Appendix 15.1 Proposal for Alternative Lighting Scheme

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BHLARAIDH EXTENSION WIND FARM, HIGHLAND: PROPOSAL FOR ALTERNATIVE LIGHTING SCHEME

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EXECUTIVE SUMMARY

1 SSE Generation Ltd proposes an 18-turbine Extension to the existing wind farm at Bhlaraidh, 35km south west of Inverness, Highland. The existing wind farm consists of 32 turbines with tip heights of 135 metres above ground level (m agl) and is fitted with infra-red lighting on seven cardinal turbines. The Bhlaraidh Extension turbines will have tip heights of 180m agl. Since this exceeds 150m, the Air Navigation Order (ANO) Article 222 requirement for medium intensity red lights will apply. In order to meet the requirements of users of the night low level airspace while reducing the night time visual impact of such aviation lighting, SSE Generation Ltd requests CAA permission to provide lighting other than in accordance with the ANO, as provided in ANO Article 222(7).

2 ICAO Annex 14 provides for objects 150m or more above ground level not to be regarded as obstacles – and therefore not to be lit - if a special aeronautical study indicates that they do not constitute a hazard to aeroplanes. In addition Article 222 (7) of the ANO allows the CAA to grant permissions for lighting other than as stipulated in ANO Article 222 to be fitted to objects 150m or more above ground level. This document is designed to be a special aeronautical study, to provide a basis for the CAA to grant permission for the Bhlaraidh Extension wind farm to be lit otherwise than in accordance with the ANO.

3 A review of the potential users of the night low level airspace in the vicinity of the Bhlaraidh Extension site shows that low level civil VFR traffic in the area is rare and the majority of users are Night Vision Goggle (NVG) equipped.

4 The residual risk of an aircraft colliding with the turbines because they are not lit is assessed as extremely low because (a) the proposed turbines have tip heights lower than the immediately adjacent existing turbines; (b) this area has a low probability of overflight by a non-NVG equipped aircraft flying VFR at night; and (c) the presence of terrain in the surrounding area that is higher than the proposed blade tips means that the additional risk posed by the turbines is small. It is found that the Extension does not generate additional risk sufficient to justify fitting the turbines with visible spectrum lighting. Further, the fitting of visible lighting to the Bhlaraidh Extension turbines could introduce a new element of risk of a pilot flying at an unsafe altitude taking avoidance action on seeing the lit turbines and flying into the adjacent unlit turbines.

5 Visible spectrum LED lights are of limited or no visibility to aircrew wearing NVGs. Since night airspace users in the area are predominantly NVG-equipped, visible lighting provides little or no additional safety benefit over infra-red lighting.

6 The proposed lighting scheme for the Bhlaraidh Extension wind farm aims to identify the corners and perimeter of the combined Bhlaraidh and Bhlaraidh Extension wind farms, using infra-red lighting only, extending the lighting scheme design of the Bhlaraidh wind farm to the combined Bhlaraidh and Bhlaraidh Extension development. The lighting scheme is illustrated in Figure 5 (p.19).

7 Potential users of the night low level airspace in the vicinity of the Bhlaraidh Extension site are being consulted on the proposed lighting scheme.

1. Introduction

1.1 This document sets out a request to the Civil Aviation Authority for permission to provide an alternative lighting scheme on the proposed Bhlaraidh Extension wind farm, Highland, under the terms of Article 222(6) and 222(7) of the Air Navigation Order (ANO).

1.2 This request is submitted by Gladhouse Planning Ltd (trading as Aviatica) on behalf of Scottish and Southern Energy Generation Limited (SSE).

1.3 A summary of the proposed lighting scheme is in section 11.

2. Background

2.1 The proposed Bhlaraidh Extension wind farm is an 18-turbine extension to the east of the existing operational 32-turbine Bhlaraidh wind farm, located 35 km south west of the town of Inverness. The proposed turbines will be 180 metres above ground level (agl) to blade tip. They therefore qualify as “en route obstacles” as defined by Article 222(8) of the ANO and as such are subject to the provision in Article 222(1) requiring the fitting of medium intensity steady red lights. The location of the development site is shown in Figure 1.

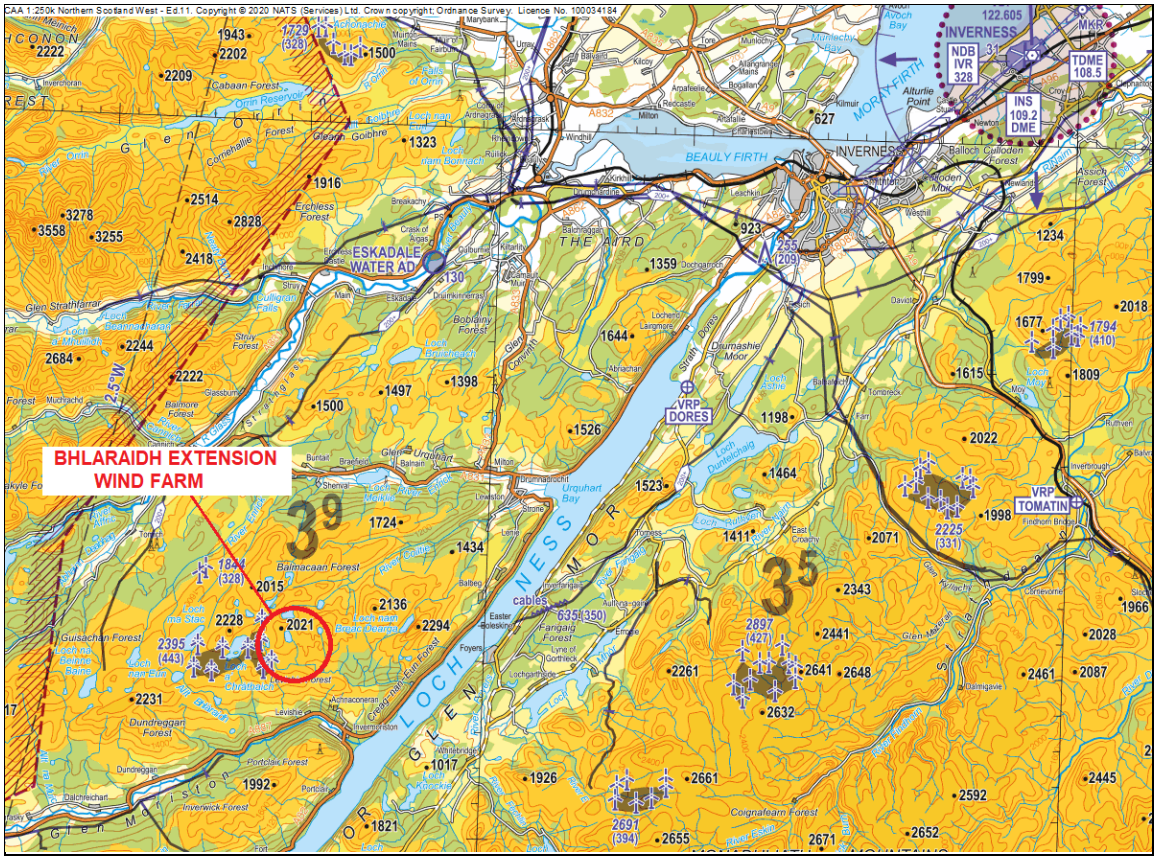

Figure 1: Location of the Bhlaraidh Extension wind farm

2.2 The Bhlaraidh Extension proposal will have a generating capacity in excess of 50 MW and will therefore be submitted to the Scottish Government for consent under Section 36 of the Electricity Act.

