional judgement.
Will the hydrology of the proposed development be restored on decommissioning	Yes. Upon the decommissioning of the wind farm, best practice principles will be adopted.
Will the habitat of the proposed development be restored on decommissioning?	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.

Wind Farm CO_2 Emission Savings

8.4.12. 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.

8.4.13. The calculator tool uses coal-fired power as an alternative generation type. However, in October 2024 the UK shut down its last coal plant (Poynting & Stallard, 2024)[4]. This is a great step towards a net zero carbon emission goal. It also means that coal emissions should not be used as a reference anymore. The tool should be updated to use natural gas instead of fossil fuel-mix, but the assessment relies on the current structure of the published tool.

8.4.14. Based on an 8.4 MW turbine scenario, the expected potential annual energy output of the Proposed Development is 220,163 MW/yr (8,806,533 MW over 40 years), with minimum and maximum potential outputs at 149,454 MW/yr and 264,682 MW/yr respectively. For a conservative analysis, the power time-shifting from Battery Energy Storage System (BESS) has not been applied in the assessment. However, infrastructure associated with the BESS has been considered.

8.4.15. Based on the expected annual energy output of the Proposed Development (is 220,163 MWh/yr), the potential expected emissions saved over grid-mix generation is 37,648 tonnes of CO_2 (tCO_2) per year and over fossil-fuel mix generation is 96,211 tCO_2/yr.

Emissions due to Turbine Life

8.4.16. Energy is consumed and associated 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.

8.4.17. 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.

8.4.18. The carbon calculator reveals an expected emissions figure of 81,191 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.

Capacity Required due to Back Up

8.4.19. 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 is however 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.

8.4.20. 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

[4] UK to close last coal power station after 142 years

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.

8.4.21. 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.

8.4.22. The carbon calculator assumes that backup is provided by a fossil fuel mix of energy generation and reveals an expected emissions figure of 70,744 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 9 months.

Loss of Carbon Fixing Potential

8.4.23. This parameter concerns the emissions due to loss of bog plants and is calculated by multiplying the area of the wind farm by the annual carbon accumulation due to bog plant fixation.

8.4.24. 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 sites that contain 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. To demonstrate a worst-case scenario of the Proposed Development's impact on carbon fixing potential through drainage, the extent of drainage around infrastructure that may result in impacts on peat is given as 5 m expected and 3 m and 10 m as minimum and maximum values respectively. These values are reasonable as the site has many existing drainage furrows.

8.4.25. 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 a worst-case scenario as bog habitat cover is less than 90% of the Proposed Development's total habitat characteristics (see EIAR Volume 1, Chapter 6 – Ecology and Biodiversity).

8.4.26. Habitat identification and habitat loss calculations for the development have been calculated based on the infrastructure and are discussed in EIAR Volume 1, Chapter 6 – Ecology and Biodiversity.

8.4.27. Habitats on site that may have potential for bog plants are considered to include wet modified bog, blanket bog, marshy grassland and wet heath. However, the Phase 1 Habitat Survey and National Vegetation Classification (NVC) results show that across the whole Proposed Development Area, these habitats are limited to small, isolated pockets. Most of the site is dry modified bog. Accordingly, the tool's assumption that the construction footprint of the wind farm has 100% coverage of bog plant habitat is unrealistic.

8.4.28. The carbon calculator reveals that the expected total emissions attributable to the loss of carbon accumulation by bog plants is 2,522 tCO_2 equiv. over the 40 year operational period of the Proposed Development. 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 half a month.

Loss of Carbon Dioxide from Removed Peat (Direct Loss)

8.4.29. 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).

8.4.30. 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 material (Warburton, et al., 2004). 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.

8.4.31. A second layer, 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.

8.4.32. Overall, 4,900 peat depth measurements were taken during Phase 1 and Phase 2 peat depth surveys to inform peat depths across the site boundary for the proposed wind farm development alone. 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.

8.4.33. Site specific values of carbon content of dry peat (% by weight) and dry soil bulk density (g/cm3) obtained through laboratory analysis (see Annex A for results) were employed and utilised within the tool to reflect the site-specific characteristics of the peat on site.

8.4.34. The excavated peat/soil volumes calculated by the tool 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 widening 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 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:

[7,310 m (expected length of new track) x 24.5 m (expected width)]

+ [4,233 m (expected length of widened track) x 10.5 m (expected width of widening)]

= 223,436.5 m^2

Then; 223,436.5 m^2 /11,533 m (total expected length of tracks) = 19.37 m expected weighted average width.

