WPAC
Wind Power Aviation Consultants Ltd

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Eredine Aviation Lighting and Mitigation Technical Appendix V2.0

Our Reference: WPAC 054/25
Your Reference: Eredine EIA 4300006262-S1-U21

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Reference Documents

A. Civil Aviation Publication (CAP) 764 Civil Aviation Authority (CAA) Policy and Guidance on Wind Turbines Version 6, Feb 2016
B. CAP 764 Version 7 (Draft) issued for comment in June 2020
C. CAP 764 Version 7 (Draft) issued for comment in April 2024
D. Air Navigation Order (ANO) Article 222
E. CAA 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 dated 01/06/17.
F. International Civil Aviation Organisation (ICAO) Annex 14 Vol 1 Chapter 6
G. MOD Obstruction Lighting Guidance Document 01 Jan 2020
H. Landscape Institute Guidance on Landscape and Visual Impact Assessment Version 3
I. NatureScot Guidance on Aviation Lighting Impact Assessment dated November 2024

Scope

1. This report is divided into two parts. Part 1 proposes a lighting design that is compliant with existing and draft (but soon to be ratified) regulations and guidance contained within References A to G as discussed with the CAA and the MOD. It explains the rationale behind the lighting design considering the requirement to minimise the number of turbines illuminated with aviation obstruction lights whilst maintaining flight safety and provides a detailed assessment of the brilliance of the lighting when viewed from a number of viewpoints provided by the LVIA consultant after consultation with the relevant stakeholders. Part 2 of the report identifies and explains those mitigation measures that can be utilised to minimise the environmental effect of the lights including an assessment of the historical meteorological data from which to predict the luminous intensity requirements for the lights. The entire report can be considered to fulfil the requirements for an Aviation Lighting Landscape and Visual Impact Mitigation Plan and can be used to inform the Landscape and Visual Impact Assessment as recommended in the guidance laid down in the Landscape Institute's Guidelines for Visual Impact Assessment Version 3 (GLVIA3).

Part 1 Turbine Lighting Layout Design

Introduction

2. WPAC have designed a large number of CAA and MOD compliant lighting layouts for wind farms and are also in constant dialogue with the CAA regarding the proposed changes to CAP 764 in terms of aviation lighting requirements. Whilst Reference A is technically the current publication for policy and guidance on this issue, Reference B was released for comment and is already being used by the CAA as the current de facto policy. Reference C is also currently out for consultation with all aviation stakeholders, but the proposed release date has passed, and the CAA have yet to publish a new release date. Discussions with the CAA have clarified that the draft regulations at Reference B will not be changing in terms of the overarching policy but the wording may be slightly amended in the interests of clarity.

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Lighting Layout Starting Point and Assumptions

3. The Proposed Development has seventeen turbines located between Loch Awe and Loch Fyne. The wind farm sits on two hills and a ridge line that straddle the Abhainn-a'-Bhealaich and the Ally-nan-Sacs river valleys.

4. The proposed site is located in MOD Low Flying Area (LFA) 14 by day. This area is the largest and most used low flying training airspace available to both MOD and NATO aircraft. The area around Eredine converts to Night Allocated Region (NAR) 1BE during the hours of darkness. Although primarily a fast jet training area, the airspace is also used by both military and civilian helicopters by day and night.

5. Military fast jet and tactical transport aircraft operate down to 250ft (30m) above ground level in LFA 14. Helicopters routinely operate down to 100ft (30m) and on occasion ground level. Military helicopters are cleared to fly through (operate within) wind turbine sites, but fast jets must fly around these sites separated by their minimum separation distance (msd) which typically is 250ft. Civilian aircraft also operate in the area of the Proposed Development by day and night and this will include helicopters from the Coastguard, Helicopter Emergency Medical Services (HEMS), Police and Air Ambulance. The lighting solution will be required to provide a flight-safe solution for civilian and military aircraft and helicopters operating at both the height of the turbines using night vision devices and above the site without such equipment.

Lighting Assessment Overview

6. From a CAA perspective, Eredine is located outside controlled airspace and away from airports and airfields. As a result, it will be assessed against visible lighting in accordance with Class G 'en-route' airspace requirements as detailed in CAP 764 (latest draft).

- To accommodate MOD requirements the site will be assessed for NVG compatible lighting in accordance with MOD published obstruction lighting specifications.
- Where possible the recommended final lighting configuration will be optimised to reduce light impact on the local area.
- CAA obstruction lighting dispensations that are currently offered where flight safety can be maintained will be included.
- The Eredine wind farm proposal is for 17 turbines at a tip height of 200m. Turbine numbering is not sequential due to a reduction in the number of turbines from the previous site layout.

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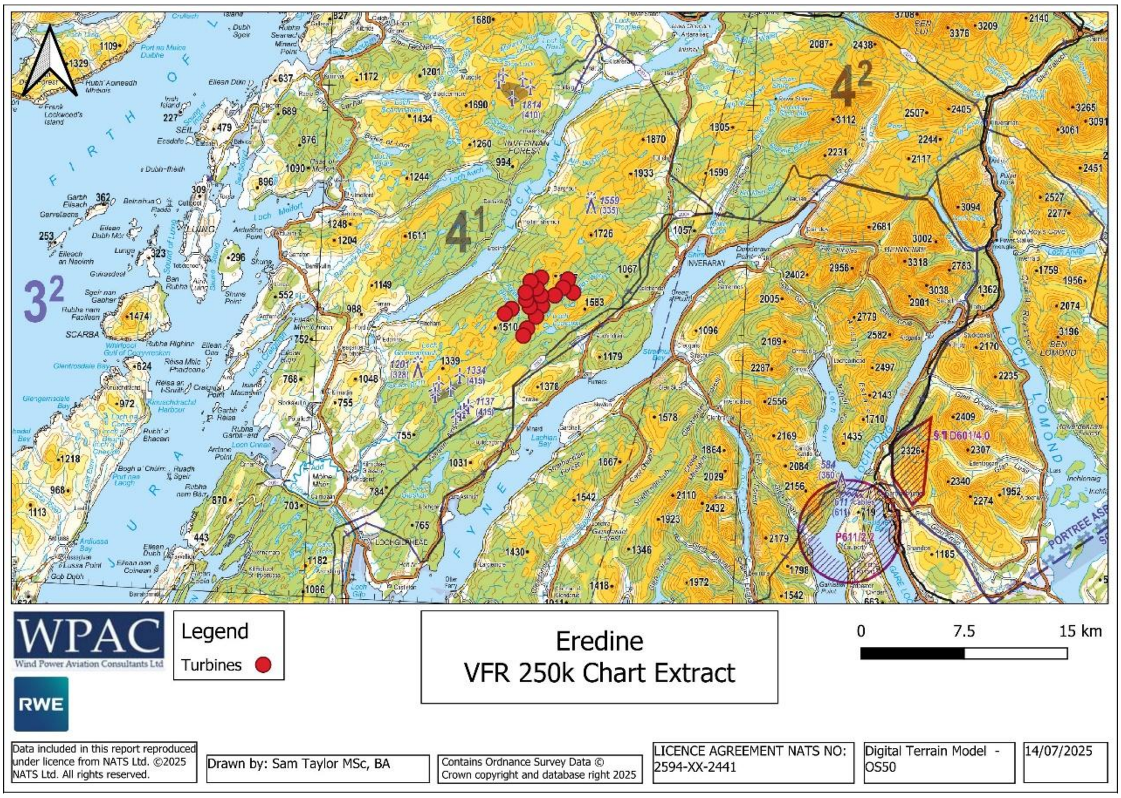

Figure 1 Eredine on an aviation chart

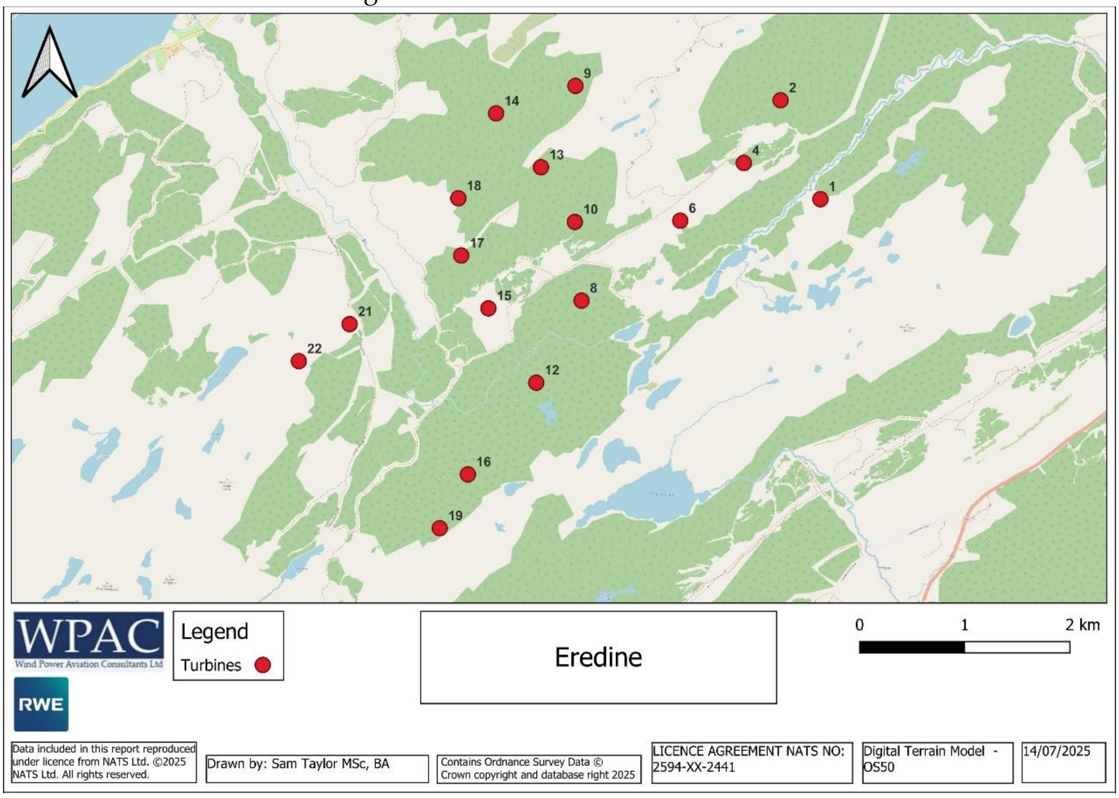

Figure 2 Eredine

CAA-ANO Red 2000/200cd Lighting (In compliance with CAA CAP 764 - Draft)

7. In accordance with the CAP 764 (draft) conditions, the CAA requires:

- That all perimeter turbines be lit unless removing a light will leave a gap of less than 900m total between the remaining lit turbines. This requires T1, T2, T8, T9, T12, T14, T19 and T22 to carry lights.
- That any turbine within 200m of a 'string perimeter' be lit unless the distance between adjacent turbines is less than 900m total. NB: additional spacing dispensation is sometimes available for the above criteria. This requires T16, T18 and T21 to carry lights.
- That any unlit turbine does not exceed a 10° up-slope from adjacent lit turbines.
- No turbine shall be more than 1800m (1nm) from a lit turbine.