2.3 Bhlaraidh Extension is located in a remote area with relatively sparse habitation and few sources of artificial light at night. The designated Central Highlands Wild Land Area – WLA 24 – lies 10 km west of the wind farm site. In their scoping response to the project in 2019, NatureScot commented that:

> The proposal is approximately 8km from The Central Highlands Wild Land Area (WLA). The proposed turbines are in excess of 150m tall and therefore may legally require to have visible aviation lights fitted. The introduction of lighting, which is likely to be visible over large distances, could result in significant adverse impacts on the qualities of this wild land area.[1]

2.4 This proposal for an alternative lighting scheme is designed to meet concerns relating to adverse visual impacts of aviation lighting on non-aviation receptors while ensuring that the lighting installed on the turbines meets air safety requirements.

3. The obstacle environment around Bhlaraidh Extension

3.1 There are two existing wind farms within 10km of the Bhlaraidh Extension site. These are shown in Table 1 and Figure 2.

Table 1: Status of existing and consented wind farms

Project	*No. of turbines*	*Tip height (m agl)*	*Max tip ht (ft amsl[2])*	*Operational status*	*Lighting status*
Bhlaraidh Extension	18	180	2346	Proposed	To be approved
Bhlaraidh	32	135	2395	Operational	Infra-red only on seven cardinal turbines; remainder not lit
Corrimony	5	100	1844	Operational	25 candela flashing red on all turbines[3]

3.2 The lighting scheme for the adjacent existing Bhlaraidh wind farm was developed in consultation with the Ministry of Defence (MoD) in the post-consent period during 2015. The approved and built lighting scheme consists of infra-red only

[1] Bhlaraidh Extension Wind Farm, consultation response from NatureScot, 23 August 2019.

[2] Above mean sea level.

[3] According to the planning consent. However the AIP lists the Corrimony turbines as having no lights. The wind farm owner has confirmed that the turbines are fitted with lights but has not clarified whether these are visible spectrum or infra-red.

lighting on seven of the 32 turbines, marking the perimeter of the wind farm and one central point. The remaining 25 turbines have no lighting.

3.3 The existing Bhlaraidh wind farm occupies an area approximately 4.2km across in an east-west direction and 2.5km from north to south. The proposed Bhlaraidh Extension wind farm is located immediately to the east of the existing Bhlaraidh wind farm and will extend the area of turbines eastwards by 2.7km. The minimum gap between the Bhlaraidh and Bhlaraidh Extension turbines will be 475 metres and the two schemes will appear as a single integral wind farm when the Extension is built.

3.4 The existing Bhlaraidh turbines are 135m agl to blade tip height. Consequently they are not “en route obstacles” as defined in Article 222(8) of the ANO. The proposed Extension turbines, although 45 metres higher above ground level than those of the existing Bhlaraidh wind farm, are predominantly located on lower ground. Thus the highest blade tips in the Extension will be 2346 feet above sea level, slightly lower than the maximum 2395 feet amsl of the existing wind farm.

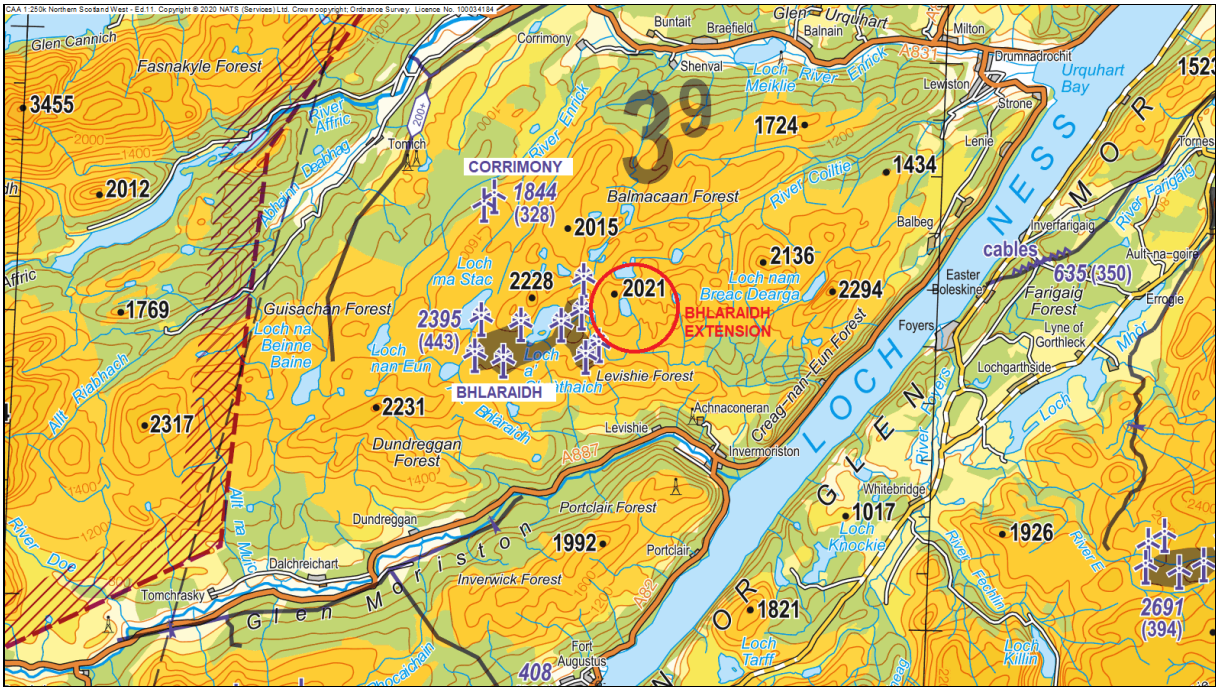

Figure 2: Existing and consented wind farms in the Bhlaraidh Extension area

4. Regulatory basis for the proposed lighting scheme

4.1 The International Civil Aviation Organisation (ICAO) sets out Standards and Recommended Practices (SARPs) governing the marking and lighting of obstacles in Annex 14 to the Chicago Convention. The UK, as an ICAO Contracting State, seeks to implement all ICAO SARPs.

4.2 ICAO Annex 14 paragraph 4.3.2 recommends that:

> In areas beyond the limits of the obstacle limitation surfaces, at least those objects which extend to a height of 150 m or more above ground elevation should be regarded as obstacles, unless a special aeronautical study indicates that they do not constitute a hazard to aeroplanes.
> Note.— This study may have regard to the nature of operations concerned and may distinguish between day and night operations.

4.3 ICAO Annex 14 paragraph 6.2.4.1 states:

> A wind turbine shall be marked and/or lighted if it is determined to be an obstacle.

However Note 2 to that paragraph states "See 4.3.1 and 4.3.2", which again allows for a wind turbine to be deemed not to be an obstacle, on the basis of an aeronautical study.

4.4 Article 222(1) of the Air Navigation Order (ANO) requires all en route obstacles (defined as any construction 150m or more above ground level) to be lit with medium intensity steady red lights. However Article 222(6) states:

> A permission may be granted for the purposes of this article for a particular case or class of cases or generally.

while Article 222(7) states:

> This article does not apply to any en-route obstacle for which the CAA has granted a permission to the person in charge permitting that person not to fit and display lights in accordance with this article.

4.5 It is therefore open to the CAA to grant permissions for lighting schemes other than as specified in ANO Article 222(1). ICAO Annex 14 paragraph 4.3.2 provides a methodological basis for the grounds on which any such permission may be given. The CAA has granted approvals for reduced lighting schemes on this basis in respect of the wind farms at Crystal Rig IV, Clash Gour, Rothes III and Garvary.[4]

4.6 This document is designed to be a 'special aeronautical study' as referred to in ICAO Annex 14 paragraph 4.3.2, aimed at providing a basis on aviation safety grounds for lighting the Bhlaraidh Extension wind farm other than in accordance with ANO Article 222(1).

4.7 The CAA guidance on wind turbines, CAP 764, is in the process of revision. The June 2020 draft of the revised edition contains a new section on lighting of onshore wind turbines with tip heights of 150m or more, incorporating existing CAA policy[5] and ICAO Recommended Practices from paragraph 6.2.4.3 of Annex 14. The key features of the draft guidance are as follows:

- the requirement to fit lights is based on the maximum height from the ground to the tip of the blades, but the requirement for the positioning of lights is based on the fixed structure (nacelle and tower);

[4] CAA letters dated 19 February 2020, 17 July 2020, 20 August 2020 and 26 August 2020 refer, respectively.

