14 Aviation, Radar and Other Issues

14.1 Introduction

14.1.1 This chapter assesses the potential effects of the proposed development in relation to:

- Aviation, Radar & Defence;
- Television and Telecommunications;
- Shadow Flicker & Reflected Light; and
- Carbon Balance

14.1.2 Elements relating to Major Accidents and Disasters have been addressed in the individual technical discipline chapters where relevant.

14.1.3 Impacts on Population and Human Health have been addressed in the individual EIA topic chapters where relevant.

14.1.4 This assessment has been undertaken by the applicant.

14.2 Aviation, Radar & Defence

Introduction

14.2.1 This section of the chapter considers the likely significant effects on aviation, radar and defence associated with the construction, operation and decommissioning of the proposed development.

14.2.2 The assessment of potential effects on aviation, radar and defence considers technical acceptability, based on air navigation safety, rather than following a strict EIA process of assessing the significance of effects. Such effects often require the implementation of technical mitigation solutions to ensure continued safe operation in the presence of a wind farm. The assessment of effects on these receptors is therefore one of technical analysis and consultation and seeks to identify whether the effect is likely to be 'acceptable' or 'not acceptable' to air navigation services provision.

Statement of Competence

14.2.3 The aviation, radar and defence assessment was conducted by Sam Johnson of RES. Sam is the Senior Aviation Manager at RES, with an MMath in Mathematics. Sam has over 20 years' experience in the radar industry with over 15 years specifically in the area of wind farms. Sam is a member of the Renewable UK Aviation Working Group and is Chair of Aviation Investment Fund Company Limited (AIFCL).

Guidance

14.2.4 This assessment has been prepared with reference to Civil Aviation Authority (CAA) Publication (CAP) 764, Policy and Guidelines on Wind turbines (CAA, 2016). This is the primary guidance in relation to the assessment of wind turbines on aviation in the UK.

Consultation

Table 14.1: Consultation Responses relating to Aviation, Radar & Defence

Consultee and Date	Scoping / Other Consultation	Issue Raised	Response / Action
Defence Infrastructure Organisation (03.05.23)	Scoping	The turbines will be 73km from, detectable by, and will cause unacceptable interference to the AD radar at Brizlee Wood. Wind turbines have been shown to have detrimental effects on the operation of radar. These include the desensitisation of radar in the vicinity of the turbines, and the creation of "false" aircraft returns. The probability of the radar detecting aircraft flying over or in the vicinity of the turbines would be reduced, hence turbine proliferation within a specific locality can result in unacceptable degradation of the radar's operational integrity. This would reduce the RAF's ability to detect and deter aircraft in United Kingdom sovereign airspace, thereby preventing it from effectively performing its primary function of Air Defence of the United Kingdom.	The Defence Infrastructure Organisation (DIO) indicated a potential impact on the AD radar at Brizlee Wood. The MOD will be consulted to ascertain the extent of the impact on the radar and agree a suitable scheme of mitigation.
		In this case the development falls within Low Flying Area 14 (LFA 14), an area within which fixed wing aircraft may operate as low as 250 feet or 76.2 metres above ground level to conduct low level flight training. The addition of turbines in this location has the potential to introduce a physical obstruction to low flying aircraft operating in the area. If the developer is able to overcome the issues stated above, to address	The DIO indicated that the proposed site lies within a low flying tactical training area. The MOD Low Flying team will be consulted to agree a suitable aviation lighting scheme if deemed necessary.