8. Applying these criteria dictates that eleven perimeter turbines of the Eredine site will require ANO lighting. This gives 11 of the 17 total turbines carrying visible red lights

Turbines with 2000/200cd Lights: T1, T2, T8, T9, T12, T14, T16, T18, T19, T21 and T22

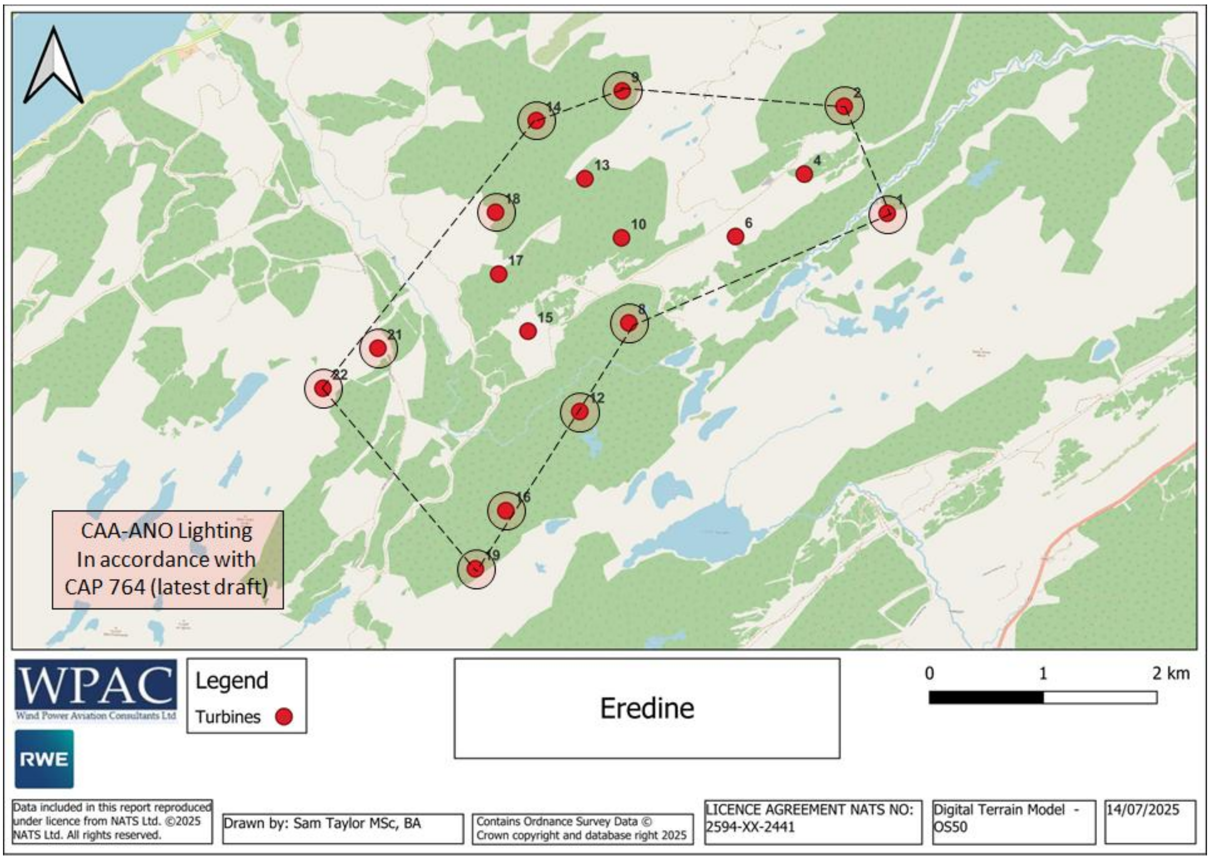

Figure 3 Lighting Layout without CAA Dispensations

CAA-ANO Red 2000/200cd Reduced Lighting Proposal

9. The military have operated at low level at night for many decades now using night vision equipment. In the last decade, more civilian operators have moved to night low level using suitable night vision equipment: night vision goggles (NVGs) etc. Such civilian operators include Coast Guard (CSAR), Police, Helicopter Emergency Medical Services (HEMS) and Air Ambulance.

10. Although, in the past, some night operators would fly at night at low level without night equipment (on carefully pre-planned exercises pre-flown by day) such events have been overtaken by the ever-widening use of night vision equipment. As a result, operators who now night fly without night vision equipment will fly at or above 'safety altitude' when not under the guidance of Air Traffic Control.

11. Aircraft operating at safety altitude or above and depending upon the protocol adopted or phase of flight, the safety altitude used will be 1000ft (300m), 1500ft (450m) or 2000ft (600m) above the local terrain/highest obstacle, this includes the turbine tip heights. Aircraft/helicopters flying as such, will only need enough visible lights to define the wind farm and its size/shape/perimeter.

12. Accordingly, the outline of the Eredine turbine site could be identified with eight visible red lights on turbines T1, T2, T6, T9, T12, T18, T19 and T22 to indicate the approximate perimeter of this large site

Turbines with 2000/200cd Lights: T1, T2, T6, T9, T12, T18, T19 and T22

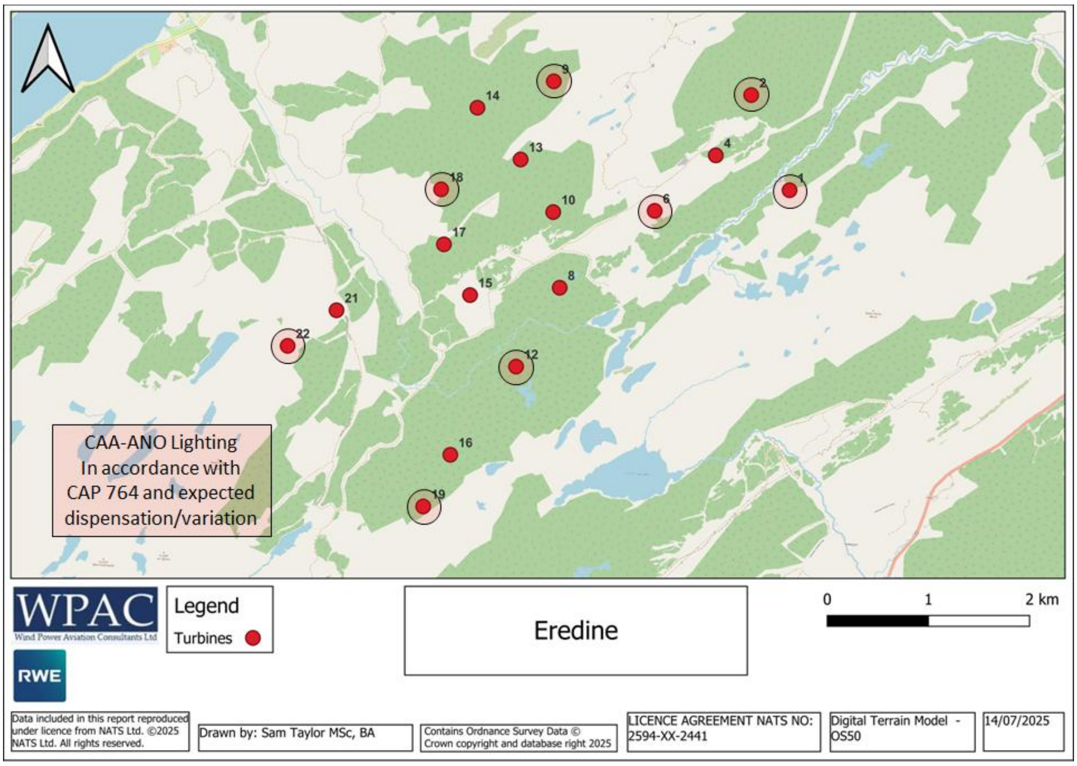

Figure 4 CAA-ANO Lighting Arrangement (including CAA dispensations).

MOD Lighting Requirements

13. Early detection is important especially if the aircraft is manoeuvring hard and the air temperature profile causes the turbines to blend into the background. Suitable lighting is necessary for flight safety.

14. MOD IR lights have been developed to be invisible to the public at large but very detectable to aircrew night vision aids. As such the MOD IR lights can have a wide beam width and flash continuously without disturbing the visible environment.