[5] CAA Safety & Airspace Regulation Group, Policy Statement: Lighting of Onshore Wind Turbine Generators in the United Kingdom with a maximum blade tip height at or in excess of 150m Above Ground Level, June 2017.

- one medium intensity (2000 candela) red light must be placed on the nacelle of the turbine; a second 2000 candela red light serving as an alternate should be provided in case of failure of the operating light;
- at least three (to provide 360° coverage) low-intensity Type B (32 cd) lights must be provided at an intermediate level of half the nacelle height ± 10 m;
- the lights required as above must be so fitted to show when displayed in all directions without interruption;
- obstacle lighting must be fitted and operated when required to identify the corners and perimeter of the wind farm;
- if the height of other turbine nacelle(s) in the wind farm exceed the height of a plane extending at an elevation of 10 degrees above the horizontal from the nacelle of a turbine that is required to be lit, then obstacle lighting must be fitted and operated on these wind turbines;
- obstacle lighting may be omitted on the perimeter of the wind farm if it can be demonstrated that the maximum distance between lit turbines does not exceed 900 metres, the corners of the wind farm are lit and that any change of direction of the perimeter of the wind farm can be recognised;
- any wind turbine that is located at a distance greater than 1800 m from the nearest lit turbine must also be lit;
- lights may be operated by a suitable control device (e.g., photocell, timer, etc.). In the event that a photocell is used, in lieu of the 30 minutes after sunset and 30 minutes before sunrise requirement, the CAA will accept a solution that turns the lights whenever illuminance reaching a vertical surface falls below 500 LUX. The control device should turn the lights off when the illuminance rises to a level of 500 LUX or more;
- if visibility in all directions from every wind turbine generator in a group is more than 5 km, the light intensity for any light required to be fitted to any generator in the windfarm and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type.

4.8 The draft text refers to the specifications listed above as “specific lighting requirements apply[ing] to wind turbines”. However, the stated purpose of CAP 764, as with other CAPs, is “to provide UK industry with:
a) guidance and clarification on the means of achieving compliance with global, UK and European regulatory requirements, and where applicable:
b) details of United Kingdom (UK) ‘Alternative Means of Compliance’, and
c) details of any additional national requirements, including CAA administrative procedures.”
Therefore, except where it is stating mandatory lighting requirements set out in the ANO, the CAP 764 specifications for lighting are guidance. It has been confirmed in consultations with the CAA that the new draft text of CAP 764 on lighting does not supercede the provisions of ANO Articles 222(6) and (7) and ICAO Annex 14 paragraph 4.3.2 allowing for approval of alternative lighting schemes on the basis of an aeronautical study; and that the CAA will continue to appraise wind farm lighting schemes on a case-by-case basis.

5. Methodological approach to the study

5.1 As set out in section 3, the proposed Bhlaraidh Extension wind farm is located immediately to the east of the existing Bhlaraidh wind farm, which has a lighting scheme consisting of infra-red lights on seven cardinal turbines only. The maximum tip height of the Extension turbines above sea level will be lower than those of the existing wind farm and the combined development will appear as a single wind farm when the Extension is built.

5.2 During the past decade, UK search and rescue has been transferred from military to civil responsibility and police and air ambulance helicopter units now cover the whole country. A growing proportion of these civil operators routinely fly at night at low level using Night Vision Imaging Systems (NVIS). Military night low level operations in this part of UK airspace are exclusively conducted using NVIS.

5.3 In view of the immediate proximity of the Bhlaraidh and Bhlaraidh Extension wind farms, their similarity in vertical extent, and the type of night low level air operations conducted in the airspace surrounding the Bhlaraidh Extension wind farm site, this lighting scheme proposal has been designed on the basis of extending the configuration of infra-red only lighting on the existing wind farm, with adjustments to take account of the fact that the Extension turbines are larger than the existing Bhlaraidh turbines.

5.4 The method adopted in developing this proposal aims to comply with the principle set out in ICAO Annex 14 paragraph 6.2.4.3 that lighting should be designed, as far as possible, to identify the perimeter of the wind farm. In addition the proposal aims to respect the recommendation in Annex 14 paragraph 6.2.3.15(b) that perimeter lights should be spaced no more than 900 metres apart – albeit applying to infra-red lighting, not visible lighting.

5.5 The proposal has also been developed on the basis of consultation with key aviation stakeholders. A review of likely or possible users of the night low level airspace in this part of Scotland identified the following operators:

- MCA/Bristows search and rescue (SAR) helicopter unit, Inverness;
- Scottish Ambulance Service/Helimed, Inverness/Glasgow;
- PDG Helicopters, Inverness;
- Highland Aviation Training Ltd, Inverness;
- Scotland’s Charitable Air Ambulance (SCAA), Perth and Aberdeen;
- Police Scotland Air Support Unit, Glasgow;
- Ministry of Defence.

6. The night low level air traffic environment around Bhlaraidh Extension

6.1 ICAO Annex 14 paragraph 4.3.2 advises that a special aeronautical study of the nature of any hazard created by an obstacle of 150m or more "may have regard to the nature of operations concerned and may distinguish between day and night operations." For this report, an assessment has been made of the volume and types of air traffic that may use the night low level airspace in the vicinity of the Bhlaraidh Extension site.

Airspace structure and classification

6.2 The Bhlaraidh Extension site is in Class G (uncontrolled) airspace from surface level to Flight Level 195 (approximately 19,500 feet). Above that level is the Class C controlled airspace of the Scottish Flight Information Region (FIR) and Upper Information Region (UIR). The nearest controlled airspace at surface level is the Aberdeen Control Zone, 125km to the east of the Bhlaraidh Extension site. A proposal to introduce controlled airspace around Inverness Airport has been in progress since 2013.[6] However the closest boundary of the proposed Inverness controlled airspace is 17km from the Bhlaraidh Extension site.[7]

6.3 The Bhlaraidh Extension site lies 11km east of the eastern boundary of the Highlands Restricted Area (R610A), where military low flying is permitted in instrument conditions (i.e. without requiring sight of the ground or obstacles), by day and night. R610A is activated between surface level and 5000 ft by Notice to Airmen (NOTAM) when required. Activations are infrequent. Since flights within R610A, when activated, are being conducted by aircraft that are not flying by visual reference, the configuration and specification of obstacle warning lights is not relevant. In addition, the Bhlaraidh Extension site lies within a part of the Military Night Low Flying System known as Allocated Region 1B East, where night low flying under the Visual Flight Rules (VFR) is carried out.

6.4 Licensed and government aerodromes within 50 nautical miles (93km) of the Bhlaraidh Extension site, with their status, are shown in Table 2.

Table 2: Licensed and government aerodromes within 50nm[8]

Airfield	*Distance from Bhlaraidh site (nm)*	*Equipped and open for night flying?*	*Remarks*
Inverness	25	Yes	Based Helimed and SAR helicopters; Highland Aviation training
Kinloss	42	Yes	Relief Landing Ground for Lossiemouth; Moray Flying Club training
Lossiemouth	50	Yes	Operational RAF fighter and maritime base

[6] Inverness Airport | UK Civil Aviation Authority (caa.co.uk)

[7] CTA-6 (base altitude 5000ft). The closest proposed segment with a base at or lower than the Bhlaraidh/Bhlaraidh Extension turbines will be CTA-7 (proposed base altitude 2200ft), 20km north east of the Bhlaraidh Extension site.

[8] Unlicensed airfields, airstrips and gliding sites are excluded from this table. There are no such facilities within 50nm of Bhlaraidh Extension that are equipped or open for night flying.