The calculations for expected weighted peat depths were as follows:

[7,310 m (expected length of new track) x 0.66 m (expected average peat depth)]

+ [4,233 m (expected length of widened track) x 0.66 m (expected average depth for widened tracks)

= 7,611.78 m^2

Then; 7,611.78 m^2/11,533 m (expected total length of tracks) = 0.66 m expected weighted average peat depth.

- An expected value for excavated new roads width of 24.5 m is based on 4.5 m running width (+ 1 m for shoulders), 6 m to allow for drainage/cable trenches on one side, 4 m batters either side and 4 m working areas on one side. Minimum and maximum values allow for variation in working areas.
- An expected value for widening to existing tracks of 10.5 m is based on a 1.5 m increase in running width (one side), 3 m cable trench and 3 m batter on one side with a 3 m working area. Minimum and maximum values allow for variation in working areas.
- 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.
- No floating roads have been entered into the tool to present a worst-case scenario.

8.4.35. As the infrastructure dimensions inputted into the tool have included working areas (as well as the excavation footprint) as worst case to account for any damage or disturbance to peat, not all of this 20,340 m³ peat volume reported within this assessment will actually be excavated or removed. This volume is considered to be inaccurate as the tool assumes that all peat (and any carbon sequestered therein) that underlies the infrastructure dimensions provided is lost (and doesn't account for peat management plans). Therefore, it is considered that the peat volumes expected are more accurately reflected in EIAR Volume 3, Appendix 8.1 – Peat Management Plan which focusses on the peat that is excavated, stored and re-used.

8.4.36. The carbon calculator also requires information relating to other ancillary infrastructure not explicitly accounted for above, namely the substation, BESS and construction compound. Table 8.4.2 utilises the expected dimensions of the additional infrastructure and peat depths used to calculate the total area and total volume of excavations.

Table 8.4.2: Additional peat excavated calculations

Additional Peat Excavated			
	Expected	**Minimum**	**Maximum**
Substation and BESS (m^2)	18,000	15,000	18,000
Substation and BESS Average Peat Depth (m)	0.38	0	0.89
Construction Compound (m^2)	15,000	12,000	15,000
Construction Compound Average Peat Depth (m)	0.9	0.76	1.04
Total Area of Peat Removed (m^2)	33,000	27,000	33,000
Total Volume of Peat Removed (m^3)	20,340	9,120	31,620

8.4.37. Total volumes and areas have been stated within the results of the tool, and 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.

Loss of Carbon Dioxide from Drained Areas (Indirect Loss)

8.4.38. 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.

8.4.39. As described within the technical guidance for the use of the tool (Scottish Government, 2018), indirect loss of carbon due to drainage can be estimated using default emissions factor values from the Intergovernmental Panel on Climate Change (IPCC) as well as by more site-specific equations derived from the scientific literature (Smith *et al.,* 2007) (Nayak *et al*., 2010). Although the IPCC generic values are widely accepted, the figures are averaged across cool temperate peatlands and allows no use of site-specific information such as water table depths before wind farm development. The guidance advises that if the site is not pristine peatland or where the water table depth may already have been lowered before any drainage associated with the development more site-specific factors are to be used and this method has been selected within the tool. Accordingly, this assessment uses the site-specific method selection in the tool, which is shown in Sheets 5c, 5d, and 5e.

8.4.40. The extent of the Proposed Development 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 the existing drainage conditions within the Proposed Development and also topography. The carbon calculator, however, calculates that a 15.2 ha area (Sheet 5c in the Excel tool) will be affected by drainage as it assumes no existing drainage and flat terrain which is not representative of the actual Proposed Development site characteristics. Therefore, results using this parameter should only be considered as highly indicative at best.

8.4.41. Hydrological and site investigation specialists visually observed water table depths during surveys which informed the Proposed Development design evolution and reviewed the water content and von Post results[5] from the peat cores. The extent of drainage is a reasonable estimation based on knowledge of the Proposed Development (topography, observations 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 3 m and 10 m were inserted as inputs to represent best and worst-case scenarios respectively.

8.4.42. Sheet 5a of the carbon calculator calculates the total expected area of land lost due to the Proposed Development construction as 34.8 ha. The expected volume of peat removed over the footprint of the wind farm is expected to be 238,081 m³.

8.4.43. Overall, in terms of direct and indirect losses, Sheet 5 identifies that the total expected amount of CO_2 lost from soil (removed and drained) is calculated to be 16,862 tCO_2 equivalent. This increases the overall payback of the construction of the Proposed Development by 2 months for the fossil fuel-mix scenario.

[5] The Von Post scale is a method for assessing the degree of decomposition (humification) in organic soils, primarily peat. It assigns a numerical value (H) from 1 to 10, with 1 representing the least decomposed (most fibrous) and 10 representing the most decomposed (amorphous, structureless).

Loss of Carbon Dioxide from DOC and POC loss

8.4.44. 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.