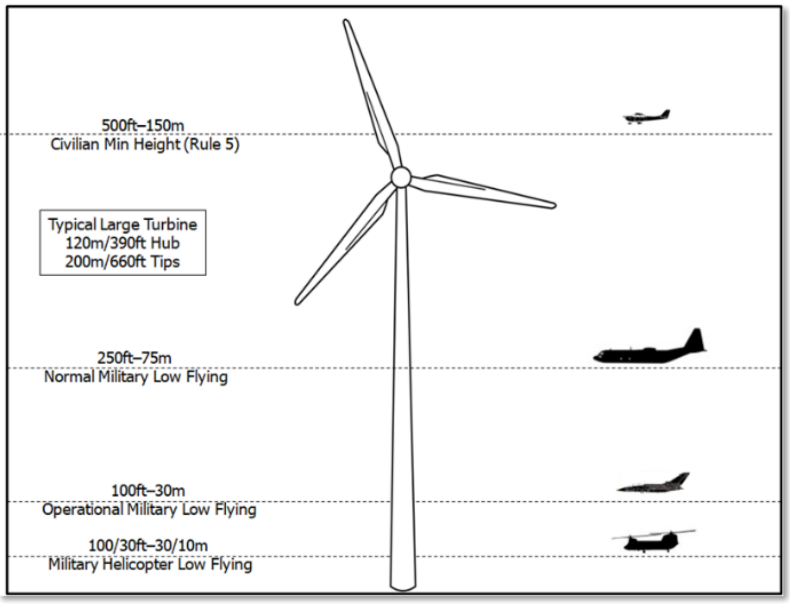

Figure 5 Wind turbine in context with MOD Low Flying

MOD Infrared Lighting Layout

15. The MOD requires:

- That all 'compound-perimeter' turbines (see blue dotted line) be lit unless removing a light will leave a gap of less than 500m between the remaining perimeter lit turbines.
- That any dominant turbine, by location or height, be lit. Note: here all turbines are lit.
- That some central turbine(s) be lit to provide 'depth perception' to approaching aircraft unless the site meets the MOD small site criteria (Red Circle). Eredine does not meet this criterion and the central turbines should be lit.

16. Applying these criteria dictates that all turbines of the Eredine site will require MOD IR lighting.

Turbines with Infra-Red Lights: **T1, T2, T4, T6, T8, T9, T10, T12, T13, T14, T15, T16, T17, T18, T19, T21 and T22**

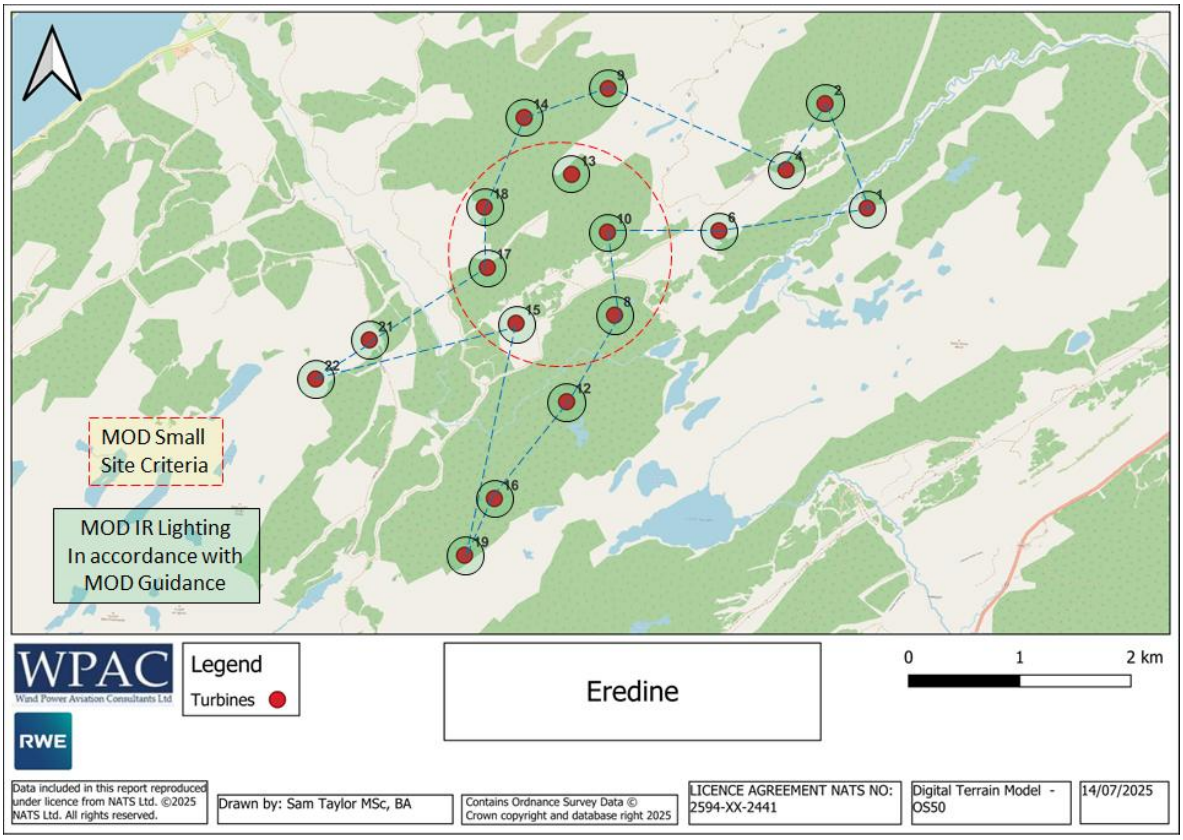

Figure 6 Proposed MOD Infrared Lighting Arrangement

Combined CAA Visible Lighting and MOD Infrared Lighting

Eredine Turbine Lighting Table					
Turbine	Easting	Northing	Tip Ht	CAA-ANO	MOD-IR
1	201508	706114	200m	2000/200cd	600mW/sr
2	201129	707055	200m	2000/200cd	600mW/sr
4	200779	706459	200m		600mW/sr
6	200175	705910	200m	2000/200cd	600mW/sr
8	199236	705150	200m		600mW/sr
9	199178	707191	200m	2000/200cd	600mW/sr
10	199172	705898	200m		600mW/sr
12	198805	704370	200m	2000/200cd	600mW/sr
13	198850	706418	200m		600mW/sr
14	198423	706930	200m		600mW/sr
15	198350	705077	200m		600mW/sr
16	198155	703498	200m		600mW/sr
17	198092	705579	200m		600mW/sr
18	198064	706123	200m	2000/200cd	600mW/sr
19	197887	702987	200m	2000/200cd	600mW/sr
21	197030	704927	200m		600mW/sr
22	196547	704575	200m	2000/200cd	600mW/sr

Table 1 CAA and MOD Lighting Arrangement

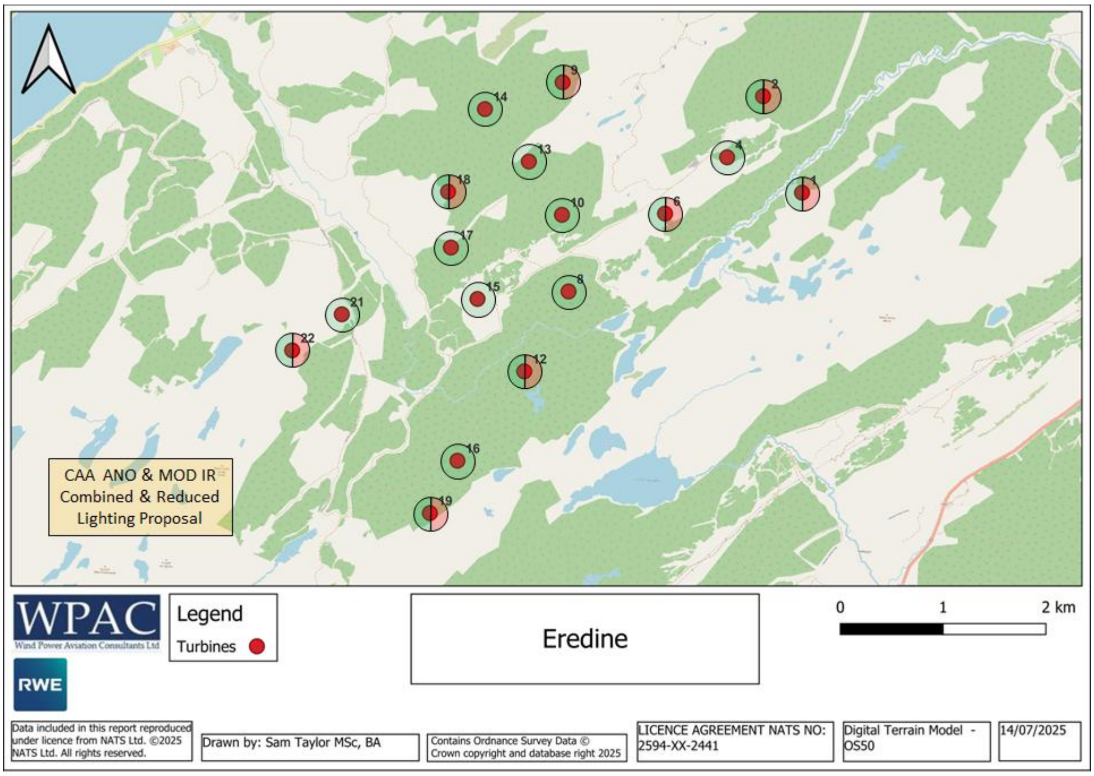

Figure 7 CAA-ANO Visible Red and MOD Infrared Lighting Arrangement

ANO Light Specifications

17. The ANO 2000/200cd lights will conform to the ICAO specification as set out in Annex 14 Table 6-3. The lights will also be controlled such that when the visibility is greater than 5km in all directions from all turbine hubs, the lights will be reduced to 200cd (10% of normal power). This reduction in power will not apply to MOD IR Lights.

ICAO Annex 14 Table 6-3 (excerpt)

Benchmark intensity	Minimum requirements					Recommendations				
	Vertical elevation angle (b)			Vertical beam spread (c)		Vertical elevation angle (b)			Vertical beam spread (c)	
	0°		-1°			0°	-1°	-10°		
	Minimum average intensity (a)	Minimum intensity (a)	Minimum intensity (a)	Minimum beam spread	Intensity (a)	Maximum intensity (a)	Maximum intensity (a)	Maximum intensity (a)	Maximum beam spread	Intensity (a)
2000	2000	1500	750	3°	750	2500	1125	75	N/A	N/A

a) 360° horizontal. All intensities are expressed in Candela. For flashing lights, the intensity is read into effective intensity, as determined in accordance with the Aerodrome Design Manual (Doc 9157), Part 4.
b) Elevation vertical angles are referenced to the horizontal when the light unit is levelled.
c) Beam spread is defined as the angle between the horizontal plane and the directions for which the intensity exceeds that mentioned in the "intensity" column.