Types of air traffic

6.5 Night Visual Flight Rules (VFR) operations from Inverness Airport include regular operational and training flights by the based SAR and air ambulance helicopters, and occasional night training flights by aircraft from Highland Aviation Training.

6.6 Kinloss Barracks is a Relief Landing Ground for the Typhoon and Poseidon aircraft based at RAF Lossiemouth but is not routinely open at night. Operations from Lossiemouth include night low level training by based Typhoons and occasional visiting military aircraft. All such operations are conducted using night vision goggles (NVGs).

6.7 Other than aircraft flying to or from the airfields listed in Table 2, civilian night VFR transit traffic over the Bhlaraidh Extension area is likely to be restricted to flights that are either (a) emergency services helicopters or (b) aircraft that, for aircraft certification and/or pilot licensing reasons, are unable to fly at higher altitudes and/or under the Instrument Flight Rules (IFR). In practice this means that the possible types of civil aircraft flying VFR at night in the Bhlaraidh Extension area at altitudes less than 1000 feet above the highest obstacle within 8km of the aircraft are:

- light (mainly single piston-engined) fixed-wing aircraft;
- helicopters not certified for flight in known icing conditions, when the cloudbase and freezing level are below c.3400ft;[9]
- emergency services helicopters.

Volume/frequency of traffic

6.8 Light fixed-wing aircraft, particularly single piston-engined types, rarely fly VFR at night in Scotland except when doing so for training to obtain a Night Rating. Frequent poor weather, widespread high terrain and relative scarcity of airports open and equipped for night flying compound the generic risks of flying VFR at night – i.e. the inability to see and avoid cloud and obstacles or to select a suitable forced landing field in the event of engine failure. For these reasons, commercial fixed wing flights at night operate under the IFR and therefore fly above the levels at which lighting of obstacles is required. Pilots of private VFR flights in light fixed wing aircraft will seek to avoid flying at night at altitudes where terrain and obstacle clearance are a factor. They will also seek to avoid flight over higher ground where the margin between the cloudbase and the terrain is reduced and where forced landing options are poor. All of these factors apply to the airspace surrounding the Bhlaraidh Extension site. The very low probability of light fixed-wing aircraft flying at low level in this part of Scotland is compounded by the fact that a Lower Airspace Radar Service is not generally available at night in this area.[10]

[9] The highest obstacle within 8km of the Bhlaraidh Extension wind farm is and will remain Turbine 13 of the existing Bhlaraidh wind farm, 2395ft amsl, requiring flight not below 3400ft to comply with IFR (assuming rounding-up to the next highest hundred feet).

[10] The Lossiemouth LARS service extends only to 40nm radius, and closes at 1700hrs Local. Inverness ATC is not an official LARS provider.

6.9 In 2017 the Future Airspace Strategy VFR Implementation Group (FASVIG), using funding provided by the CAA, carried out a research exercise to identify "VFR Significant Areas" (VSAs) in UK airspace. These were defined as "a volume of airspace which has been identified as being particularly important to VFR operations. A VSA might take the form of a route, a zone or an area chosen for its particular importance to its VFR users."[11]

6.10 FASVIG identified the Great Glen Corridor, between Fort William and Inverness, as one such VSA, characterising its 'uniqueness and importance' as "a vital VFR transit area when cloudbases are low over high terrain", noting that "high terrain and regular low cloud bases frequently require use of low level valley" and that "due to terrain the corridor can be narrow in parts".[12]

6.11 The FASVIG report does not specifically address the feasibility or desirability of using this route at night. However, the probability of an aircraft flying such a route VFR at low altitude at night is extremely low because of:

- the absence of airfields open at night at the south west end of the corridor;
- high terrain on either side of the glen;
- very poor forced landing options due to extensive lochs and steeply sloping terrain, much of it forested;
- the narrowness of the glen in some areas, making turn-backs due to deteriorating weather difficult.[13]

These constraints are particularly true in the circumstances cited by FASVIG as the reasons for the route's importance – low cloud over the surrounding high terrain. The Bhlaraidh Extension site is 5km from the nearest part of the Great Glen and on terrain more than 2000ft higher than the surface of Loch Ness. It is therefore highly unlikely that, in the extremely rare circumstances of a non-NVG equipped aircraft flying VFR at night through the Great Glen, it would fly in the vicinity of the Bhlaraidh Extension wind farm.

6.12 For any aircraft operating at night over the general area, rather than transiting through the Great Glen corridor - for example, aircraft on night training flights from Inverness - terrain considerations would also apply. The 1:500,000 VFR chart shows the Maximum Elevation Figure (MEF) for this area as 3900 feet above sea level (see Figure 3). Any such flights would therefore be rare and would be likely to remain at altitudes in excess of the MEF, at which obstacle lighting would not be necessary for safety of flight.

6.13 For helicopters not certified to fly in icing conditions – all but the larger multi-engined types – the same considerations apply as to light fixed wing aircraft. Commercial helicopters – other than emergency services aircraft - are unlikely to be in transit in the Bhlaraidh Extension area at night since Bhlaraidh Extension is not on

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11 FASVIG, *Register of VFR Significant Areas*, 2nd Edition, September 2017, paragraph 2.1.

12 FASVIG, *Register of VFR Significant Areas*, 2nd Edition, September 2017, pp.82-83.

13 In some places the valley is less than 1.5nm wide at a level 1500ft above the valley floor, making a Rate 1 turn-back at typical light aircraft speeds extremely challenging.

a route between any significant points. Any helicopters routing VFR to the west coast at night, for example via Glen Moriston and the A887 road (south of the Bhlaraidh site) would seek to follow the valley and would therefore be unlikely to route over or in the vicinity of the Bhlaraidh or Bhlaraidh Extension wind farms. Private helicopter flights at night in the Bhlaraidh Extension area are even less likely to occur than private fixed wing flights and can effectively be discounted.

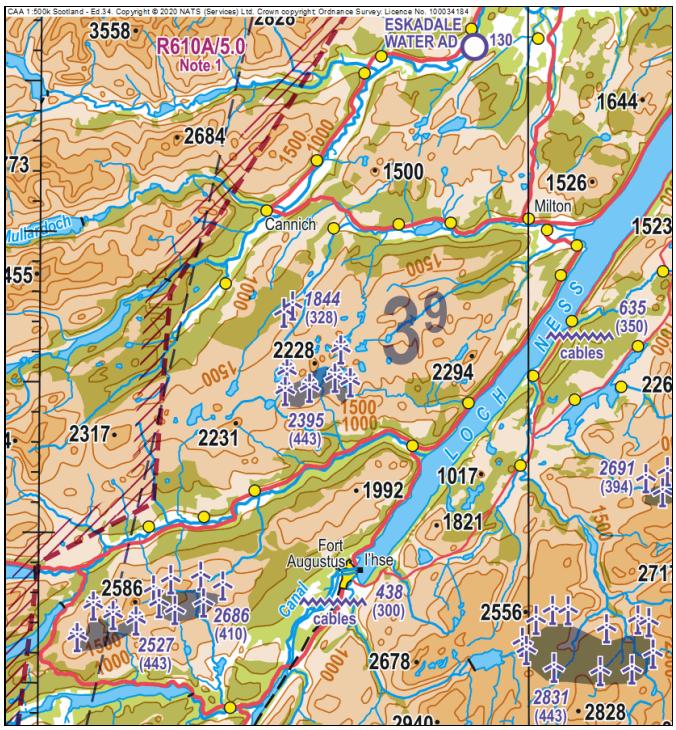

Figure 3: 1:500,000 chart showing Maximum Elevation Figure (MEF)

6.14 The remaining category – emergency services helicopters – are therefore, in practice, likely to be the only civil aircraft operating VFR at low level at night in the vicinity of the Bhlaraidh Extension wind farm. In this part of the UK the emergency services operators are:

- Bristow Helicopters/Maritime & Coastguard Agency Search & Rescue Unit, Inverness (AgustaWestland AW189);
- Scottish Air Ambulance Service, Inverness (Eurocopter EC-145T2);
- Police Scotland Air Support Unit, Glasgow Heliport (Eurocopter EC-135T3);
- Scotland's Charitable Air Ambulance (SCAA), Perth (Eurocopter EC-135T2+);
- SCAA, Aberdeen (Eurocopter EC-135T2+).