8.4.45. 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).

8.4.46. The carbon calculator calculates that there will be an expected 0 tCO_2 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

8.4.47. The following calculations on total loss of CO_2 from impacts 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;
- 5 m metre expected average extent of drainage to demonstrate a conservative expected scenario and 10 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;
- Emissions from drained and undrained land have the same proportion over the emissions period;
- 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.

8.4.48. The combined expected impact of the Proposed Development on peat and vegetation over the operational lifetime for the proposed layout is calculated as shown in Table 8.4.3.

Table 8.4.3: Total CO_2 (tCO_2 eq.) loss/gains 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
	2,522	16,862	0
Total CO_2 loss/gains equiv.		**19,383**	

8.4.49. Based on the calculated emissions for fossil fuel-mix generation, the total payback time for loss of peat is two months.

Loss of Carbon Fixing due to Forest Felling

8.4.50. Of the total felling area of 210 ha, approximately 131 ha will be returned to Forestry and Land Scotland (FLS) 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 forestry management plans (FMP). Forest design principles, habitat gains and landscaping may require modification of the replanting plan from that in the approved FMP. Any change necessary will be led by FLS requirements.

8.4.51. 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 and supporting infrastructure is 79 ha. However, a commitment has been made for compensatory planting (see EIAR Volume 1, Chapter 12 – Forestry) which would result in a net loss of forestry of 0 ha. A precautionary and worst-case approach has been taken in this assessment however, that does not accommodate for the compensation as the compensatory planting is likely to be offsite.

8.4.52. In accordance with the guidance for the carbon calculator the net forestry felled is therefore inserted as 79 ha into the carbon calculator tool as 131 ha of replanting will be undertaken onsite.

8.4.53. The carbon calculator calculates that there will be an expected 41,716 tCO_2 equiv. lost due to felling for the Proposed Development and supporting infrastructure. 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

8.4.54. Restoration of areas within a proposed 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 takes into account reductions for emissions resulting from the improvement of degraded bog, felled plantation land as well as the restoration of borrow pits and early removal of drainage from turbine foundations.

8.4.55. 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 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.

8.4.56. Opportunities for habitat management and potential peat restoration have been investigated and are reported in the Outline BERP presented in Appendix 6.3, Volume 3 of the EIAR. To present a worst-case scenario for this assessment however, no values for improvement of degraded bog, felled plantation or peat restoration of borrow pits have been entered into the tool.

8.4.57. The results report -1,355 tCO_2 equiv. in carbon gains from the removal; of drainage measures in the expected scenario and -3,095 tCO_2 equiv. in carbon gains 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 at all.

Carbon Balance Summary

8.4.58. Table 8.4.4 reveals the carbon losses and carbon gains for each of the above parameters for the proposed development. Table 8.4.4 also reveals the net CO_2 emissions.

Table 8.4.4: Expected CO_2 losses and gains

Carbon Balance Input Parameter	Expected Results
1. Windfarm CO_2 emission saving over other types of energy generation	
Coal fired electricity generation (tCO_2yr^{-1})	230,291
Grid mix of electricity generation (tCO_2yr^{-1})	37,648
Fossil fuel mix of electricity generation (tCO_2yr^{-1})	96,211
Energy output from windfarm over lifetime (MWh)	**8,806,533**
Total CO_2 losses due to wind farm (tCO_2 eq.)	
2 Losses due to turbine life (e.g. manufacture, construction, decommissioning)	81,191
3. Losses due to backup	70,744
4. Losses due to reduced carbon fixing potential	2,522
5. Losses from soil organic matter	16,862
6. Losses due to DOC & POC leaching	0
7. Losses due to felling forestry	41,716
Total losses (tCO_2 eq.)	**213,034**
8. Total CO_2 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	-1,355
Total gains (tCO_2 eq.)	**-1,355**
Net CO_2 emissions (tCO_2 eq.)	**211,678**

8.4.59. 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 site from the total CO_2 emissions from manufacture of, construction of, and impacts on peat from, the individual elements of the Proposed Development (described in the preceding paragraphs).

8.4.60. 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 parameters into account is the carbon payback time and it is this value that provides an indication of the carbon balance of the Proposed Development.

8.4.61. The carbon payback time for the Proposed Development 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. Figures 8.4.1 and 8.4.2 below illustrate the payback times for the alternative Proposed Development in years and months.