Consultee and Date	Scoping / Other Consultation	Issue Raised	Response / Action
		the impact up on low flying given the location and scale of the development, the MOD would require that conditions are added to any consent issued requiring that the development is fitted with aviation safety lighting and that sufficient data is submitted to ensure that structures can be accurately charted to allow deconfliction. The development proposed includes wind turbine generators and/or meteorological mast(s) that exceed a height of 150m agl and are therefore subject to the lighting requirements set out in the Air Navigation Order 2016. In addition to CAA requirements, the MOD will require the submission, approval, and implementation of an aviation safety lighting specification that details the installation of MOD accredited aviation safety lighting.	
Edinburgh Airport Limited (24.03.23)	Scoping	Edinburgh Airport had concerns related to the proposed development. No turbine tower of any turbine may be erected, unless and until such time as the Local Planning Authority receive confirmation from the Airport Operator in writing that: (a) an IFP Assessment has demonstrated that an IFP Scheme is not required; or (b) if an IFP Scheme is required such a scheme has been approved by the Airport Operator; and (c) if an IFP Scheme is required the Civil Aviation Authority has evidenced its approval to the Airport Operator of the IFP Scheme (if such approval is required); and (d) if an IFP Scheme is required the scheme is accepted by NATS AIS for implementation through the AIRAC Cycle (or any successor publication) (where applicable) and is available for use by aircraft.	An Instrument Flight Procedure (IFP) assessment was commissioned by a Civil Aviation Authority (CAA) approved provider that showed there would be no impact on the IFPs. Edinburgh Airport confirmed on 07/08/2023 that they no longer had concerns.
NATS (05.04.23)	Scoping	NATS has indicated an impact from the proposed development on the Great Dun Fell NATS (En Route) plc (NERL) radar, Kincardine Radar and Edinburgh Airport Radar.	Dialogue is ongoing with NATS to identify the most appropriate mitigation scheme.

Scope of Assessment

Effects Scoped Out

14.2.5 Interference with surveillance systems and radar can occur when wind turbine blades are moving, therefore potential effects during construction are not assessed.

14.2.6 Upon decommissioning, the Defence Geographic Centre (DGC) will be informed of the removal of wind turbines. Following this, no decommissioning effects are expected and are not considered further.

Effects Assessed in Full

14.2.7 The assessment identifies and considers the potential effects that the proposed development may have on civilian and military aviation, air safeguarding and, if required, the mitigation measures proposed to prevent, reduce or offset any potential adverse effects where possible.

14.2.8 In relation to military and civil aviation assets it considers potential impacts on the military Air Defence (AD) radar at Brizlee Wood, the NATS En Route Ltd (NERL) radars at Great Dun Fell and Kincardine, and Edinburgh Airport, and the potential mitigation measures identified to address these.

14.2.9 The assessment is based on an evaluation of existing data sources and desk studies, and consultation with key stakeholders.

14.2.10 The effects of wind turbines on aviation interests are well known but the primary concern is one of safety. The two principal scenarios that can lead to effects on the operations of aviation stakeholders are:

- physical obstruction: wind turbines can present a physical obstruction at or close to an aerodrome or in the military low flying environment, which itself presents a health and safety risk or otherwise requires changes to flight routes in the area which brings about other operational effects; and
- radar/air traffic services (ATS): wind turbine clutter appearing on a radar display can affect the safe provision of ATS as it can mask unidentified aircraft from the air traffic controller and/or prevent them from accurately identifying aircraft under control. In some cases, radar reflections from wind turbines can affect the performance of the radar system itself.

14.2.11 In this context the scope of the assessment is to consider the impact of the proposed development on aviation stakeholders, including military, en route, airports and other airfields, radar systems and air space users. This assessment also considers civil and military stakeholder aviation obstruction lighting requirements.

14.2.12 As standard, the DGC will be provided with the following information for incorporation on to aeronautical charts and documentation:

- the date of commencement of the proposed development.
- the exact position of the wind turbine towers in latitude and longitude;
- a description of all structures over 300 feet high;
- the maximum extension height of all construction equipment;
- the height above ground level of the tallest structure; and
- details of a visible and/or infrared aviation lighting scheme.

Baseline Characterisation

Study Area

14.2.13 Consideration is given to aviation infrastructure that is within operational range of the proposed development. Operational range varies with the type of infrastructure but broadly includes regional airports operating radar up to 50km of the proposed development, non-radar aerodromes within 17km, parachute drops zones within 3km, and military radar and en route radar systems up to 100km from the proposed development (dependent on operational range).

Desk Study

14.2.14 The applicant has a dedicated aviation manager who has provided input to the proposed development since its inception. This has included:

- civil and military radar line of sight (LoS) analysis;
- review of relevant aviation charts;
- review of military low flying charts; and
- general aviation advice based on prevailing civil and aviation issues

Significance Criteria

14.2.15 Significance criteria for aviation impacts are typically difficult to establish; they are not strictly based on the sensitivity of the receptor or magnitude of change but on whether the industry regulations for safe obstacle avoidance or radar separation (from radar clutter) can be maintained in the presence of the wind turbines.

14.2.16 Any anticipated impact upon aviation stakeholders which results in restricted operations is therefore considered to be of significance.

Assessment Limitations

14.2.17 No limitations have been identified that would affect the findings of the assessment, based on the information available at the time of writing.