Table 2 ICAO Annex 14 Table 6-3 Medium Intensity Lighting Specifications.

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18. **Low Intensity Mid Mast Lights** – Mid mast lighting was originally intended to give an attitude/range reference (horizon indication) to pilots flying at night in the days before NVGs. Hub and mid mast lights will give a vertical reference (from which a horizontal reference can be gauged) when fitted to a single vertical structure. In contrast, a single light will not be able to give a vertical or horizontal reference or indication of range and range-rate. However, a series of single hub lights, on a group of structures, will provide a good horizon reference together with range and range-rate clues. Accordingly, the requirement for mid-masts lights is much diminished if not made redundant in the case of multiple vertical structures such as wind farms.

19. All of the current commercially available 32cd (supposedly focused) lights are over-engineered (up to 70cd between -30deg and +40deg to fit a multitude of aviation and marine applications) they induce a disproportionately large environmental impact, often significantly more than the focused hub 2000/200cd lights. WPAC proposed that the CAA guidance requirement for 32cd (Type B) mid mast lights be removed for Eredine. CAA have agreed that intermediate lighting is not required as reflected in their lighting reduction concession approval letter attached at Appendix C to this report.

Table 6-2. Light distribution for low-intensity obstacle lights

	Minimum intensity (a)	Maximum intensity (a)	Vertical beam spread (f)	
			Minimum beam spread	Intensity
Type A	10 cd (b)	N/A	10°	5 cd
Type B	32 cd (b)	N/A	10°	16 cd
Type C	40 cd (b)	400 cd	12° (d)	20 cd
Type D	200 cd (c)	400 cd	N/A (e)	N/A

Note.— This table does not include recommended horizontal beam spreads. 6.2.1.3 requires 360° coverage around an obstacle. Therefore, the number of lights needed to meet this requirement will depend on the horizontal beam spreads of each light as well as the shape of the obstacle. Thus, with narrower beam spreads, more lights will be required.

Table 3 ICAO Annex 14 Table 6-2 Low Intensity Obstacle Lights.

IR Light Specifications

20. The IR lights will conform to the MOD specification as set out in MOD Lighting Guidance and shown below in Table 4.

MOD Specification IR. IR wavelength – 750 to 900nm. But ideally concentrated within 800 to 850nm for optimum detection by all military NVG types. IR intensity – 600mW/sr minimum at peak flash but not above 1200mW/sr. (Note: Typically a 300mW/sr steady burn LED IR light will generate 600mW/sr at peak flash) This will generate a 7-8 nm NVG pick-up range - remaining above 5nm as the light ages. Horizontal Pattern – unrestricted 360 deg. Vertical Pattern – Minimum flash intensity of 600 mW/sr between +30 deg and -15 deg elevation. – up to 50% reduction between +25 to +30 deg and -10 to -15 deg is acceptable. – Maximum intensity of 1200 mW/sr for all angles of elevation. – Vertical overspill is acceptable. Flash Pattern – 60 flashes per min at 100-500 ms duration (ideally 250ms) Synchronisation – all lights to be visually synchronised across a wind farm site

Table 4 MOD Specification for IR Obstacle Lights

Timings

21. The lights (IR and ANO) will be switched on between Evening Civil Twilight and Morning Civil Twilight in accordance with the UK Almanac; approximately 11 hours per day when averaged over the year.

Assessment of Aviation Lighting and Potential Mitigation Measures Designed into the Lights

22. Having defined a layout of turbines to be fitted with visible lighting, an assessment has been undertaken to calculate the brilliance of the lights when seen from a number of viewpoints. The standard aviation lights to be fitted to the nacelle of the turbines are required to fulfil certain design criteria in terms of brilliance and coverage as per Table 2. They are designated 'medium intensity obstruction lights' and have a **minimum** luminous intensity of 2000 candela[1] at horizontal and slightly above. The LED lights are also required to be able to shine a beam that reduces in intensity above and below the horizontal. One manufacturer of such obstruction lights, CEL, have tested their light, the CEL-WT-MIC[2] in a calibration chamber and produced results showing precisely how much the beam reduces in brilliance at any specified elevation angle. The results are interpolated to every 0.1°. This light is a finely tuned upgrade to the previous version and has been developed specifically for onshore wind turbine lighting in order to minimise downward light intensity and is now available from the manufacturer.

[1] Candela is the SI Unit of luminous intensity and refers to the amount of light emitted in a particular direction.
[2] CEL-WT-MIC - rev1.pdf

23. Figure 8 demonstrates the reduction in luminous intensity below the horizontal and also above 1° in elevation. The various coloured lines are the candela measured from different angles in the horizontal in order to measure the performance all around the light.

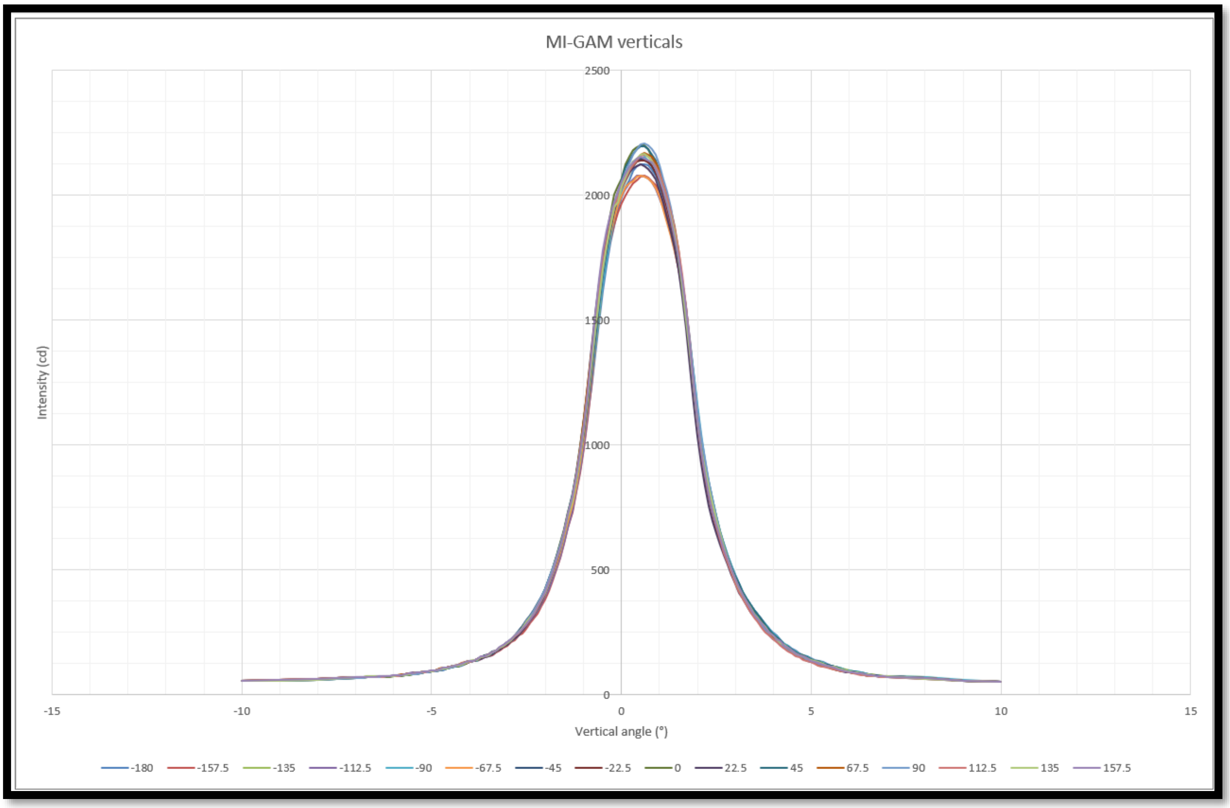

Figure 8 (MI GAM CEL-WT-MIC Light Measurement Results)

24. WPAC have utilised their propagation modelling system (Rview) to calculate the precise angle of elevation between the turbine light and a viewpoint assuming a height of eye of 1.5 metres and a turbine hub height of 122.5 metres as required. The system utilises a standard atmospheric model and an earth model that uses actual earth curvature between the turbine light and the viewpoint. Ordnance Survey OS50 DTM is used as the terrain model. The calculations have been undertaken for each designated lit turbine against all designated Eredine viewpoints. The locations of the viewpoints are shown in Figure 9 and Table 5.