RESULTS	*Exp.*	*Min.*	*Max.*
Net emissions of carbon dioxide (t $CO_{2\ eq.}$)	**211678**	**144356**	**285512**
Carbon Payback Time			
…coal-fired electricity generation (years)	0.9	0.5	1.9
…grid-mix of electricity generation (years)	5.6	2.9	11.2
…fossil fuel - mix of electricity generation (years)	**2.2**	**1.2**	**4.4**

Figure. 8.4.1: Carbon payback time (in years) for the Proposed Development

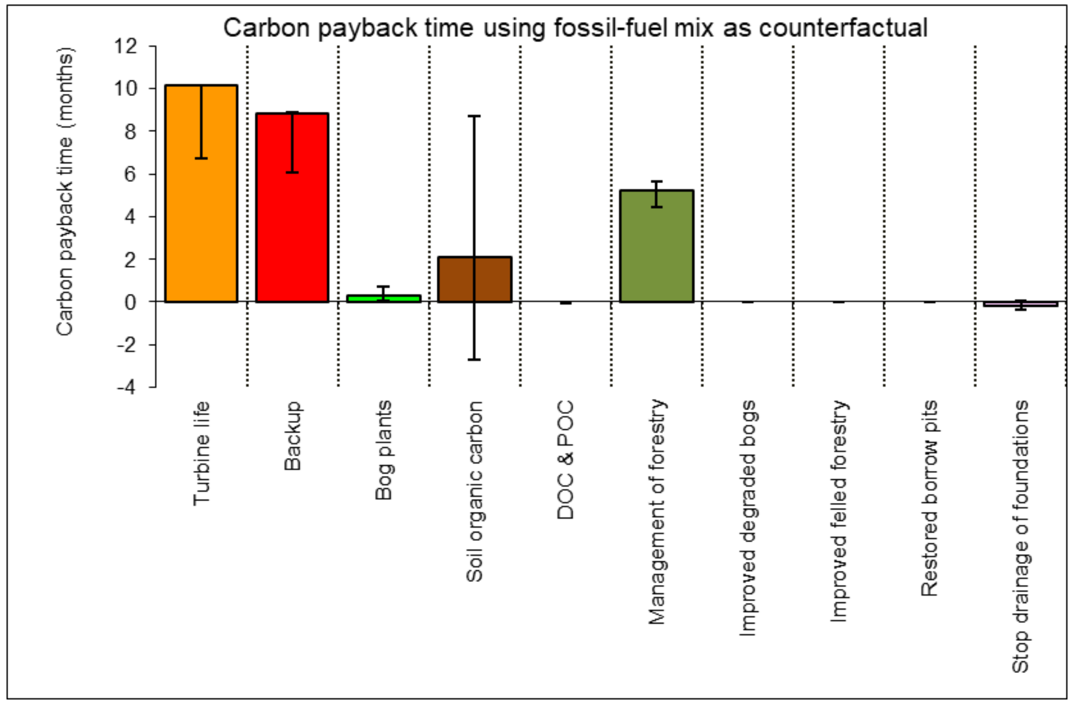

Figure 8.4.2: Carbon payback time (in months) for different elements of the assessment

8.4.62. 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 2.2 years, if it replaced the fossil fuel-mix 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 1.2 to 4.4 years respectively.

8.4.63. 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.

8.4.64. In this regard, IEMA concludes that:

8.4.65. *"…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.*"

8.4.66. In this context, the results of this assessment reveal that the net impact of the Proposed Development will be positive overall, as over its 40-year lifespan, it is expected to generate over 37 years' worth of clean energy if it replaced fossil fuel-mix electricity generation and nearly 33 years' worth of clean energy even if it replaces cleaner grid-mix electricity generation. Therefore, over the expected 37 years that the wind farm is likely to be generating carbon-free electricity, this could result in expected CO_2 emission savings of over 3,559,807 tonnes[6] of CO_2 when replacing fossil fuel-mix electricity generation. This illustrates a positive net impact through contributing significantly towards the reduction of greenhouse gas emissions from energy production.

[6] Calculation is 37 years x 96,211 tCO_2 (as shown in Table 8.4.4).

Annex A: Laboratory Results

Certificate of Analysis

Certificate Number	23-28658	*Issued:*	13-Dec-23

Client	MATTest Ltd. 10 Queenslie Point 120 Stepps Road Glasgow G33 3NQ
Our Reference	23-28658
Client Reference	23/1293
Order No	MATSC5521
Contract Title	South Kyle 2
Description	5 Soil samples.
Date Received	06-Dec-23
Date Started	06-Dec-23
Date Completed	13-Dec-23
Test Procedures	Identified by prefix DETSn (details on request).
Notes	Opinions and interpretations are outside the laboratory's scope of ISO 17025 accreditation. This certificate is issued in accordance with the accreditation requirements of the United Kingdom Accreditation Service. The results reported herein relate only to the material supplied to the laboratory. This certificate shall not be reproduced except in full, without the prior written approval of the laboratory.