Baseline

CAA

14.2.18 The only civil airport to respond to Scoping was Edinburgh Airport with concerns of impacts on their IFPs.

14.2.19 The Civil Aviation Authority will require the proposed development to have visible lighting to assist with air safety.

NERL

14.2.20 The proposed development is approximately 123km north of the Great Dun Fell radar, 68km north-west of Kincardine radar and 43km north-west of Edinburgh radar.

14.2.21 NERL has indicated that the proposed development will have an unacceptable impact upon the Great Dun Fell en route radar, the Kincardine radar and Edinburgh radar as they each have LoS to some of the wind turbines at the proposed development.

Military Aviation

14.2.22 The proposed development is approximately 71km north-west of the Brizlee Wood radar. The DIO has indicated that the proposed development will have an unacceptable impact upon the Brizlee Wood radar as it has LoS to some of the wind turbines at the proposed development.

14.2.23 While not expressed specifically in scoping opinion, the DIO is likely to have a requirement for the proposed development to agree a suitable scheme of visible and/or infrared lighting to assist military aircraft in avoiding the proposed development.

Mitigation and Residual Effects

Predicted Operational Effects

14.2.24 Wind turbines have the potential to impact the performance of air traffic control radars. These impacts include:

- The creation of "false" targets, whereby the wind turbines present on the radar display. Multiple false targets can lead to the radar initiating false aircraft tracks.
- False returns can also cause track seduction, i.e. real aircraft tracks are ‘seduced’ away from the true position as the radar updates the aircraft track with the false return. This can lead to actual aircraft not being detected.

- Shadowing whereby the aircraft is not detected by the radar as it is flying within the physical 'shadow' of the wind turbine.

Aviation & Radar

14.2.25 Prior to mitigation, it is considered that the proposed development would affect the operation of the military AD radar at Brizlee Wood and also the NERL Great Dun Fell radar, Kincardine and Edinburgh radars.

Proposed Mitigation

Aviation & Radar

14.2.26 There are a number of mitigation options available to alleviate problems caused by wind turbines to aviation and radar. Mitigation solutions are highly specific to the effect in questions. Consultation with relevant consultees is key to establishing the appropriate method of mitigation.

14.2.27 Should it be required by DIO, a Radar Mitigation Scheme (RMS) will be agreed with them that will remove or reduce the impact upon their AD radar at Brizlee Wood to an acceptable level. The RMS will be agreed prior to the proposed development becoming fully operational. It is likely that a technical mitigation will be provided, consistent with technical mitigation that has been provided for the adjacent, operational wind farm, Fallago Rig. The applicant is currently in discussion with DIO to determine to most suitable technical mitigation solution.

14.2.28 Should it be required by NATS, an RMS will be agreed with them that will remove or reduce the impact on NERL Great Dun Fell Radar, Kincardine and Edinburgh radars to an acceptable level. The RMS will be agreed prior to the proposed development becoming fully operational. It is likely that a technical mitigation will be provided through a standard 'blanking contract'. The applicant is currently in discussion with NATS to determine to most suitable technical mitigation solution.

14.2.29 A reduced visible aviation lighting scheme has been agreed with the CAA. The reduced scheme means that not every perimeter wind turbine needs to be lit and no tower lights are required provided an infrared scheme is agreed with the DIO. A copy of the correspondence from the CAA can be seen in **Technical Appendix 14.1** and **Figure 14.1** presents the wind turbines that are proposed to be lit in accordance with this correspondence. The results of the assessment for night-time lighting are contained in **Chapter 6: Landscape & Visual Impact Assessment**. An infrared lighting scheme will be agreed with the DIO prior to the proposed development becoming fully operational.

Summary

14.2.30 The proposed development will potentially impact the MOD radar at Brizlee Woodand the NERL radar at Great Dun Fell, plus Kincardine and Edinburgh radars. In both cases it is expected that the impact can be mitigated with a suitable mitigation scheme that could be secured through an appropriately worded suspensive planning condition. Infrared lighting will be agreed with the DIO for the MOD low flying requirements and a visible lighting scheme has been agreed with the CAA.

14.3 Television and Telecommunications

Introduction

14.3.1 This section of the chapter summarises the potential television and telecommunications effects associated with the proposed development.

Guidance

14.3.2 Tall structures such as wind turbines may cause interference of nearby television signal or telecommunications links. As such, any links in the vicinity of the proposed development must be identified and operators must be consulted.