6.15 The first three operators are certified, equipped and crewed to use NVGs to aid VFR flight at night. Transit flights at low level at night are carried out using NVGs and/or at heights that ensure vertical separation from obstacles. Obstacle acquisition and identification in search areas at low level may be carried out using a combination of NVGs and unaided vision.

6.16 The SCAA helicopters at Perth and Aberdeen are not currently NVG-equipped and their hours of operation do not extend beyond 1900hrs local time.[14] Their operations at night are therefore limited. These helicopters may carry out night transit flights between lit and surveyed sites but operations to unlit sites at night are not permitted. Night VFR transit flights are flown at altitudes and on routes that ensure horizontal and/or vertical clearance from charted obstacles, whether lit or unlit.

6.17 In view of the low frequency of air traffic in this part of UK airspace, particularly at night and under VFR; the fact that the bulk of any flight operations that may occur in this area are conducted using NVIS; and the fact that the existing and immediately adjacent Bhlaraidh wind farm has been operating safely for more than three years with infra-red lighting only, it is considered that there is a case for the Bhlaraidh Extension wind farm to also be lit using infra-red lights only.

7. Residual risk

7.1 While the frequency of night VFR flight with unaided vision in the vicinity of the Bhlaraidh site is assessed as being very low, it may be argued that the lighting provisions in ANO Article 222 are designed to cover the extreme worst case of an aircraft whose pilot is lost or uncertain of position and either unaware of their proximity to the ground or obstacles and/or attempting to maintain VFR by descending below a lowering cloudbase.

7.2 In order to attempt to quantify the probability of an aircraft colliding with unlit wind turbines, Aviatica has initiated research in the Air Accidents Investigation Branch (AAIB) database to identify any accidents in the period 2000-2020 in which an aircraft collided with an unlit obstacle in the en route phase of a night VFR flight in UK airspace. Due to limitations in the data categorisation parameters used by AAIB, this work has not yet been completed. However the initial indications are that no such accident has occurred in the 21 year period covered.

7.3 The lighting provisions in ANO Article 222 are, in risk assessment terms, a blunt instrument. They deem objects lower than 150m agl to be insufficient a collision risk at night to require lighting, whereas any object at 150m or higher is by definition unsafe unless lit. The origins of the 150m figure are in ICAO Annex 2 (Rules of the Air), which establishes a Standard that aircraft are not to be flown VFR "at a height less than 150 m (500 ft) above the ground or water".[15]

7.4 The Standardised European Rules of the Air (SERA) - applicable in the UK from 2014 until the UK left the EU and its aviation safety regulator the European Aviation Safety Agency (EASA) on 31 December 2020 – inserted an additional requirement to the ICAO Annex 2 Standard quoted above by requiring that aircraft

[14] Official night is earlier than 1900hrs local time at Invermoriston between approximately 29th September and 27th March.

[15] ICAO Annex 2 Amendment 46 (8 November 2018), paragraph 4.6(b).

are also not permitted to fly VFR at a height less than "150 m (500 ft) above the highest obstacle within a radius of 150 m (500 ft) from the aircraft".[16]

7.5 The UK has applied further variation to the SERA minimum height rules for VFR flight, allowing such flights to operate at less than 150 metres (500 feet) above the ground or water or less than 150 metres (500) above the highest obstacle within a radius of 150 metres (500 feet) from the aircraft, subject to the proviso that:

> The aircraft must not be flown closer than 150 metres (500 feet) to any person, vessel, vehicle or structure except with the permission of the CAA.[17]

7.6 The UK also applies a further exemption to the SERA rules relating to VFR flight at night. SERA.5005(c) permits VFR flight at night but requires that aircraft must:

- maintain continuous sight of the surface[18]; and
- fly at a level which is at least 300 m (1 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft.

The UK, however, permits an exemption to that rule, allowing aircraft flying VFR at night to be flown at less than 1000ft above the highest obstacle within 8 km, subject to the aircraft remaining:

- at an altitude not exceeding 3000ft amsl, or 1000ft above terrain, whichever is the higher;
- clear of cloud and with the surface in sight;
- at a height of more than 500ft above the ground or water, or 500ft above the highest obstacle within a radius of 500ft from the aircraft.[19]

7.7 The net result is that the UK allows VFR flight at night at levels lower than the standard European rules and lower than provided by ICAO Standards and Recommended Practices. However, in considering a worst case collision risk scenario at Bhlaraidh, it is important to take account of the mitigations in place through flight planning practices and information available to the pilot.

7.8 In planning a VFR flight at night, a pilot will pay special attention to calculation of a minimum flight altitude to ensure safe separation from terrain and obstacles that may not be visible to them. There are numerous methods for doing this. Table 3 sets out the resulting minimum flight altitudes over the Bhlaraidh site calculated using different methods.

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16 SERA.5005(f)(2).

17 Official Record Series 4, No.1174: *Standardised European Rules of the Air – Exceptions to the Minimum Height Requirements*, 6 June 2016, paragraph 2. Following UK exit from the EU and EASA, the SERA rules (as amended) continue to apply in UK airspace under the terms of the European Union (Withdrawal) Act 2018.

18 Unless flying higher than 3000ft amsl or 1000ft above terrain, whichever is the higher. In the Bhlaraidh context this would mean that aircraft flying at or above 3300ft amsl would not be subject to this 'surface in sight' rule.

19 Official Record Series 4, No.1342: *Standardised European Rules of the Air – Visual Flight Rules (VFR) and Special VFR Flight at Night*, 13 February 2020, paragraphs 2 & 3.

Table 3: Minimum night VFR flight altitude calculations		
Method	*Description*	*Calculated minimum flight altitude over the Bhlaraidh site (ft amsl)*
Maximum Elevation Figure (MEF)	CAA 1:500,000 and 1:250,000 VFR aeronautical charts publish a Maximum Elevation Figure for quadrangles bounded by each half degree of latitude and longitude. Each MEF is based on the highest known feature in each quadrangle, plus an allowance of 300 feet for unknown and uncharted obstacles, rounded up to the next highest hundred feet.	4400 (assuming flight at 500ft above the MEF)
Minimum Safe Altitude (MSA)	Unofficial but widely used method, typically applying a minimum level criterion of 1000ft above the highest obstacle within 5nm, using VFR charts to ascertain terrain/obstacle heights.[20]	3600 (assuming 300ft allowance for unknown/uncharted obstacles)
500ft rule	Applying the minimum 500ft vertical separation above the highest obstacle over which the aircraft is likely to fly, rounded up to the next highest hundred feet.	2900

7.9 The lowest altitude calculation in Table 3 is 2900ft amsl. This is based on the height of the highest existing Bhlaraidh wind turbine blade tips (2395ft). This will be unchanged when the Bhlaraidh Extension is built since the highest Bhlaraidh Extension blade tips will be 2346ft amsl, lower than those of the immediately adjacent existing wind farm.

7.10 Having applied one of the minimum altitude calculations illustrated in Table 3 at the flight planning stage, the pilot is then reliant, in flight, on a combination of visual and avionics means of determining his/her position. Clearly, positional certainty/accuracy is crucial to the selected flight altitude delivering the desired safety from risk of collision with the terrain or obstacles.