Approved By

Kirk Bridgewood
General Manager

UKAS TESTING 2139

Summary of Chemical Analysis
Soil Samples

Our Ref 23-28658
Client Ref 23/1293
Contract Title South Kyle 2

Test	Method	LOD	Units					
			Lab No	2272524	2272525	2272526	2272527	2272528
			.Sample ID	PP-595	PP-72	PP-692	PP-802	T03
			Depth	0.00-1.00	0.00-0.65	0.00-1.10	0.00-0.80	0.00-0.90
			Other ID					
			Sample Type	SOIL	SOIL	SOIL	SOIL	SOIL
			Sampling Date	13/11/2023	08/11/2023	08/11/2023	08/11/2023	30/10/2023
			Sampling Time	n/s	n/s	n/s	n/s	n/s
Inorganics								
Carbon, Total	DETSC 2084*	0.5	%	38	33	35	43	37
Total Organic Carbon	DETSC 2084#	0.5	%	37	32	35	43	39

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

Information in Support of the Analytical Results

Our Ref 23-28658
Client Ref 23/1293
Contract South Kyle 2

Containers Received & Deviating Samples

Lab No	Sample ID	Date Sampled	Containers Received	Holding time exceeded for tests	Inappropriate container for tests
2272524	PP-595 0.00-1.00 SOIL	13/11/23	PT 1L	Carbon, Total (14 days)	
2272525	PP-72 0.00-0.65 SOIL	08/11/23	PT 1L	Carbon, Total (14 days)	
2272526	PP-692 0.00-1.10 SOIL	08/11/23	PT 1L	Carbon, Total (14 days)	
2272527	PP-802 0.00-0.80 SOIL	08/11/23	PT 1L	Carbon, Total (14 days)	
2272528	T03 0.00-0.90 SOIL	30/10/23	PT 1L	Carbon, Total (14 days), Organic Matter (Auto) (28 days)	

Key: P-Plastic T-Tub

DETS cannot be held responsible for the integrity of samples received whereby the laboratory did not undertake the sampling. In this instance samples received may be deviating. Deviating Sample criteria are based on British and International standards and laboratory trials in conjunction with the UKAS note 'Guidance on Deviating Samples'. All samples received are listed above. However, those samples that have additional comments in relation to hold time, inappropriate containers etc are deviating due to the reasons stated. This means that the analysis is accredited where applicable, but results may be compromised due to sample deviations. If no sampled date (soils) or date+time (waters) has been supplied then samples are deviating. However, if you are able to supply a sampled date (and time for waters) this will prevent samples being reported as deviating where specific hold times are not exceeded and where the container supplied is suitable.

Soil Analysis Notes

Inorganic soil analysis was carried out on a dried sample, crushed to pass a 425µm sieve, in accordance with BS1377.

Organic soil analysis was carried out on an 'as received' sample. Organics results are corrected for moisture and expressed on a dry weight basis.

The Loss on Drying, used to express organics analysis on an air dried basis, is carried out at a temperature of 28°C +/-2°C.

Disposal

From the issue date of this test certificate, samples will be held for the following times prior to disposal :-

Soils - 1 month, Liquids - 2 weeks, Asbestos (test portion) - 6 months

End of Report

LABORATORY TEST CERTIFICATE

MATtest Limited
materials testing & consultancy

10 Queenslie Point
Queenslie Industrial Estate
120 Stepps Road
Glasgow
G33 3NQ

Tel: 0141 774 4032

email: info@mattest.org
Website: www.mattest.org

Certificate No :	**23/1293 - 01-1**
To :	**Alasdair Ellis**
Client :	**The Natural Power Consultants** The Green House Forrest Estate Dalry Castle Douglas **DG7 3XS**

LABORATORY TESTING OF SOIL

Introduction

We refer to samples taken from South Kyle 2 and delivered to our laboratory on 27th November 2023.

Material & Source

Sample Reference	:	See Report Plates
Sampled By	:	Client
Sampling Certificate	:	Not Supplied
Location	:	See Report Plates
Description	:	See Page 2
Date Sampled	:	Not Supplied
Date Tested	:	27th November 2023 Onwards
Source	:	14805UKC - South Kyle 2

Test Results

As Detailed On Page 2 to Page 4 inclusive

Comments

The results contained in this report relate to the sample(s) as received
Opinions and interpretations expressed herein are outside the scope of UKAS accreditation
This report should not be reproduced except in full without the written approval of the laboratory
All remaining samples for this project will be disposed of 28 days after issue of this test certificate

Remarks

Approved for Issue

T McLelland (Director)