14.3.3 The Ofcom Spectrum Information Portal was used in the first instance to identify fixed telecommunications crossing or adjacent to the site.

14.3.4 A number of other telecommunications services in addition to fixed links may be present, however most of these services are generally only affected if wind turbines are located in immediate vicinity. Furthermore, where other services are present, there is usually a supporting fixed link to allow onward signal transmission, which would be identified in this assessment. It is therefore considered that the search for fixed microwave links, and discussion with identified operators, also covers all other services.

Scope of Assessment

Effects Scoped Out

14.3.5 Effects on television and radio signal have been scoped out of detailed assessment for the following reasons:

- Operational effects on television / radio broadcasting: digital television is less likely to be affected by the atmospheric conditions that rendered analogue television unwatchable and does not suffer from reflection effects or ghosted image generation.
- It is not considered likely that radio broadcasting signals will be affected by the proposed development once operational. This is because:

- the length of radio broadcast signal wavelengths are such that interference from wind turbines is unlikely; and
- any interference to the radio signal is unlikely to noticeably affect the audio signal.

Microwave Fixed Links and Scanning Telemetry

14.3.6 Fixed links are direct line-of-sight communication links between transmitting and receiving dishes placed on masts generally located on hilltops that vary in length from a few kilometres to over 70km. They are used for the transmission of information to broadcasting masts for television and radio and for the mobile telephone networks and other use-cases.

14.3.7 No nearby operations were identified on the Ofcom Spectrum Information Portal[1] which was used in the first instance to identify fixed telecommunications links crossing or adjacent to the site.

14.3.8 Three major operators were still contacted as a matter of best practice.

14.3.9 Telecommunications and broadcasting network operators were consulted during the scoping exercise. **Table 14.2** summarises the responses from link operators contacted.

Table 14.2: Link Operators responses

Link Operator	Response/Issue Raised	Actions
BT	No concerns raised	No actions required
JRC	No concerns raised	No actions required
Atkins	No concerns raised	No actions required

14.3.10 BT responded the 28th of March 2023, to confirm that the proposed development should not cause interference to their current and presently planned radio network and maintained this position on 20 September 2023 with sight of the final layout of the proposed development.

14.3.11 The Joint Radio Company (JRC) Limited responded on the 20th of March 2023, to confirm that the proposed development should not cause interference to JRC's current and presently planned radio network and maintained this position on 14 September 2023 with sight of the final layout of the proposed development.

14.3.12 Atkins confirmed with the applicant on 14 September 2023 that it would have no objection to the proposed development.

14.3.13 With the information available to the applicant, the proposed development does not directly affect fixed links.

Summary

14.3.14 The proposed development does not directly affect fixed links.

14.3.15 The potential effect of the proposed development is considered to be not significant with respect to other television or radio communication networks.

14.4 Shadow Flicker & Reflected Light

Introduction & Background

14.4.1 In sunny conditions, any shadow cast by a wind turbine will mirror the movement of the rotor. When the sun is high, any shadows will be confined to the site but when the sun sinks to a lower azimuth moving shadows can be cast further afield and potentially over adjacent properties. Shadow flicker is generally not a disturbance in the open as light outdoors is reflected from all directions. The possibility of disturbance is greater for occupants of buildings when the moving shadow is cast over an open door or window; since the light source is more directional.

14.4.2 Whether shadow flicker is a disturbance depends upon:

- the observer's distance from the wind turbine;
- the direction of the dwelling and the orientation of its windows and doors from the wind farm;
- the frequency of the flicker; and
- the duration of the effect, either on any one occasion or averaged over a year.

[1] https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal

14.4.3 The common rate or frequency at which photosensitive epilepsy might be triggered is between 3 and 30Hz (flashes per second). It has been recommended (Clarke, 1991)[2] that the critical frequency should not be above 2.5Hz, which for a three-bladed wind turbine is equivalent to a rotational speed of 50rpm. The candidate wind turbines considered for the proposed development would rotate at 8.8rpm, therefore unlikely to cause epileptic seizures. (Harding et al., 2008[3]; Smedley et al., 2010[4]). Therefore, there are not considered to be any health effects associated with the shadow flicker due to the proposed development and the assessment will address the effects of shadow flicker related only to local amenity.