7.11 Before discussing the means used by pilots to determine their horizontal position during VFR flights at night, it is important to set out the altitude datum used by pilots of light aircraft not equipped with radar altimeters or night vision systems. When flying over areas of terrain of varying heights, pilots of these aircraft have no means of determining their height above the ground. Their only means of achieving and maintaining safe vertical separation from the terrain and obstacles is to set their

[20] This criterion differs slightly from the ICAO and SERA minimum level for IFR flight which is 1000ft above the highest obstacle within 8km. However UK aviation uses nautical miles, not kilometres, for distance measurement. The origin of the 5nm criterion is in the pre-SERA UK rules for IFR – *Rules of the Air Regulations 2007*, Rule 33(1).

altimeter to an appropriate QNH (i.e. setting the altimeter datum to sea level) and to fly at or above the safe altitude above sea level derived from one of the calculations in Table 3. Consequently, for a pilot flying a basic equipment light aircraft at night, VFR, the height of any potentially hazardous obstacles above ground level is irrelevant. The only means of ensuring safe separation from those obstacles is by flying at an appropriate altitude above sea level.

7.12 Visual situational awareness during VFR flight at night depends almost entirely on reconciliation of the lights visible on ground features with positions on the aeronautical chart. Adherence to the VFR at night – other than in conditions of strong moonlight - also depends on remaining in visual contact with sufficient lights to be able to determine the aircraft's flight attitude solely by visual reference:

> "With the surface in sight" means with the flight crew being able to see sufficient surface features or surface illumination to enable the flight crew to maintain the aircraft in a desired attitude without reference to any flight instrument and "when the surface is not in sight" is to be construed accordingly.[21]

7.13 In remote rural areas such as the Scottish Highlands, the relative scarcity of cultural lighting makes it more difficult for VFR flights to meet the "surface in sight" criterion. This is a further reason why pilots making such flights are more likely to choose to fly at the higher of the altitudes shown in Table 3,[22] or to select routes along the coast and/or major roads where towns, villages and road traffic provide more visual cues to determine the aircraft's position and flight attitude.

7.14 Positional situational awareness during VFR flight at night may also be aided by use of avionics. However, conventional radio navigation aids such as NDB, VOR and DME are unlikely to be of much practical assistance to an aircraft being flown single pilot VFR at night without an auto-pilot, since converting radio-derived bearing and distance information to a position fix requires the pilot to physically plot the information on a paper chart, head-down in the cockpit, which is impractical due to the need to focus attention on maintaining the attitude of the aircraft.

7.15 GPS and related flight planning software does, however, provide a significant increase in the ability of night VFR pilots to determine their horizontal position and maintain a safe flight altitude. Basic GPS equipment with a moving map display, suitable for VFR flight, has been on the market since the late 1990s and is now commonplace in the types of light aircraft certificated for flight at night. These GPS units have a terrain and obstacle database which can provide visual and aural warnings to the pilot. GPS is not certified for use as the sole or primary means of navigation and the efficacy of their obstacle data is dependent on keeping the databases current. The expense and effort of doing this may deter some aircraft owners from doing so. However, in the case of the Bhlaraidh site, even out-of-date GPS databases are likely to show the 2395ft maximum elevation of the existing Bhlaraidh wind farm, which has been in place since 2017.

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[21] *The Air Navigation Order 2016*, SI 2016 No.765, Schedule 1.

[22] The requirement to maintain continuous sight of the surface during VFR flight at night does not apply if the aircraft is flying higher than 3000ft amsl or 1000ft above terrain, whichever is the higher – SERA.5005(c)(3)(iii).

7.16 In recent years a number of flight planning and logging apps have come on to the market which provide a further step-change in the ability of light aircraft pilots to plan and navigate VFR flight at lower altitudes, taking account of airspace, terrain and obstacle constraints. Pre-eminent in the UK market is Skydemon.[23] Others include Foreflight, EasyVFR and Air Navigation Pro. All of these apps contain obstacle databases obtained from NATS AIS and updated regularly online for those subscribed to the software. This provides awareness to pilots at the flight planning stage of terrain and obstacles that might affect the flight, and also provides visual and aural warnings of terrain and obstacles ahead of the aircraft during flight. Figure 4 is a screenshot of Skydemon's warning page for an aircraft on a simulated local flight from Inverness, approaching the Bhlaraidh wind farm while flying at an altitude of 2300ft – 95ft below the blade tips. It is accompanied by an aural warning.

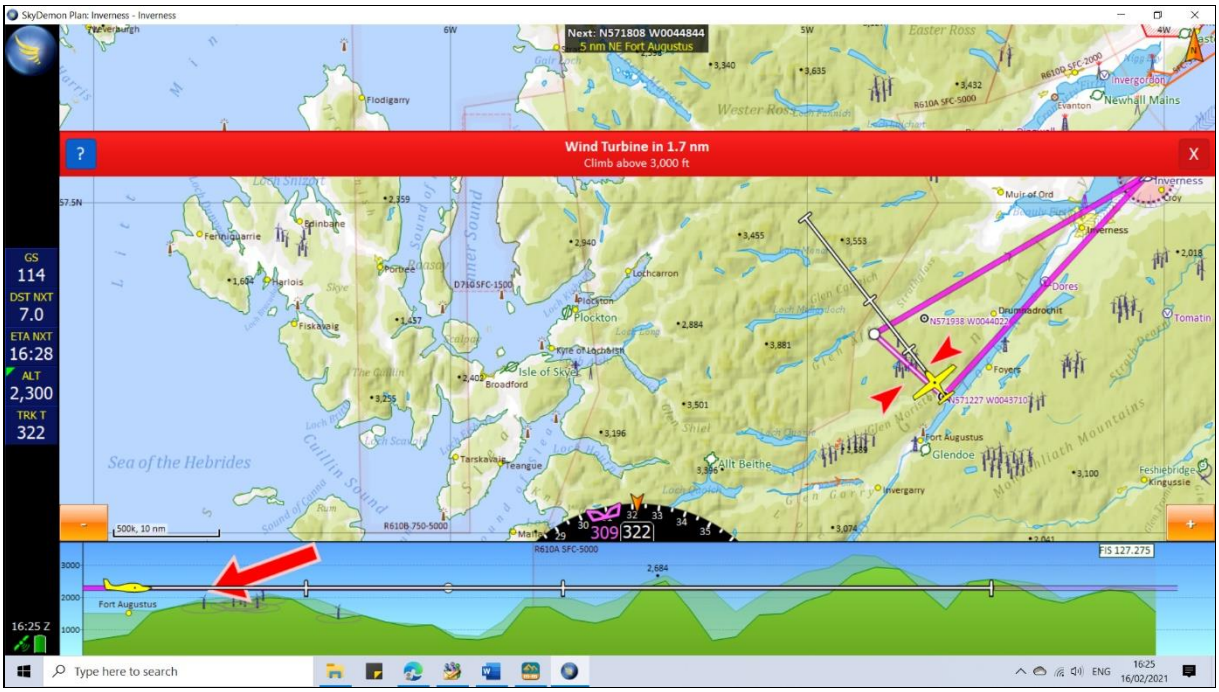

Figure 4: Skydemon obstacle warning screen

7.17 The technology outlined above reduces the already very low probability of an aircraft finding itself in the Bhlaraidh area at night at an altitude where it is at risk of colliding with unlit wind turbines. However the central point of the risk assessment of the lighting scheme proposed in this document does not rely on whether or not a particular aircraft is equipped with GPS-based flight planning, navigation and obstacle warning technology. It is based on the fact that the existing Bhlaraidh wind farm is officially not an en route obstacle since its blade tips are less than 150m above ground level.[24] Thus unlit blade tips higher than the immediately adjacent proposed Bhlaraidh Extension turbines are effectively deemed to be of no material

[23] Skydemon declined to provide data for this study on the number of units they have sold in the UK market but author experience is that a high proportion of PPL owner-pilots use this system.

[24] This would remain the case if the Bhlaraidh blade tips were up to 149.9m agl – giving a maximum blade tip height at the existing wind farm of 2460ft amsl, more than 100ft higher than the proposed Bhlaraidh Extension turbines.

risk to an aircraft, whereas the Extension turbines, despite being lower above sea level, are regarded as an unacceptable risk unless lit.