Date 11/12/2023

UKAS TESTING 2643

BOREHOLE	SAMPLE	DEPTH (m)	SAMPLE DESCRIPTION
PP-72	B	0.00-0.65	Black PEAT (Von Post Classification - H5)
PP-595	B	0.00-1.00	Black PEAT (Von Post Classification - H6)
PP-692	B	0.00-1.10	Brown PEAT (Von Post Classification - H7)
PP-802	B	0.00-0.80	Brown PEAT (Von Post Classification - H7)
T03	B	0.00-0.90	Brown PEAT (Von Post Classification - H7)

SUMMARY OF SAMPLE DESCRIPTIONS

BOREHOLE	SAMPLE	DEPTH (m)	WATER CONTENT (%)
PP-72	B	0.00-0.65	537
PP-595	B	0.00-1.00	426
PP-692	B	0.00-1.10	906
PP-802	B	0.00-0.80	659
T03	B	0.00-0.90	726

Tested in accordance with BS 1377 - 2 : 2022 : Clause 4.1

SUMMARY OF WATER CONTENT TEST RESULTS

MATtest Limited
materials testing & consultancy

BOREHOLE	SAMPLE	DEPTH (m)	WATER CONTENT (%)	BULK DENSITY (Mg/m^3)	DRY DENSITY (Mg/m^3)
PP-72	B	0.00-0.65	537	0.99	0.16
PP-595	B	0.00-1.00	426	1.04	0.20
PP-692	B	0.00-1.10	906	0.97	0.10
PP-802	B	0.00-0.80	659	0.99	0.13
T03	B	0.00-0.90	726	0.98	0.12

Tested in accordance with BS 1377 - 2 : 2022 : Clause 8
Bulk Density : Linear Measurement

SUMMARY OF WATER CONTENT AND BULK DENSITY TEST RESULTS

Annex B: Input Data

Core input data

ENTER INPUT DATA HERE! VALUES SHOULD ONLY BE CHANGED ON THIS SHEET. **DO NOT USE EXAMPLE VALUES AS DEFAULTS!** ENTER YOUR OWN VALUES THAT ARE SPECIFIC TO YOUR PARTICULAR SITE.

Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.

Click here to move to Payback Time — Click here

Click here to return to Instructions — Click here

Input data	Expected values: Enter expected value here	Record source of data	Possible range of values: Enter minimum value here	Record source of data	Enter maximum value here	Record source of data
Windfarm characteristics						
Dimensions						
No. of turbines	11		11		11	
Lifetime of windfarm (years)	40	Fixed	40		40	
Performance						
Power rating of turbines (turbine capacity) (MW)	8.4		6.6		8.4	
Capacity factor	Direct input of capacity fact		Direct input of capacity fact		Direct input of capacity fact	
Enter estimated capacity factor (percentage efficiency)	27.2		23.5		32.7	
Backup						
Extra capacity required for backup (%)	5		5		5	
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10		10		10	
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	Calculate wrt installed capa		Calculate wrt installed capa		Calculate wrt installed capa	
Characteristics of peatland before windfarm development						
Type of peatland	Acid bo		Acid bo		Acid bo	
Average annual air temperature at site (^oC)	8.04		4.35		11.73	
Average depth of peat at site (m)	0.74		0.71		0.77	
C Content of dry peat (% by weight)	37.2		32.05		42.35	
Average extent of drainage around drainage features at site (m)	5.00		3.00		10.00	
Average water table depth at site (m)	0.40		0.20		0.60	
Dry soil bulk density (g cm^{-3})	0.14		0.09		0.19	
Characteristics of bog plants						
Time required for regeneration of bog plants after restoration (years)	15		10		20	
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25		0.12		0.31	
Forestry Plantation Characteristics						
Method used to calculate CO_2 loss from forest felling	Enter simple data		Enter simple data		Enter simple data	
Area of forestry plantation to be felled (ha)	79		71.1		86.9	
Average rate of carbon sequestration in timber (tC ha-1 yr-1)	3.60		3.60		3.60	
Counterfactual emission factors						
To update counterfactual emission factors from the web — Click here (not yet operational)						
Coal-fired plant emission factor (t CO_2 MWh^{-1})	1.046		0.994		1.046	
Grid-mix emission factor (t CO_2 MWh^{-1})	0.171		0.171		0.191	
Fossil fuel-mix emission factor (t CO_2 MWh^{-1})	0.437		0.437		0.44	
Borrow pits						
Number of borrow pits	0		0		0	
Average length of pits (m)						
Average width of pits (m)						
Average depth of peat removed from pit (m)						
Foundations and hard-standing area associated with each turbine						
Method used to calculate CO_2 loss from foundations and hard-standing	Rectangular with vertical w		Rectangular with vertical w		Rectangular with vertical w	
Average length of turbine foundations (m)	30		25		32	
Average width of turbine foundations (m)	30		25		32	
Average depth of peat removed from turbine foundations (m)	0.77		0.74		0.80	
Average length of hard-standing (m)	200		200		200	
Average width of hard-standing (m)	37		32.5		45	
Average depth of peat removed from hard-standing (m)	0.77		0.74		0.80	
Access tracks						
Total length of access track (m)	11533		10000		12686	
Existing track length (m)	4223		3800		4645	
Length of access track that is floating road (m)	0		0		0	
Floating road width (m)						
Floating road depth (m)						
Length of floating road that is drained (m)						
Average depth of drains associated with floating roads (m)						
Length of access track that is excavated road (m)	11533		13800		17331	
Excavated road width (m)	19.37		17.54		20.54	
Average depth of peat excavated for road (m)	0.66		0.62		0.69	
Length of access track that is rock filled road (m)						
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	
Average depth of peat cut for cable trenches (m)	0.00		0.00		0.00	
Additional peat excavated (not already accounted for above)						
Volume of additional peat excavated (m^3)	20340		9120		31620	
Area of additional peat excavated (m^2)	33000.0		27000.0		33000.0	
Peat Landslide Hazard						
Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments						
Improvement of C sequestration at site by blocking drains, restoration of habitat etc						
Improvement of degraded bog						
Area of degraded bog to be improved (ha)						
Water table depth in degraded bog before improvement (m)						
Water table depth in degraded bog after improvement (m)						
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)						
Improvement of felled plantation land						
Area of felled plantation to be improved (ha)						
Water table depth in felled area before improvement (m)						
Water table depth in felled area after improvement (m)						
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)						
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)						
Restoration of peat removed from borrow pits						
Area of borrow pits to be restored (ha)						
Depth of water table in borrow pit before restoration with respect to the restored surface (m)						
Depth of water table in borrow pit after restoration with respect to the restored surface (m)						
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)						
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)						
Early removal of drainage from foundations and hardstanding						
Water table depth around foundations and hardstanding before restoration (m)	0.5		0.3		0.7	
Water table depth around foundations and hardstanding after restoration (m)	0.3		0.1		0.5	
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	3		2		5	
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	
Will you attempt to block all artificial ditches and facilitate rewetting?	Yes		Yes		Yes	
Will the habitat of the site be restored on decommissioning?	No		No		No	
Will you control grazing on degraded areas?	No		No		No	
Will you manage areas to favour reintroduction of species	No		No		No	