Reflected Light

14.4.4 A related visual effect to shadow flicker is that of reflected light. Theoretically, should light be reflected off a rotating wind turbine blade onto an observer then a stroboscopic effect would be experienced. In practice a number of factors limit the severity of the phenomenon and there are no known reports of reflected light being a significant problem at wind farms.

14.4.5 A limiting factor is that wind turbines have a semi-matt surface finish which means that they do not reflect light as strongly as materials such as glass or polished vehicle bodies.

14.4.6 Secondly, due to the convex surfaces found on a wind turbine, light will generally be reflected in a divergent manner.

14.4.7 Thirdly, as with shadow flicker, certain weather conditions and solar positions are required before an observer would experience this phenomenon.

14.4.8 It is therefore concluded that the proposed development will not cause a material reduction to amenity owing to reflected light.

Policy and Guidance

14.4.9 The update to Shadow Flicker Evidence Base (2011)[5], published by the then Department for Energy and Climate Change (DECC), states that assessing shadow flicker effects within ten times the rotor diameter of wind turbines has been widely accepted across different European countries, and is deemed to be an appropriate area.

14.4.10 The Scottish Borders Council Supplementary Guidance, Renewable Energy, (2018)[6] further describes that,

14.4.11 *"… there is some recent evidence that shadow flicker can be experienced at greater than 10 rotor diameter distance and that the modelling of those residences within 10 rotor diameter may not capture all homes where people experience shadow flicker effects .Where requested by the Council, the developer will be required to produce shadow flicker assessments modelled to take into account all residential property within 2km of a wind turbine. This distance threshold should take into account any screening of turbines offered by topography."*

Assessment Methodology

14.4.12 Analysis was performed on all properties within 2,000m of any wind turbine, in accordance with Scottish Borders Council Supplementary Guidance.

14.4.13 The planning application includes a 100m micro-siting distance for infrastructure. As such, this 100m distance is added to the 2,000m distance to give a total distance of 2,100m from any wind turbine.

14.4.14 Analysis was undertaken for shadow flicker at all properties within 2,100m from any wind turbine.

14.4.15 The assessment area and properties included therein are shown in **Figure 14.2**.

14.4.16 This analysis takes into account the motion of the Earth around the Sun, the local topography and the wind turbine locations and dimensions. The analysis was performed using a layout of 19 turbines, each with maximum tip heights of 220m.

Results

14.4.17 With due reference to 2,000 m distance of interest requested, and allowance for 100m micro-siting, the potential shadow flicker is given in **Table 14.3**.

Table 14.3: Predicted maximum annual potential shadow flicker

RES Property ID	Property Address	Distance to the Nearest Wind Turbine (m)	Maximum Hours of Flicker Per Year
H315	The Howe, Tollishill, Lauder, Berwickshire, TD26QZ	1,192	81.3
H265	Longcroft Farm, Oxton, Lauder, TD2 6QZ, UK, LCKV79LH	1,397	18.7
H260	4 Longcroft Farm Cottages, Oxton, Lauder, TD2 6QZ, UK, LCBJ41KK	1,442	0.0

[2] Clarke A.D (1991), A case of shadow flicker/flashing: assessment and solution, Open University, Milton Keynes

[3] Harding et al. (2008), Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them, Epilepsia

[4] Smedley et al. (2010), Potential of wind turbines to elicit seizures under various meteorological conditions, Epilepsia

[5] Brinckerhoff, Parsons (2011) 'Update of UK Shadow Flicker Evidence Base', Department of Energy and Climate Change, UK Government

[6] Scottish Borders Council Supplementary Guidance (2018), Renewable Energy.

RES Property ID	Property Address	Distance to the Nearest Wind Turbine (m)	Maximum Hours of Flicker Per Year
H261	3 Longcroft Farm Cottages, Oxton, Lauder, TD2 6QZ, UK, LC6JJM3Y	1,444	0.0
H262	2 Longcroft Farm Cottages, Oxton, Lauder, TD2 6QZ, UK, LCWBVGR7	1,450	0.0
H263	1 Longcroft Farm Cottages, Oxton, Lauder, TD2 6QZ, UK, LCBXKV7V	1,453	0.0
H267	Soonhope Bothy, Oxton, Lauder, TD2 6QZ, UK, LC1H542W	1,254	0.0
H268	Soonhope House, Oxton, Lauder, TD2 6QZ, UK, LCTQ9Z6Z	1,220	0.0
H303	Tollishill, Oxton, TD2 6RE, UK, LCKC2Z53	1,818	0.0
H304	Dodcleugh, Lauder, TD2 6RE, UK, LCJ8JQBB	1,842	0.0