7.18 This difference in the level of risk attributed to Bhlaraidh and Bhlaraidh Extension is not simply a logical anomaly. It could also – in the worst case scenario - have real safety consequences. If some or all of the Bhlaraidh Extension turbines were fitted with visible spectrum lighting, a pilot who had made serious errors in determining his/her position and/or altitude and was flying through the area at, say, 2300ft amsl, might see the lights on the Extension turbines and turn the aircraft away from them, only to fly into the adjacent unlit Bhlaraidh turbines.

7.19 The proposed lighting scheme set out in this document would extend the area of unlit turbines to the east of the existing wind farm. To that extent it would increase the horizontal area over which the risk posed by the existing wind farm – defined by ICAO and the ANO as acceptable –applies. However, since the maximum vertical extent of the Extension turbines is 49ft lower than those of the existing wind farm, the degree of risk over that extended area is less than it is over the existing wind farm.

7.20 Any worst case assessment of the risk of an aircraft colliding with unlit obstacles in the Bhlaraidh area must also consider the range of flight altitudes at which the risk could present itself. At present, the existing Bhlaraidh turbines present such a risk to an aircraft flying at less than 2400ft amsl. This would be unchanged when the Extension turbines are built. However there are three area of high ground within 6km of the Bhlaraidh wind farm site with elevations between 2200 and 2300 feet amsl (see Figures 2 and 3). Any aircraft flying in or below that altitude band at night would be at severe risk of colliding with the terrain. Thus, any additional worst-case risk posed by the existing Bhlaraidh and proposed Bhlaraidh Extension turbines effectively applies only in a very narrow altitude band between 2300 and 2400 ft amsl. The probability of any pilot flying in that altitude band, given the rapidly changing terrain heights across the whole of this part of Scotland, is extremely low.[25]

7.21 The risk of an aircraft colliding with the existing unlit turbines at the Bhlaraidh site is currently regarded as acceptable purely because the existing turbines are less than 150m agl and therefore do not require lighting under the ANO. But the risk of an aircraft flying VFR at night colliding with obstacles relates to their elevation above sea level, not ground level – especially in an area of high and varying terrain elevation. Therefore, since the Bhlaraidh Extension turbines will have a maximum elevation lower than that of the existing Bhlaraidh turbines, the Extension does not generate additional risk sufficient to justify fitting the turbines with visible spectrum lighting. Further, the fitting of visible lighting to the Bhlaraidh Extension turbines could introduce a new element of risk of a pilot flying at an unsafe altitude taking avoidance action on seeing the lit turbines and flying into the adjacent unlit turbines.

[25] This point may be best appreciated by considering the hypothetical alternative scenario of 180m tip height turbines being installed in an area of uniformly flat terrain at or close to sea level. This would create multiple obstacles up to 591 feet in an area where an aircraft could conceivably be flying at 500ft, the pilot believing that, due to the generally flat terrain, it was safe to do so.

8. Visibility of LED lights

8.1 In 2013 the crew of a Royal Navy Lynx helicopter filed an incident report after finding that the lights of another Lynx flying in proximity to them at night were not visible to the crew through their NVGs. Investigation of the incident determined that the other Lynx had visible spectrum red light emitting diode (LED) lights switched on, and that these were not visible through NVGs because LED lighting emits in a very narrow wavelength band which is only narrowly within the spectrum visible to NVG wearers.[26]

8.2 Following the 2013 incident, research by QinetiQ for the Defence Science & Technology Laboratory found that, while the vast majority of the emissions from traditional incandescent lighting overlapped with the wavelength range visible to NVGs, LED lights occupied only a narrow part of the NVG visible spectrum and, while technically still visible, the NVG weighted radiance of LED lights was 369 times less than that of an incandescent red light. This translates to the LED light being theoretically detectable at a range 19 times less than that of the incandescent light.

8.3 Similar experiences by civilian aircrew using NVGs led EASA to issue a Safety Information Bulletin in 2019 which noted that the issue was more pronounced for civilian users because NVGs approved for civilian use are not sensitive to energy generated in the narrow band of LED lights, and advised:

> NVG users should be aware that LED obstacle lighting systems falling outside the combined visible and near-infrared spectrum of NVG (approximately 665 to 930 nm) will not be visible to their goggles. Crews that use NVGs should be extra cautious when flying near obstacle areas and to report any hazardous sites to their competent authority.[27]

8.4 The non-visibility of LED obstruction lights to civilian NVG users has also been reported by search and rescue helicopter and other consultees during research conducted by Aviatica on the scope for reduced lighting schemes in 2019-20.

8.5 The issue of non-visibility of LED lights to NVG users has significance for the design of lighting schemes for wind farms with blade tip heights of 150m or more. CAA policy requires these to have a 2000 candela light on the nacelle plus 32 candela lights at mid-tower height. All current obstacle aviation warning lights on the market use LED technology. Setting the 19-fold detection range reduction for military specification NVGs referred to above against the minimum light detection ranges promulgated by the Federal Aviation Administration, the theoretical detection ranges of LED lights by NVG wearers, assuming the minimum in-flight visibility for VFR flight at night (4.8km in the USA) are set out in Table 4.[28]

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[26] D Bigmore, 'Why NVG Users Might Not Be Seeing Anti-Collision/Obstruction Lighting As Well As They Used To', *Air Clues* Issue 23, 2017, pp.36-38.

[27] EASA Safety Information Bulletin No.2019-04, 28 February 2019: Avoiding Obstacles Lighted with Light-Emitting Diode Obstacle Lights whilst Operating with Night Vision Goggles.

[28] Federal Aviation Administration, Advisory Circular No.70/7460-1L: Obstruction Marking and Lighting, 17 August 2018, Table B-1.

Table 4: LED light detectability using NVGs[29]			
In-flight meteorological visibility (km)	*Light intensity (candela)*	*Detection range with unaided vision (metres)*	*Detection range with NVGs (metres)*
4.8	2000	4900	258
4.8	32	2200	116

8.6 Since the rotor blade length of the largest onshore turbines now being built is up to 75 metres, the detection ranges of LED lights using NVGs are clearly inadequate to ensure collision avoidance, even for 2000 candela lights. Since almost all regular VFR flights at night in the low level airspace are conducted by aircraft whose crews are using NVGs, fitting only visible spectrum LED lights to turbines provides little or no safety benefit. Additionally, since all commercial-scale wind farms in the UK now have MoD-specification infra-red lights fitted to, as a minimum, the perimeter turbines, fitting additional visible spectrum lighting provides no additional benefit to NVG-equipped airspace users.

9. Design of the lighting scheme

9.1 The proposed Bhlaraidh Extension wind farm consists of 18 turbines, all with tip heights of 180 metres above ground level. The Extension is immediately adjacent to the operational Bhlaraidh wind farm and will have blade tip heights within the range of the existing Bhlaraidh wind farm.[30] The combined Bhlaraidh and Bhlaraidh Extension wind farms will appear from the air as a single development when the Extension is built.

9.2 Given the immediate proximity of the two schemes; the fact that the Extension will not increase the height of turbines over and above those of the existing Bhlaraidh wind farm; and the nature of night low level air traffic patterns in the vicinity, the lighting scheme has been designed with the aim of achieving definition of the perimeter of the combined Bhlaraidh and Bhlaraidh Extension developments, extending the infra-red lighting scheme installed on the operational Bhlaraidh turbines. The proposed lighting scheme is shown in Figure 5.

Perimeter lighting

9.3 In line with the recommendation in paragraph 6.2.4.3 (a) of ICAO Annex 14, it is proposed to fit all perimeter turbines in the Bhlaraidh Extension wind farm with lights. However, these will be infra-red lights only. All corners and changes of direction of the wind farm perimeter will be marked with infra-red lights. The lighting of all perimeter turbines, as opposed to the cardinal turbine lighting specification applied to the existing Bhlaraidh wind farm, is in recognition of the fact that the Extension turbines have blade tips that are higher above ground level than the

[29] It should be noted that the figures shown for detection range with NVGs relate to military specification NVGs, which have a sensitivity wavelength range of approximately 630 to 930 nanometres (nm). For civil NVGs, which have a sensitivity wavelength range of 665 to 930 nm, the lights are likely not to be detectable at any range.