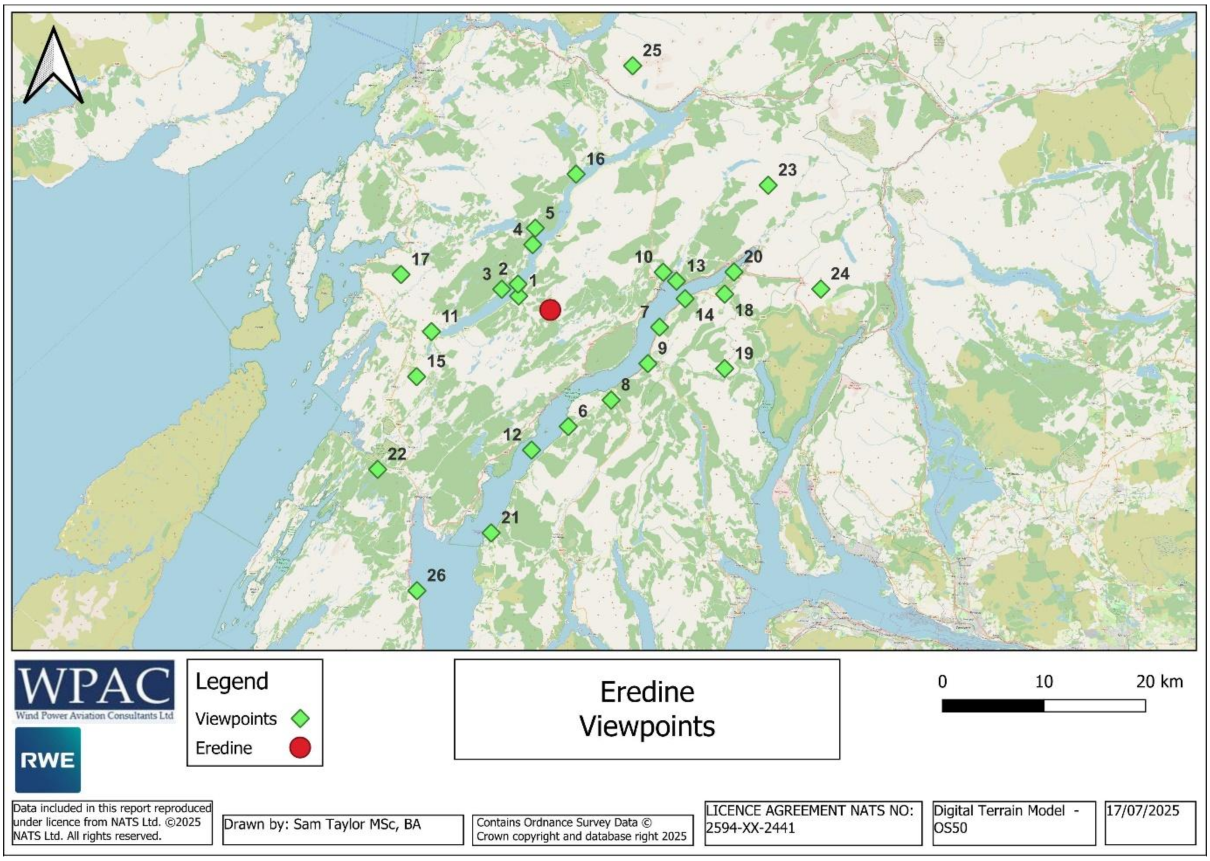

Figure 9 Viewpoint Locations

25. The next stage in the process is to take the candela figures radiated towards a viewpoint and taking into account the distance, calculate the lumens per square metre (also known as Lux) that will be experienced by the human eye at the viewpoint. The figure produced is in micro-lumens per square metre or lumen$^{(10-6)}$/m^2) or lux$^{(10-6)}$. These are perfect clear-air figures and therefore worst-case results from an LVIA perspective. Figures obtained by this method enable comparisons to be made with commonly understood light sources such as stars or planets. In practice the light intensity at the observation points will be further attenuated by scatter and absorption by airborne dust, droplets and aerosols in the atmosphere. This attenuation is typically in the order of 10 to 20% but can be as high as 75% at the more distant observation ranges.

26. The results for every lit turbine from all of the viewpoints are shown in the results tables in Appendix A to this report. Viewpoints where lights are obstructed by terrain are shaded in green, when the viewpoint is too close to a turbine to get an accurate assessment, it is shaded red. **To take into account any limitations within the terrain model we have highlighted in purple any viewpoints where the line of sight is under 10 metres above ground level but above 1.5 metres and should therefore, still be screened by terrain but may be visible within the vicinity of the viewpoint**.

Viewpoint Number	Viewpoint Name	Position
1	B840 Durran	NM 95737 07789
2	Loch Awe Waters	NM 95671 08961
3	Kilmaha	NM 94072 08455
4	Dalavich	NM 97119 12847
5	Minor Road between Dalavich and Inverinan	NM 97374 14467
6	B8000 Lachlan Bay	NS 00623 94950
7	Ardnagowan	NN 09610 04727
8	Leanach	NS 04841 97549
9	Strachur	NN 08464 01140
10	Dun na Cuaiche	NN 09970 10132
11	Ford	NM 87151 04285
12	Loch Fyne Waters	NR 97004 92631
13	A83 Old Military Road	NN 11277 09253
14	St Catherine's	NN 12121 07524
15	Beinn Bhan	NR 85690 99860
16	Minor Road at Fernoch Hill	NN 01393 19781
17	Tom Soilleir	NM 84152 09905
18	Hell's Glen Road (B839)	NN 16022 07981
19	Beinn Lochain	NN 16020 00649
20	Ardkinglas Woodland Garden	NN 16938 10155
21	Otter Ferry (B8000)	NR 93029 84481
22	Cruach Mor Dunardry	NR 81854 90731
23	Beinn Bhuidhe	NN 20301 18687
24	Beinn Ìme	NN 25492 08473
25	Ben Cruachan	NN 06960 30446
26	A83 South of Inverneill	NR 85723 78796

Table 5 Viewpoints

Interpreting the Results

27. The results show that there is a significant decrease in the luminous intensity (candela) of the light emanating towards those viewpoints which are at lower angles of elevation in relation to the turbine hub. However, when considering the perception of the light from a viewpoint in general, the distance between the light and the viewpoint is likely to be the dominant factor and the resultant figure in micro-lux is the most relevant figure to consider. This report provides the results and anticipates that the Landscape and Visual Impact Assessment (LVIA) consultants will be able to put them into the correct context for visualisations in terms of background environmental lighting and atmospheric conditions. Table 6 shows the turbine with the greatest potential perceived luminous intensity expressed in micro-lumens per m² (Lux $^{(10\text{-}6)}$) at each viewpoint.

Viewpoint	Turbine	Distance (KM)	Microlumens per m2 (lux10-6)	Microlumens at 10%	Obscured
1	18	2.86	9.2	0.9	
2	18	3.71	5.2	0.5	
3	12	6.25	7.3	0.7	
4	18	6.79	3.2	0.3	
5	18	8.37	4.1	0.4	
6	1	11.2	16.2	1.6	X
7	12	10.81	16.5	1.7	X
8	12	9.11	4.2	0.4	
9	19	10.74	2.5	0.3	
10	1	9.37	8.8	0.9	
11	9	12.37	2.1	0.2	
12	19	10.39	2.4	0.2	
13	18	13.58	11.6	1.2	X
14	6	12.06	1.8	0.2	
15	19	12.59	9.2	0.9	
16	18	14.06	3.0	0.3	
17	22	13.49	9.3	0.9	
18	1	14.63	4.0	0.4	
19	1	15.51	8.7	0.9	
20	1	15.95	2.3	0.2	
21	12	20.71	1.8	0.2	
22	19	20.18	3.2	0.3	
23	2	22.42	4.1	0.4	
24	2	24.4	3.4	0.3	
25	9	24.52	3.3	0.3	
26	19	27.08	1.3	0.1	

Table 6 Brightest Turbine Hub Light from each Viewpoint (measured in micro-lumens)

28. In order to place the values in microlumens per m^2 (lux$^{10-6}$) in context, Table 7 provides some examples of approximate values placed on a number of environmental comparators, however these are just an illustration to place the results in a real world environment. The actual perceived brightness will depend upon a number of factors including bulb manufacturer, bulb type, specific construction (single/multiple colour LEDs etc) atmospheric conditions, absorption spectrum, individual eye characteristics and capabilities.

Comparison Object	Approximate Illuminance (micro-lumens per m²)
Car Halogen main beam approaching 1km	Up to 1,000,000 (can vary significantly between cars)
International Space Station (400km up)	1000 (depends upon relative position of sun)
Car Brake Light at 0.5km	400
Car Brake Light at 0.7km	200
Car Brake Light at 1.0km	100
Car Brake Light at 2.0km	25
Car Brake Light at 5.0km	4
Car Brake Light at 10km	1
Front Cycle Light at 0.5km	140 (Modern high power white LED)
Front Cycle Light at 0.7km	70
Front Cycle Light at 1.0km	35
Front Cycle Light at 2km	9
Front Cycle Light at 5km	2
White LED Street Light at 0.5km	500 (Viewed from the horizontal)
White LED Street Light at 0.7km	250
White LED Street Light at 1.0km	120
White LED Street Light at 2.0km	30
White LED Street Light at 5.0km	8
Sodium Street Light at 0.5km	300 (Viewed from the horizontal)
Sodium Street Light at 0.7km	150
Sodium Street Light at 1.0km	75
Sodium Street Light at 2.0km	20
Sodium Street Light at 5.0km	5
Brightest Star in the Sky (Sirius)	13
Airliner flying at 30,000ft)	Nav Lights 0.4 to 5; anti-collision lights 2 to 20
Typical bright star (e.g. Orion)	0.5 to 2.0
Faintest light visible from street lit area	0.4
Visible limit for fully dark-adapted eyes	0.02

Table 7 Comparisons of approximate micro-lumens values

29. If there is a requirement to consider the brightest turbine in terms of emitted candela rather than micro-lumens, Table 8 provides data on which turbine emits the most candela towards each viewpoint but takes no account of the distance between light and viewpoint.

Viewpoint	Turbine	Distance (KM)	Candela	Candela at 10%	Obscured
1	18	2.86	75	8	
2	19	6.37	136	14	
3	12	6.25	284	28	
4	22	8.29	196	20	
5	19	11.49	448	45	
6	1	11.2	2028	203	X
7	22	13.06	1984	198	X
8	12	9.11	350	35	
9	19	10.74	284	28	
10	12	12.56	1055	106	
11	9	12.37	324	32	
12	19	10.39	262	26	
13	18	13.58	2142	214	X
14	6	12.06	262	26	
15	19	12.59	1451	145	
16	22	15.96	642	64	
17	19	15.38	1790	179	
18	1	14.63	858	86	
19	2	16.21	2142	214	
20	1	15.95	584	58	
21	12	20.71	776	78	
22	12	21.76	1451	145	
23	9	24.05	2117	212	
24	9	26.34	2092	209	
25	9	24.52	1955	195	
26	18	29.98	1055	106	

Table 8 Brightest Turbine Hub Light measured in Candela emitted towards a viewpoint

Part 2 Mitigation

Intensity Reduction (ANO Lighting: 2000cd down to 200cd)

30. The lights (IR and visible red lights) will be switched on between Evening Civil Twilight and Morning Civil Twilight in accordance with the UK Almanac; approximately 11 hours per day averaged over the year.