14.4.18 The above predictions in **Table 14.3** represent a worst-case scenario for the following reasons:

- The analysis assumes that there is always sufficient lack of cloud cover, for there to be sufficient sunlight for shadows to be cast by the wind turbine blades.
- The analysis assumes that there is always enough wind for the wind turbine blades to be turning.
- The analysis assumes that the wind is always coming from the right direction for the wind turbine rotor to be facing towards the property, to thus cast a shadow.
- The analysis assumes that the property has windows and/or glazed doors facing towards the wind turbine rotor.
- The analysis assumes there is no shielding, e.g. in the form of trees or outbuildings, between the wind turbine rotor and the property.

Mitigation and Residual Effects

14.4.19 Mitigation can be incorporated into the operation of the proposed development to reduce the instance of shadow flicker including shutting down individual wind turbines during periods when shadow flicker could theoretically occur.

14.4.20 Shadow flicker control modules, consisting of light sensors and specialised software, will be installed on turbines identified as having the potential to cause shadow flicker. This is to prevent operation during periods when shadow flicker is experienced at nearby properties if it is determined there is an issue post-construction.

14.4.21 The shadow flicker control module consists of bespoke software, a clock, a timer, a switch, a wind direction sensor and a light sensor. The module can control a specific turbine (or turbines) which would be programmed to shut down on specific dates at specific times when the sun is bright enough, there is sufficient wind to rotate the blades and the wind direction is such that nuisance shadow flicker could occur.

14.4.22 The installation of a programmable shadow flicker module will allow future conditional control of turbines in order to eliminate shadow flicker, irrespective of which turbine in the range is installed. The correct operation of the installed shadow flicker control measures will ensure that there will be no impact from shadow flicker. The operation and performance of the shadow flicker control measures will be monitored on an ongoing basis.

Summary

14.4.23 The proposed development will not cause a material reduction to amenity owing to reflected light.

14.4.24 Under conservative assumptions, as mentioned in paragraph 14.4.18, the proposed development is predicted to create shadow flicker for two properties within the 2,100m assessment area. Should it be required, mitigation can be provided, including shutting down individual wind turbines during periods when shadow flicker could theoretically occur.

14.5 Climate and Carbon Balance

Introduction

14.5.1 In addition to generating electricity, Scottish Government sees wind turbines and other renewable technologies as an important mechanism for reducing the UK's carbon dioxide (CO_2) emissions. However, such development projects can themselves create carbon emissions (e.g. use of concrete and vehicle emissions). Therefore, this section estimates the CO_2 emissions associated with the manufacture and construction of the proposed development compared to the estimated contribution the proposed development would make to reducing CO_2 emissions. This gives an estimate of the whole life carbon balance of the proposed development. Once the CO_2 emissions have been offset or paid back by the proposed development, each subsequent unit of wind generated electricity transmitted would be likely to displace a unit of conventionally generated electricity, thereby replacing traditional fossil fuel based power station emissions and contributing to reduction of CO_2 emissions.

14.5.2 **Table 14.4** provides a breakdown of the estimated emissions displaced per annum and over the assumed lifespan for the proposed development. The proposed development is seeking consent for an operational lifespan of 50 years, and so this figure has been used.

Carbon and Peatland

14.5.3 Renewable energy developments in upland areas may often be sited on peatlands which hold stocks of poorly protected carbon, and so have the potential to release carbon to the atmosphere in the form of CO_2 if disturbed. Scotland has the majority of peat soils in the UK and, therefore, has a responsibility to ensure stability of this carbon and to ensure that developments do not cause a significant loss of this carbon reservoir.

14.5.4 The proposed development is located in area where peaty soils and peat have been impacted by commercial land use management by the shooting estate, which will have reduced the underlying 'peat resource' as a source of carbon. This peatland cannot be considered as pristine due to the disturbance from muirburn and drainage activity resulting in release of CO_2 to the atmosphere and long term degradation as a 'carbon sink'. The deeper peat, (below the water table) will still be a carbon sink as long as the water table is maintained and the peat is not artificially drained.

14.5.5 The carbon balance assessment considers the implications of any parts of the proposed development which could lead to the additional release of CO_2 resulting from the disturbance of peat.