[30] The Bhlaraidh turbines have tip heights ranging from 2001 to 2395ft amsl. The Bhlaraidh Extension turbines will have tip heights ranging from 2039 to 2346ft amsl.

existing wind farm and is in response to consultations on other wind farm lighting schemes with the Bristows search and rescue helicopter unit at Inverness.

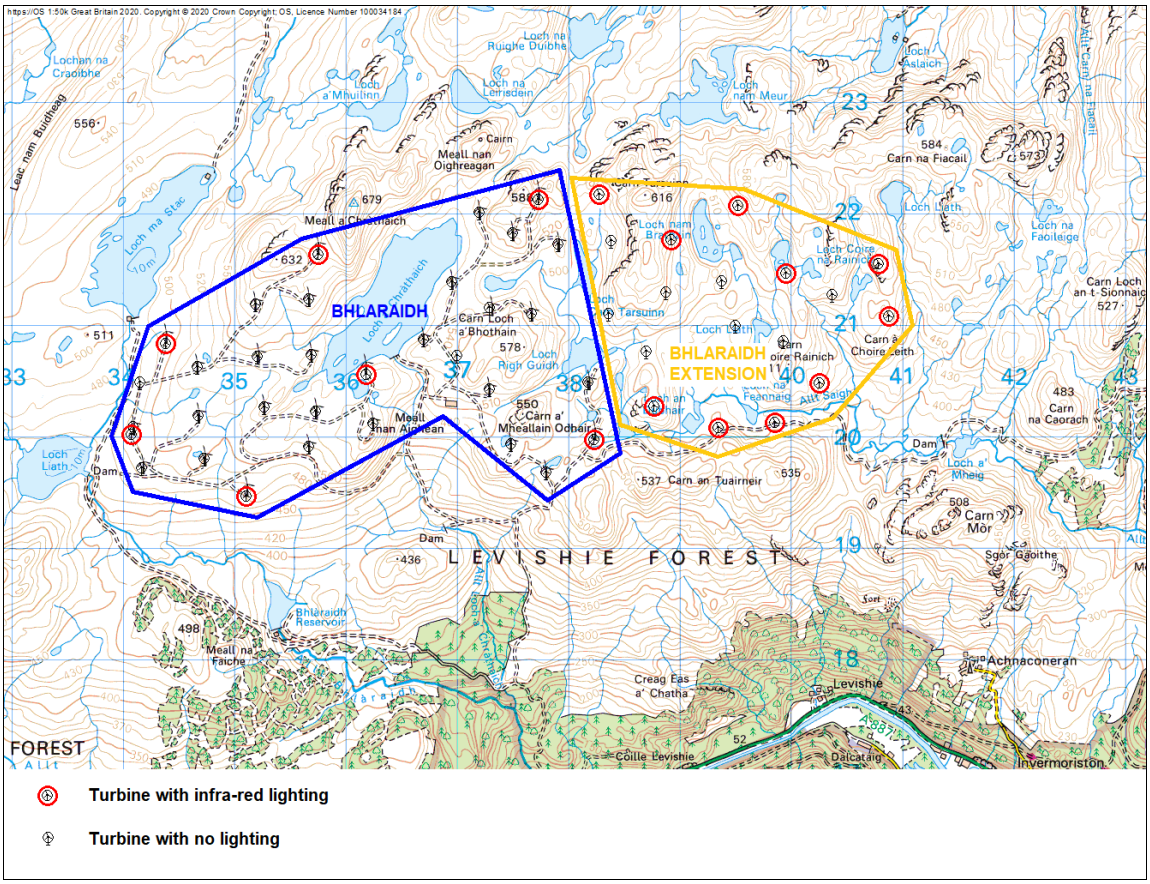

Figure 5: Bhlaraidh and Bhlaraidh Extension combined wind farms proposed lighting scheme

9.4 The lighting scheme has also been designed with the aim of meeting the recommendations in paragraphs 6.2.4.3 (a) and 6.2.3.15 (b) of ICAO Annex 14 that perimeter lights be spaced at intervals not exceeding 900m.[31] That aim has been met for all inter-turbine spacings – the maximum distance between the infra-red lit perimeter turbines – between Turbines 14 and 18 on the south east corner of the wind farm - will be 865 metres.

Identifying higher turbines

9.5 The two highest turbines in the Bhlaraidh Extension wind farm will be T5 and T3, on the northern edge of the wind farm. Both of these will be fitted with infra-red lights, thus meeting the principle of the recommendation in ICAO Annex 14 paragraph 6.2.4.3(d) that lights should be installed on a wind farm "so that, within a wind farm, any wind turbines of significantly higher elevation are also identified wherever they are located". The highest turbine in the existing Bhlaraidh wind farm – T13, on the north west edge – is also lit. In addition, none of the proposed unlit turbines will be at angles of elevation greater than 10° from adjacent lit turbines, thus

[31] Albeit that in this proposed scheme, all the lights will be infra-red, not Medium Intensity Type C.

meeting the principle of the recommendation in paragraph 5.6(f) of the draft revised CAP 764 that any such turbines should be lit.

Mid-tower lighting

9.6 The CAA Policy Statement of June 2017 on lighting of turbines 150m or more in height recommends that "at least three (to provide 360 degree coverage) low-intensity Type B lights (32 candela) lights should be provided at an intermediate level of half the nacelle height." This reflects an ICAO recommendation in Annex 14 paragraph 6.2.4.3(e)(iii) for turbines between 150m and 315m tip height.

9.7 The purpose of the intermediate-level lights is understood to be to enable pilots to identify particular turbines that are greater than 150m in height. However, during consultations with stakeholders on this and other proposed wind farm lighting schemes, the point has been made that because of their low intensity, 32 candela lights are of limited visibility to pilots especially when operating in low visibility conditions. In addition, as explained in section 7 above, it is likely that LED lights will not be visible to aircrew wearing NVGs since modern LED red aviation obstacle lights operate in a narrow frequency spectrum which is outwith the range of frequencies detectable through NVGs. Consequently, Aviatica on behalf of SSE Generation Ltd proposes not to fit intermediate-level 32 candela lights to the Bhlaraidh Extension turbines, and seeks CAA permission for that deviation from the provisions of the 2017 Policy Statement and draft CAP 764.

10. Consultations

9.1 Consultations on the proposed lighting scheme for the Bhlaraidh Extension wind farm are being undertaken with the aviation stakeholders listed in paragraph 5.5. Consultee responses will be forwarded to the CAA for consideration when received.

11. Summary of the proposed lighting scheme

11.1 The 18 wind turbines in the proposed Bhlaraidh Extension wind farm will have tip heights exceeding 150 metres above ground level and will therefore trigger the ANO Article 222 requirement for visible spectrum lighting. In order to meet the requirements of users of the night low level airspace while reducing the night time visual impact of such aviation lighting on observers on the ground, Aviatica on behalf of SSE Generation Ltd requests CAA permission to install lighting on the turbines other than in accordance with the ANO, as provided in ANO Article 222(7).

11.2 The proposed Bhlaraidh Extension lighting scheme is as follows:

- infra-red lights to MoD specification will be installed on the nacelles of turbines in the Bhlaraidh Extension wind farm to identify the combined perimeter of the

Bhlaraidh and Bhlaraidh Extension wind farms, i.e. all turbines in the Extension except numbers 1, 2, 4, 7, 10, 11, 15 and 17.

- in view of the close proximity of the Extension to the existing infra-red lit Bhlaraidh wind farm; the remoteness of the site; the low frequency of air traffic in the area; and the prevalence of NVG-equipped aircraft flying at night in the vicinity, no visible spectrum lighting is proposed.

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