31. The primary mitigation consideration in addition to the already described reduction in brilliance due to elevation angle, is taken from Reference D which states:

> '*If the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5 km, the intensity for the light positioned as close as practicable to the top of the fixed structure 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*'.

32. It is therefore possible to take advantage of the CAA SARG Policy Statement dated 01/06/2017 and incorporate the option to reduce the hub height lighting to not less than 10% of the of the minimum peak intensity specified for the installation in good weather. In essence, reducing the 2000cd obstruction lights to 200cd in meteorological visibilities greater than 5km. This will not apply to any lights permanently set to 200cd.

Note: This concession is not applicable to MOD specification IR lighting.

33. It will be necessary to calculate how much time the lights would spend at 2000cd and at 200cd. To assess historical visibility in this Argyll & Bute region, the closest meteorological stations to Eredine are at Tiree Airfield and Glasgow Airport. Note: there are no meteorological stations that provide historical data closer to Eredine. However, although the visibility will not be identical at the three locations it will be in the same air-mass for the majority of the time and will give similar observations. On the following page are tables of visibilities throughout the year for Tiree and Glasgow which are averaged over a 20 or 30-year period.

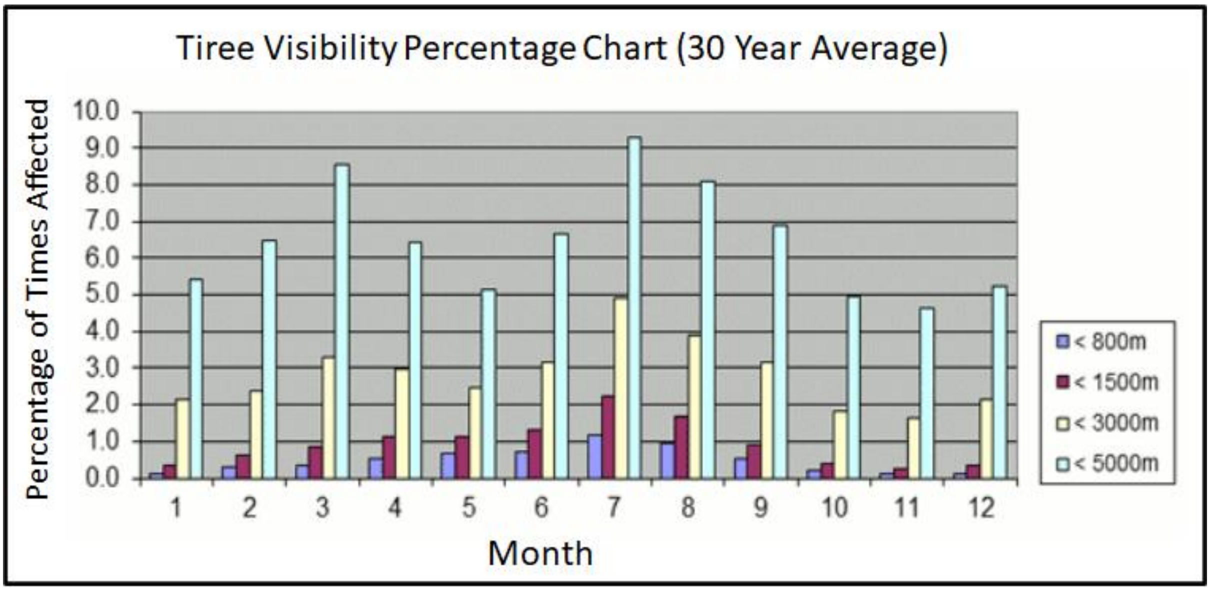

Table 11 Visibility Table Tiree Airport (Light Blue is 5km Indicator)

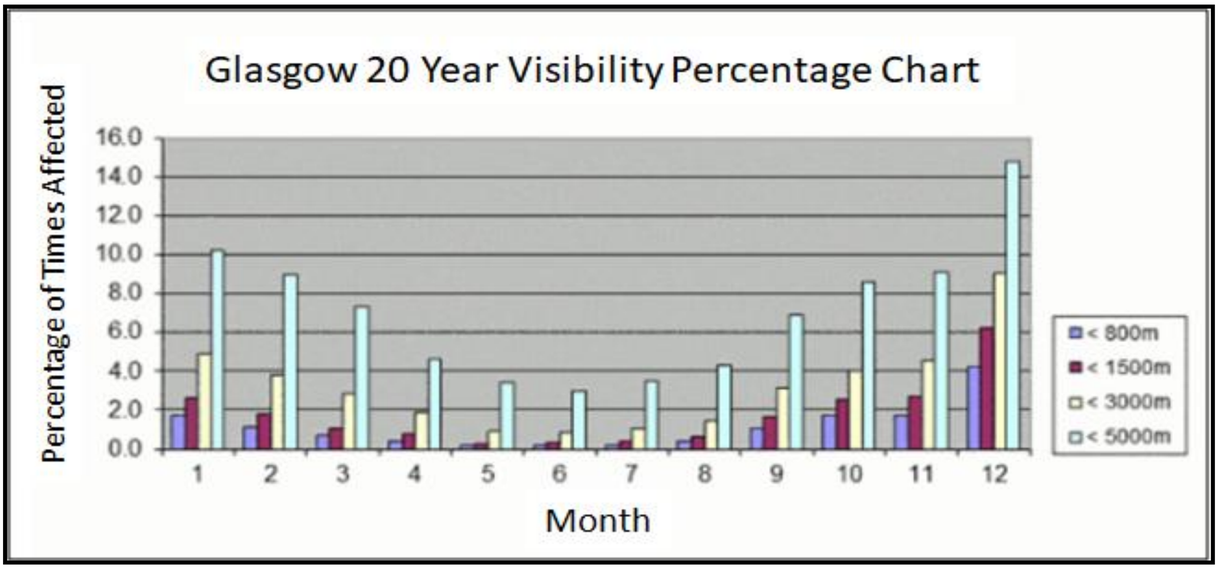

Table 12 Visibility Table Glasgow Airport (Light Blue is 5km Indicator)

34. These Met Office tables show us that the visibility is below 5km (light blue bar) for an average of 7% of the time averaging both Tiree and Glasgow. This suggests that the lights will be at 2000cd for 7% of the time and 200cd for 93% of the time.

35. Whilst Tiree and Glasgow are not Eredine, met visibility improves with height since the concentration of particles (dust, haze) and liquid droplets (water) reduces with height and the air also becomes thinner. It could be argued that the Eredine visibility, situated on a 400-500m hill, will be better than that at Tiree and Glasgow.

Obstruction Light Weather Obscuration.

36. On occasion, the visibility in the area of Eredine will reduce significantly due to the presence of cloud on the hills. If the Eredine turbines are in cloud, then the obstruction lights will not be seen. In a similar vein, if the turbines are partially shrouded in cloud then the light intensity will be much reduced.

Note: All heights and elevations in aviation are measured in feet and not metres.

37. The turbines will carry the CAA/ANO lights on the turbine hub. The average height at the base of these turbines is around 500m above mean sea level (amsl). The hub heights, for the proposed turbines will be around 122.5m (400ft) above ground level (agl) giving hub heights of 1600ft amsl. Note: in aviation heights are measured in feet including all meteorological observations and forecasts.

38. It is now possible to compare the average turbine hub/light height of 1600ft amsl with the actual cloud bases recorded by the Met Office at Tiree and Glasgow Airfields, again, over a 20 or 30-year period as shown in the diagrams below. The maroon bars show when the cloud-base first drops below the lights.

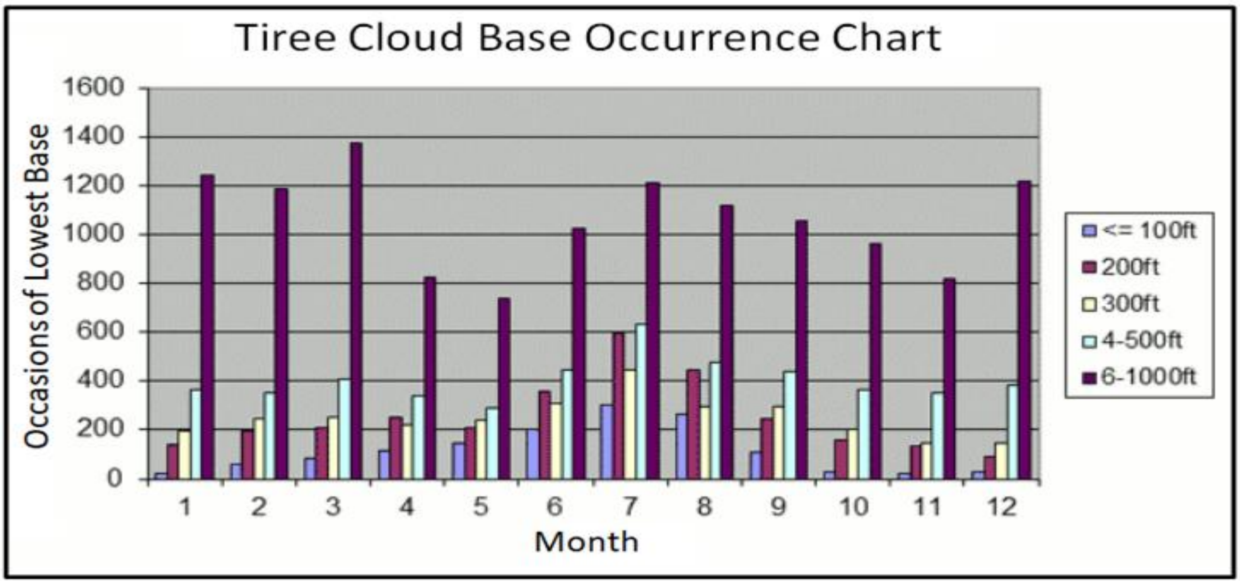

Table 13 Tiree 30 Year Average Cloud Base Table.