14.5.6 In order to minimise the requirement for the extraction of peat, the layout design process has avoided areas of deeper peat. The layout design process is described in **Chapter 2: Design Evolution & Alternatives,** and it has been agreed through consultation with SEPA that a peat management plan is not required due to the very limited peat that could be affected by the proposed development**.** Specific details on the peat depth and probing surveys undertaken are included in **Technical Appendix 10.2: Peat Landslide and Hazard Risk Assessment.**

Characteristics of Peatland

14.5.7 When flooded, peat soils emit less carbon dioxide but more methane than when they are drained. In flooded soils, carbon emissions are usually exceeded by plant fixation, so the net exchange of carbon with the atmosphere is negative and soil stocks increase. When soils are aerated, carbon emissions usually exceed plant fixation, so the net exchange of carbon with the atmosphere is positive.

14.5.8 To calculate the carbon emissions attributable to the removal or drainage of the peat, emissions occurring if the soil had remained in situ and undrained are subtracted from the emissions occurring after removal or drainage.

14.5.9 The loss of carbon from the carbon fixing potential from plants and vegetation on peatland is small but is calculated for the area from which peat is removed and the area affected by drainage. The carbon stored in the peat itself represents a much larger potential source of carbon loss.

14.5.10 The indirect loss of CO_2 uptake (fixation) by plants originally on the surface of the site but eliminated by construction activity including the destruction of active bog plants on wet sites, is calculated using a blanket bog assumption to capture a worst-case scenario.

14.5.11 Emissions due to the indirect, long-term liberation of CO_2 from carbon stored in peat due to drying and oxidation processes caused by construction of the proposed development can also be calculated from site specific data for the proposed development. This figure is a worst-case scenario, as very limited peat is anticipated to be disturbed on site. Any disturbed peat would be re-used onsite to minimise carbon losses, for restoration of the proposed development and for habitat restoration including ditch blocking, where possible.

Carbon Payback Methodology

14.5.12 The assessment of the carbon payback is based on a detailed baseline description of the proposed development and its location. All calculations are based on site specific data, where available. Where site specific data is not available approved national/regional information has been used.

14.5.13 The methodology to calculate carbon emissions is based on 'Calculating carbon savings from windfarms on Scottish peat lands - A New Approach' (Nayak et al, 2008)[7], prepared for the Scottish Government Science, Policy and Co-ordination Division. This was superseded in 2011 by the document 'Calculating Carbon Savings from Wind Farms on Scottish Peatlands - A New Approach', (Nayak et al, 2008 and 2010) and (Smith et al, 2011)[8]. In terms of carbon footprint, the 'carbon calculator' is the Scottish Government's tool provided to support the process of determining the carbon impact of wind farm developments in Scotland. It is noted that this methodology is specifically designed for wind farms and not renewable energy developments like the proposed development. Therefore, the assessment only considers the wind turbine element of the proposed development.

Effects of Carbon Emissions from Construction

14.5.14 Emissions arising from the fabrication of the wind turbines and the associated components are based on a full life analysis of a typical wind turbine and include CO_2 emissions resulting from transportation, erection, operation, dismantling and removal of wind turbines and foundations and transmission grid connection equipment from the existing electricity grid system.

14.5.15 With respect to wind turbines, emissions from material production are the dominant source of CO_2. Emissions arising from construction (including transportation of components, quarrying, building foundations, access tracks and hardstands) and commissioning are also included in the calculations. The assessment has used Nayak et al (2008) default values for 'turbine life' emissions, calculated with respect to installed capacity.

14.5.16 The proposed development is seeking consent without a limit to operational lifetime, however in order to ensure a meaningful result from the calculator, an illustrative operational lifespan of 50 years has been used.

Input Parameters

14.5.17 To undertake this assessment, the following parameters were considered, which encompass a full life cycle analysis of the proposed development. These parameters include:

- emissions arising from the fabrication of the wind turbines and all the associated components;
- emissions arising from construction, (including transportation of components; quarrying; building foundations, access tracks and hardstands; and commissioning);
- the indirect loss of CO_2 uptake (fixation) by plants originally on surface of the site but eliminated by construction activity (including the destruction of active bog plants on wet sites);
- emissions due to the indirect, long term liberation of CO_2 from carbon stored in peat due to drying and oxidation processes caused by construction; and
- loss of carbon due to drainage.