Choice of methodology for calculating emission factors	Site specific (required for planning applications)

Note: Capacity factor. The capacity factor of any power plant is the proportion of energy produced during a given period with respect to the energy that would have been produced had the wind farm been running continually and at maximum output (DECC (2004); see also www.bwea.com/ref/capacityfactors.html).
Capacity Factor = Electricity generated during the period [kWh]/ (Installed capacity [kW] x number of hours in the period [h])
We recommend that a site-specific capacity factor ~~site~~ should be used (as measured during planning stage), and should represent the average emission factor expected over the lifetime of the windfarm, accounting for decline in efficiency with age (Hughes, 2012). The 5 year average capacity factor (or "load factor") for UK onshore wind between 2010 and 2014, based on average beginning and end of year capacity, was 29.2% (DUKES, 2015).

Note: Extra capacity required for backup. If 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant (Dale et al 2004). We suggest this should be 5% of the actual output. If it is assumed that less than 20% of national electricity is generated by wind energy, a lower percentage should be entered (0%). The House of Lords Economic Affairs Committee report on The Economics of Renewable Energy (Parliamentary Business, 2008) notes that to cover peak demand a '20% margin of extra capacity has been sufficient to keep the risk of a power cut due to insufficient generation at a very low level.' The estimate provided by BERR was a range of 10% to 20% of installed capacity of wind energy. E.ON is reported as proposing that the capacity credit of wind power should be 8%, and The Renewable Energy Foundation proposed the use of the square root of the wind capacity (in GW) as conventional capacity (e.g. 36 GW of wind plant to match 6 GW of conventional plant).

Note: Extra emissions due to reduced thermal efficiency of the reserve power generation ≈ 10% (Dale et al 2004).

Note: Emissions from turbine life. If total emissions for the windfarm are unknown, emissions should be calculated according to turbine capacity. The normal range of CO_2 emissions is 394 to 8147 t CO_2 MW (White & Kulcinski, 2000; White, 2007).

Note: Type of peatland An 'acid bog' is fed primarily by rainwater and often inhabited by sphagnum moss, thus making it acidic (Stoneman & Brooks,1997).
A 'fen' is a type of wetland fed by surface and/or groundwater (McBride et al., 2011).