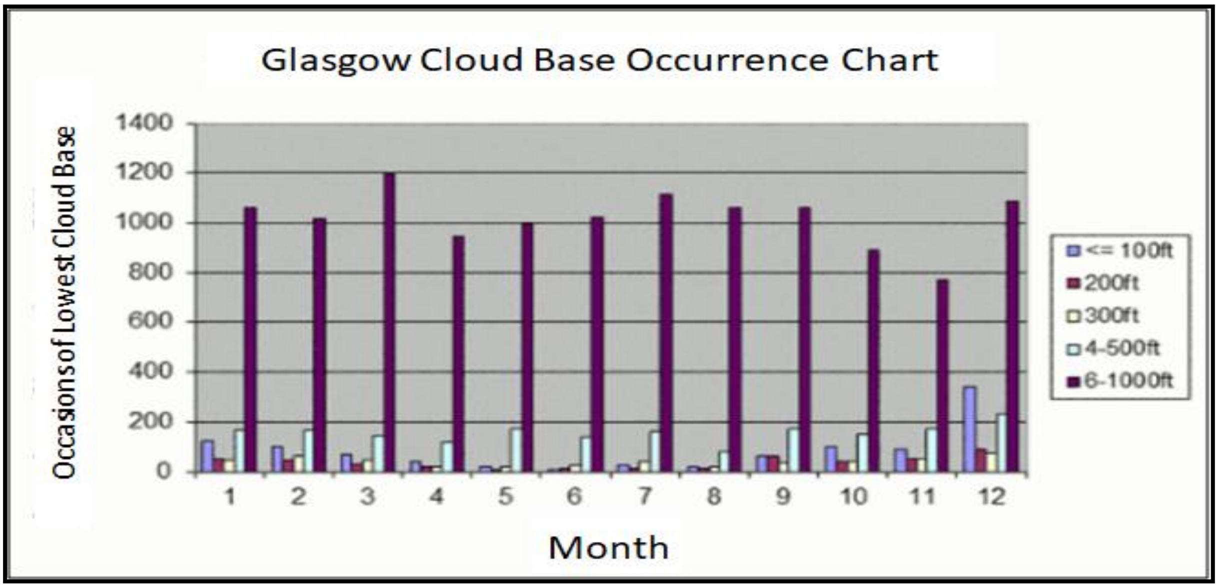

Table 14 Glasgow 20 Year Average Cloud Base

39. The maroon columns (600-1000ft) indicate that the cloud base will range from approximately 600-1000ft below turbine hub heights on around 1000 occasions a month. At this distance below the turbine hubs the lights will be significantly or, more likely, completely obscured to the general public.

40. The other columns (light blue in particular 400-500ft) indicate that on a further 200-400 or more occasions a month the lights will be obscured by cloud. Note: Met Office statistics report cloud base in occurrences (observations) as opposed to total duration.

41. Again, whilst Tiree and Glasgow are not Eredine, Met Office statistics show that the cloud-base reduces in the region of hills. It could be argued that at Eredine, located on a 400 - 500m (average) hill, the cloud-base would be lower than at Tiree or Glasgow thus providing even greater degree of light obscuration than calculated here.

Weather Obscuration Conclusion

42. It is most important not to try and combine the two different observations, visibility and cloud-base, into a single statement. Informal advice direct from Met Office and Airport forecasters indicates that the information for Eredine, so gathered, should be presented as follows:

> *Meteorological observations suggest that the turbine hubs will be obscured several hundred occasions a month by cloud.* *(Obstruction lights not visible to the public)*
>
> *When not obscured by cloud, the visibility in the area of the turbines can be expected to exceed 5km for up to 93% of the time.* *(Obstruction lights switched down to 200cd)*

Conclusion/Notes

43. The purpose of this Lighting Brief is to identify an obstruction lighting arrangement that will have the minimum effect upon the environment but at the same time is a safe design for night low level operators. This has been accomplished by using a combination of CAA ANO and MOD IR lights.

44. Applying the CAP 764 Draft criteria for visible red obstruction lighting results in a lighting solution that requires five turbines to carry a visible red ANO light. By applying current CAA dispensations and then matching the lighting to the operators that will require night visible lighting, minimal but aviation safe layout was achieved. This results in a total of:

8 x ANO Red 2000/200cd lights and 17 x MOD IR 600mW/sr lights.

45. Furthermore, the site is in an area where it will benefit from 90% light-dimming in good weather and obscuration of both turbines and the visible ANO lighting in poor weather. This lighting layout wasn sent to the CAA for approval. They have responded and their lighting dispensation approval letter is attached at Appendix C.

The lights will be regularly obscured by cloud and when not obscured set at the lower 200cd for approximately 93% of the time.

46. The CAA currently state: '*met visibility should be measured at suitable points around the wind farm*. In the case of the Eredine turbines: Visibility Meters on **T2, T5, T18** and **T20** will meet this criterion.

Technical Mitigation

47. One other form of potential mitigation commonly discussed is the installation of an Aircraft Detection Lighting System (ADLS). There are two possible methods of detecting an aircraft approaching a wind farm that will automatically turn on the aviation obstruction lights, firstly through the use of a suitable primary surveillance radar (PSR) or secondly, the use of aircraft installed Electronic Conspicuity (EC) equipment with a suitable receiver at the wind farm. There are some significant technical and regulatory issues to be overcome before any such system can be installed and operated in the UK.

48. In the case of PSR, this is already in use at wind farms in Europe; as an example the Terma Scanter 5002 radar is installed at a number of sites as shown in Figure 10. The main regulatory constraint is that although such systems are in use in Europe, in the UK, where airspace tends to be shared to a much greater extent between users, the CAA have yet to mandate the performance parameters that such a system must be capable of fulfilling. For example, the coverage requirement will need to be defined in terms of maximum range of detection and activation (which may vary depending upon the speed of the aircraft), base of cover (above ground level) and almost certainly a maximum height coverage to avoid unnecessary activations, which a PSR on its own cannot ascertain. An initial set of draft requirements was promulgated in 2018 but these were for discussion with aviation stakeholders and the wind industry and it cannot be assumed that these are going to be the final criteria. Even if the standards are defined, it may be that any single radar will not be capable of delivering the required coverage where, for example, a wind farm is located on a hill and aircraft may approach below the wind farm from any direction. It may then become necessary to install multiple radars in order to achieve the required coverage at low level. This in itself may lead to limitations due to mutual interference in what is already a crowded part of the electro-magnetic spectrum, (although the Terma radar does have some anti-interference capabilities) but the additional radars may affect other systems working in the same frequency band. There would also be additional planning issues to consider, such as the visual impact of additional aerials, and rotating arrays. Technical constraints also mean that it will be necessary to position the radars some distance outside the windfarm as shown in the example below in order to avoid turbines screening the radar and to provide the required height coverage.

Figure 10 Terma 5002 Radar at a Wind Farm in Germany

49. The one major advantage of PSR is that it will detect any aircraft, both those transponding and those that are not, known as non-co-operative targets. Depending upon how the regulatory process

moves forwards, this may have a major effect on which systems to use for ADLS. In response to a planning inquiry paper the CAA responded stating in a letter dated 21 April 2021: *For the UK, there are some challenges to be resolved. The cost/benefit of the use of primary surveillance radar for the active detection of aircraft, spectrum availability, incentive pricing cost and geographical separation required before frequencies can be re-used potentially makes this a less than optimal solution.*

50. The alternate system is one based upon a reliance on aircraft carried Electronic Conspicuity (EC) transponders. Currently light aircraft flying clear of regulated airspace in the UK below 10,000ft are not required to carry a transponder (one example being Secondary Surveillance Radar or SSR). Most aircraft do, but not all. The CAA has been encouraging fitment by all aircraft and hope to have a regulatory system in place within the next few years requiring all flying machines to be fitted. Unfortunately this is not a simple process. This issue has been running for at least 20 years so far, however some limited progress is now being made. In the same response to a recent planning inquiry paper the CAA stated: '*At the same time, the lack of interoperability between the wide variety of electronic conspicuity devices currently available may require careful consideration of the specification of any passive system receivers and how they are deemed compliant to be deployed and operated.* 'The letter goes on to state: '*We concur that not every situation may require ADLS to be fitted and operated; Article 222 or 223 requirements of the Air Navigation Order will remain, and the CAA may agree a specific solution under Section 7 of Article 222 and Section 11 of Article 223. However, ADLS could potentially provide an acceptable means of compliance that could provide greater certainty for developers when developing planning proposals on CAA acceptance and assist with discussions with communities during planning consultation.*' What this letter is saying is that ADSL using EC is technically feasible but that until the regulatory actions concerning the mandatory carriage of a compatible EC system have been completed and signed into law, and the coverage requirements agreed, uncertainty remains unless a planning condition to require the retrospective installation of a system is considered appropriate. The length of time that this is likely to take is difficult to estimate, however, realistically it is likely to be within a two to five year timeframe as it is a small part of a much wider airspace modernisation programme currently under way. Additionally, the CAA also issued a Guidance Notice dated 26/10/21 entitled: '*Electronic continuity specifications: enabling interoperability between airspace users*.' This announced the establishment of a task force to jointly develop electronic conspicuity specifications to enable interoperability between airspace users. It goes on to state: '*The adoption of EC specifications will not be mandated UK wide. Users of other systems can continue to benefit from the functionality that those products offer*'. This does not mean that an EC triggered ADLS system will not be feasible, but the regulatory challenges mentioned above may take longer to resolve, a position reinforced by the Scottish Government recently in relation to the Narachan Wind Farm decision where Ministers stated the following: '*The Scottish Ministers have carefully considered the option of imposing a suspensive condition to secure the installation of an ADLS, prior to construction of the proposed Development, but do not find that the evidence provided to date on the matter affords sufficient assurance that either method would be capable of being installed on the proposed Development within the next 5 years. As such, taking account of the resulting uncertainty on timescales for the deployment of the proposed Development if it were to be consented, the Scottish Ministers consider it would not be appropriate in this case to impose the suspensive condition proposed by the Reporter to mitigate the effects of the proposed Development's lighting on the SQs of the North Arran NSA.*' This consideration could equally apply to wind farm lighting schemes throughout the United Kingdom.