14.5.18 As part of their methodology, Nayak et al have provided a spreadsheet called 'Scottish Government Windfarm Carbon Assessment Tool' to calculate whole life carbon balance assessments for windfarms on peat lands. The calculation spreadsheet (online calculator version 1.7.0 and reference number WZ1Z-O5IW-NPTL)[9] allows a range of data to be input in order to address expected, minimum and maximum values. However, if several parameters are varied together, this can have the effect of 'cancelling out' a single parameter change. For this reason, the approach for this assessment has been to include 'maximum values' as those values which would result in the longest (maximum) payback period; and 'minimum values' as those values which would result in the shortest (minimum) payback period.

14.5.19 This spreadsheet tool provides generic values for CO_2 emissions associated with some components (such as wind turbine manufacture) and requires site specific information for other components (such as habitat type, extent of peat disturbance and ground water levels).

14.5.20 This assessment draws on information detailed in the EIA Report, **Chapter 8: Terrestrial Ecology** and **Chapter 10: Hydrology, Hydrogeology & Geology**. For the purpose of this assessment, it is assumed that all the embedded good practice measures outlined in **Chapter 8: Terrestrial Ecology**, and **Hydrology, Hydrogeology & Geology** would be employed.

7 Nayak et al (2008). http://www.gov.scot/Publications/2008/06/25114657/0 [Accessed 30 October 2023].

8 Nayak et al; (2008 and 2010) and Smith et al (2011). Calculating Carbon Savings from Wind Farms on Scottish Peatlands - A New Approach.

9 Scottish Government (2022). Windfarm Carbon Assessment Tool online version 1.7.0. Available at https://informatics.sepa.org.uk/CarbonCalculator/ [accessed 30/10/2023]

14.5.21 The final wind turbine choice is not yet known but would likely be around 6.6MW and the greenhouse gas savings and carbon payback are based on the input parameters of the proposed 19 wind turbines. Figures are based on currently available wind turbines and assume a consistent supplier for all wind turbine locations (i.e. wind turbine types are chosen by manufacturer). Note that, within the calculation spreadsheet, the expected, maximum and minimum values have been adjusted to suit the input parameter.

14.5.22 The capacity factor used within the calculation spreadsheet is based on measured onsite wind data giving a capacity factor of 46.6%.

14.5.23 The input parameters for the Scottish Government calculation spreadsheet are detailed in **Technical Appendix 14.2: Carbon Calculator**. The choice of methodology for calculating the emission factors uses the 'Site Specific methodology' defined within the calculation spreadsheet.

Results

14.5.24 This section presents a summary of the carbon assessment which has been undertaken in respect of the proposed development. The purpose of the 'carbon calculator' is to assess, in a comprehensive and consistent way, the carbon impact of wind energy developments. This is undertaken by comparing the carbon costs of manufacture and construction with the carbon savings attributable to a development through operation. An assessment has been undertaken to calculate the carbon emissions which would be generated in the construction, operation and possible decommissioning of the proposed development after an illustrative 50 years.

14.5.25 The carbon calculations spreadsheet is provided in **Technical Appendix 14.2: Carbon Calculator**. A summary of the anticipated carbon emissions and carbon payback of the proposed development relative to the current Department for Business, Energy & Industrial Strategy published figures is provided in **Table 14.4**.

Table 14.4: Anticipated carbon emissions and payback

Results	Exp.	Min.	Max.
Net emissions of carbon dioxide (t CO_2 eq.)	218,151	201,852	277,377
Carbon payback time			
Coal-fired electricity generation (years)	0.4	0.4	0.5
Grid-mix of electricity generation (years)	2.2	2.0	2.8
Fossil fuel - mix of electricity generation (years)	1.0	0.9	1.3
Ratio of CO_2 eq. emissions to power generation (g / kWh) (TARGET ratio by 2030 (electricity generation) < 50 g /kWh)	8.52	7.87	10.86

Interpretation of results

14.5.26 The calculations of total carbon dioxide emission savings and payback time for the proposed development indicates the overall payback period of a development with 19 wind turbines with an average (expected) installed capacity of around 6.6MW each would be approximately 1.0 years, when compared to the fossil fuel mix of electricity generation.

14.5.27 This means that the proposed development is expected to take around 12 months to repay the carbon exchange to the atmosphere (the CO_2 debt) through construction of the wind turbines; the proposed development would in effect be in a net gain situation following this time period and would contribute to national CO_2 reduction targets.