Note: Time required for regeneration of previous habitat. Loss of fixation should be assumed to be over lifetime of windfarm only. This time could be longer if plants do not regenerate. The requirements for after-use planning include the provision of suitable refugia for peat-forming vegetation, the removal of structures, or an assessment of the impact of leaving them in situ. Methods used to reinstate the site will affect the likely time for regeneration of the previous habitat. This time could also be shorter if plants regenerate during lifetime of windfarm. If so, enter number of years estimated for regeneration.

Note: Carbon fixation by bog plants
Apparent C accumulation rate in peatland is 0.12 to 0.31 t C ha^{-1} yr^{-1} (Turunen et al., 2001; Botch et al., 1995). The SNH guidance uses a value of 0.25 t C ha^{-1} yr^{-1}.

Note: Area of forestry plantation to be felled. If the forestry was planned to be removed, with no further rotations planted, before the windfarm development, the area to be felled should be entered as zero.

Note: Plantation carbon sequestration. This is dependent on the yield class of the forestry. The SNH technical guidance assumed yield class of 16 m^3 ha^{-1} yr^{-1}, compared to the value of 14 m^3 ha^{-1} yr^{-1} provided by the Forestry Commission. Carbon sequestered for yield class 16 m^3 ha^{-1} y^{-1} = 3.6 tC ha^{-1} yr^{-1} (Cannell, 1999).

Note: Coal-Fired Plant and Grid Mix Emission Factors. Coal-fired plant emission factor (EF) from electricity supplied in 2014 = 0.093 t CO_2 MWh^{-1}; Grid-Mix EF for 2014 = 0.394 t CO_2 MWh^{-1}. Source = DUKES, 2015b.

Note: Fossil Fuel-Mix Emission Factor. The emission factor from electricity supplied in 2014 from all fossil fuels = 0.642 t CO_2 MWh^{-1}. Source = DUKES, 2015b.

Note: Total length of access track. If areas of access track overlap with hardstanding area, exclude these from the total length of access track to avoid double counting of land area lost.

Note: Floating road depth. Accounts for sinking of floating road. Should be entered as the average depth of the road expected over the lifetime of the windfarm. If no sinking is expected, enter as zero.

Note: Length of floating road that is drained. Refers to any drains running along the length of the road.

Note: Rock filled roads. Rock filled roads are assumed to be roads where no peat has been removed and rock has been placed on the surface and allowed to settle.

Note: Depth of peat cut for cable trenches. In shallow peats, the cable trenches may be cut below the peat. To avoid overestimating the depth of peat affected by the cable trenches, only enter the depth of the peat that is cut.

Note: Peat Landslide Hazard. It is assumed that measures have been taken to limit damage (Scottish Executive, 2006, Peat Landslide Hazard and Risk Assessments. Best Practice Guide for Proposed Electricity Generation Developments. Scottish Executive, Edinburgh. pp. 34-35) so that C losses due to peat landslide can be assumed to be negligible. Link: http://www.scotland.gov.uk/Publications/2006/12/21162303/1.

Note: Period of time when improvement can be guaranteed. This guarantee should be absolute. Therefore, if you enter a value beyond the lifetime of the windfarm you should provide strong supporting evidence that this improvement can be guaranteed for the full period given. This includes the time requirement for the improvement to become effective. For example if time required for hydrology and habitat to return to its previous state is 10 years and the restoration can be guaranteed over the lifetime of the windfarm (25 years), the period of time when the improvement can be guaranteed should be entered as 25 years, and the improvement will be effective for (25 -10) = 15 years.

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Note: Period of time when improvement can be guaranteed. This is assumed to be the lifetime of the windfarm as restoration after windfarm decommissioning is already accounted for in restoration of the site

Note: Restoration of site. If the water table at the site is returned to its original level or higher on decommissioning, and habitat at the site is restored, it is assumed that C losses continue only over the lifetime of the windfarm. Otherwise, C losses from drained peat are assumed to be 100%.

Note: Choice of methodology for calculating emission factors. The IPCC default methodology is the internationally accepted standard (IPCC, 1997). However, it is stated in IPCC (1997) that these are rough estimates, and "these rates and production periods can be used if countries do not have more appropriate estimates". Therefore, we have developed more site specific estimates for use here based on work from the Scottish Government funded ECOSSE project (Smith et al, 2007. ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions. Final Report. SEERAD Report. ISBN 978 0 7559 1498 2. 166pp.).

Core input data

ENTER INPUT DATA HERE! VALUES SHOULD ONLY BE CHANGED ON THIS SHEET. **DO NOT USE EXAMPLE VALUES AS DEFAULTS!** ENTER YOUR OWN VALUES THAT ARE SPECIFIC TO YOUR PARTICULAR SITE.

Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.

Click here to move to Payback Time — Click here

Click here to return to Instructions — Click here