51. What is clear is that when ADLS is finally mandated by the CAA, the carriage of compatible transponders is also mandated and all aircraft fitted with them, this is likely to be a realistic way of triggering an ADLS system. Such systems are passive at the wind farm and will not, therefore cause any interference. As shown in Figure 11 they require unobtrusive small aerials, approximately 1.2 metres long that are very reliable and relatively inexpensive to install and operate.

Figure 11 ADSB/SSR Passive Aerial

52. Bearing the above in mind, it might be prudent to ensure that lighting installed on the turbines is compatible with any future EC triggered ADSL system, so that when the regulatory process and aircraft equipage has been completed, it will be a relatively cheap and simple exercise to retro-fit such a system. Alternately, the ADSB/SSR aerials and system could be installed when the wind farm is constructed, ready for activation when required. Unfortunately, it is still not certain that the regulatory process and equipage issues will be completed within the lifetime of a planning consent.

53. An ADLS system may not be suitable for every location, depending upon the nature of aviation operations at night in the area around the wind farm and the activation criteria that are finally mandated by the CAA. If located close to the approach for a major airport for example, the lights might be required to be turning on and off continuously, but this is very unlikely to be the case at Eredine. The EC activated ADLS system will be able to differentiate between civil traffic and SAR/HEMS/military traffic using NVD and not therefore activate when these types of aviation final operations are taking place within the activation zone for the system. The infrared lights that these types of operations rely on will always be on at night, but of course are invisible to the naked eye and will have no effect on the visual impact of the development.

Comment

54. In recent months various briefing documents have been in circulation suggesting that visible obstruction lights are not required in the current aviation environment. The CAA have briefed WPAC that they do not support this position and would consider prosecuting organisations that do not follow the existing guidance and regulations. However, change will come; this will be led by the CAA and be centred on the new draft CAP 764 (as adhered to in this report) and the future development of ADLS.

55. From the direct experience of WPAC staff who have over 40 years of day/night low flying over land and sea both with and without NVG/Ds, the inclusion of adequate visible red lighting is important to cater for both routine operations and the inevitable unplanned outcome. Pilots uncertain of their location together with emergency situations and system failures of critical night low flying equipment are circumstances that require a degree of visible obstruction lighting on large wind turbines.

56. In addition, future green energy aircraft (hydrogen/electric and battery powered) will fly considerably lower and slower than current aircraft and will be significantly limited in track variation by much shorter ranges. Good visible obstruction lighting will become more, not less important in this low direct flight environment.

57. Finally, an aircraft colliding with a wind turbine is thankfully an extremely rare event but one with enormous potential consequences. A standard risk assessment as part of an aviation safety case would conclude that even a very low probability of a significant dangerous event is still unacceptable and must be mitigated, in this case by the fitting of visible obstruction lights.

Conclusion

58. This report has assessed the requirements for both visible CAA approved aviation lighting and MOD approved Infrared lighting for the Eredine wind farm. The resulting layout is set out in Figures 4 and 6 and makes use of both CAA/ANO Red lights and MOD IR lights. The proposed layouts have been sent to the CAA and MOD DIO for approval. The MOD will approve the IR lighting layout as there is no concession required and when the CAA have considered the proposal and responded, their concession letter will be included at Appendix C.

59. The report also provides the brilliance of lights that will be visible taking into account the elevation angle between the turbine hub obstruction light and the viewpoints and the distance between each turbine and each viewpoint. The report shows that for up to 88% of the time the lights will only be required to operate at 10% luminous intensity, which will significantly reduce obstruction light effects in the area. Further interpretation of these results can be undertaken by a Landscape and Visual Impact Assessment expert.

60. The report then identifies additional mitigation options that, should the regulatory process allow, enable the visible medium intensity turbine lights to be switched off for the vast majority of the time and activated only on those occasions when an aircraft activates the system.

Authors

Sam Taylor BA(Hons) MSc (Climate Change and Policy) - Sam has 15 years experience in radar and visible light propagation modelling, aviation consultancy and aviation related GIS. He is responsible for aviation and radar research and providing modelling results for wind farms throughout the UK against any of the 250 radars in our database. He has also developed the methodology used in our aviation lighting and impact mitigation reports for sites throughout the UK. Sam has worked on over 2000 wind farm proposals in that time throughout the UK

Cdr John Taylor RN (Ret) – after a career in the Royal Navy specialising in Air Traffic Control (ATC), Airspace Management and Air Defence which culminated in leading both the ATC and Fighter Control Specialisations, John worked for Lockheed Martin UK for three years as a Principal Consultant and Business Area Manager responsible for Air Traffic Management Consultancy, including the provision of advice to wind farm developers. In 2008 he founded WPAC Ltd and since then he and his team have provided aviation advice in relation to over 2000 wind farm and wind turbine sites, given evidence at a number of planning inquiries and enabled many sites to overcome aviation objections where it was feasible to do so. He and his team have also provided advice to a number of Local Planning Authorities, Renewable UK and the Aviation Fund Management Board, including organising workshops and the provision of guidance documents. John also advises planners and developers in relation to physical and technical safeguarding of non-wind farm developments in the vicinity of aviation facilities.

Sqn Ldr Mike Hale RAF (Rtd) has over 45 years, piloting, instructing and examining experience on numerous military fast jet aircraft through to a range of civilian and military general aviation training aircraft and gliders. He has held many posts including Flying Instructor, Training Officer, Flight Commander, Squadron Commander and Principal Tornado AD Force Examiner. He has amassed over 10,000 flying hours of experience when operating at many locations around the world. In parallel to his flying duties, Mike held the post of Officer Commanding the MOD Low Flying Operations Squadron (OC LFOS). In this post he was both Low Level Airspace Manager for the MOD & Wind-Farm Subject Matter Expert for the Defence Infrastructure Organization (DIO). During that period, he assessed over 14,000 wind-farm pre-applications and 2000 full applications against low flying, weapons range, specialist airspace, local community and aerodrome safeguarding criteria. Mike also instigated two Qinetiq ground based Infra Red obstruction lighting trials. These were followed by instigating and managing the MOD Infra Red/Low Intensity (Henlow) flight trials and the CAA/MOD/Trinity-House/RUK off-shore IR/Morse (North Hoyle) flight trials. In conjunction, Mike organised numerous and various supporting trials including night vision equipment compatibility and detailed lighting beam overspill analysis (where light is emitted outside the required specification envelope). In 2012, he was awarded an MBE for generating a proactive and mutually successful working relationship between the Wind Power Industry and the MOD Air Staff.

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Appendix A Lighting Results Tables

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	6.01	1.3	1895	190	52.5	5.3	X
2	5.44	0.0	2028	203	68.5	6.9	X
6	4.82	-3.8	140	14	6.0	0.6	X
9	3.49	-8.3	75	8	6.2	0.6	
12	4.59	-4.7	104	10	4.9	0.5	X
18	2.86	-8.4	75	8	9.2	0.9	
19	5.26	-4.3	117	12	4.2	0.4	X
22	3.31	-7.5	75	8	6.8	0.7	

Viewpoint 1 B840 Durran

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	6.49	1.6	1643	164	39.0	3.9	X
2	5.78	0.2	2093	209	62.6	6.3	X
6	5.44	-3.3	176	18	5.9	0.6	X
9	3.93	-7.5	75	8	4.9	0.5	
12	5.56	-3.9	136	14	4.4	0.4	X
18	3.71	-6.7	72	7	5.2	0.5	
19	6.37	-3.9	136	14	3.3	0.3	
22	4.47	-5.7	80	8	4.0	0.4	

Viewpoint 2 Loch Awe Waters

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	7.8	1.3	1895	190	31.2	3.1	X
2	7.2	0.3	2117	212	40.9	4.1	X
6	6.61	-3.1	196	20	4.5	0.5	
9	5.26	-4.1	128	13	4.6	0.5	
12	6.25	-2.5	284	28	7.3	0.7	
18	4.62	-3.6	154	15	7.2	0.7	
19	6.67	-2.5	284	28	6.4	0.6	
22	4.6	-3.7	149	15	7.0	0.7	

Viewpoint 3 Kilmaha

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	8.04	0.9	2092	209	32.4	3.2	X
2	7.04	-1.7	535	54	10.8	1.1	X
6	7.58	-2.1	378	38	6.6	0.7	X
9	6.02	-5.0	94	9	2.6	0.3	
12	8.64	-1.5	642	64	8.6	0.9	X
18	6.79	-3.7	149	15	3.2	0.3	
19	9.89	-2.3	324	32	3.3	0.3	X
22	8.29	-3.1	196	20	2.8	0.3	

Viewpoint 4 Dalavich

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	9.32	0.8	2117	212	24.4	2.4	X
2	8.31	-2.3	324	32	4.7	0.5	X
6	9	-2.1	378	38	4.7	0.5	X
9	7.5	-3.5	158	16	2.8	0.3	
12	10.2	-1.3	776	78	7.5	0.8	X
18	8.37	-2.6	284	28	4.1	0.4	
19	11.49	-1.9	448	45	3.4	0.3	
22	9.93	-2.2	350	35	3.6	0.4	

Viewpoint 5 Minor Road between Dalavich and Inverinan

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	11.2	0.0	2028	203	16.2	1.6	X
2	12.12	-1.8	488	49	3.3	0.3	X
6	10.97	-2.7	245	24	2.0	0.2	X
9	12.33	-2.0	409	41	2.7	0.3	X
12	9.59	-1.4	706	71	7.7	0.8	X
18	11.46	-1.0	1055	106	8.0	0.8	X
19	8.49	-1.1	949	95	13.2	1.3	X
22	10.45	-0.6	1580	158	14.5	1.5	X

Viewpoint 6 B8000 Lachlan Bay

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	8.22	-1.0	1055	106	15.6	1.6	X
2	8.8	-3.2	186	19	2.4	0.2	X
6	9.51	-2.0	409	41	4.5	0.5	X
9	10.72	-2.3	324	32	2.8	0.3	X
12	10.81	-0.2	1934	193	16.5	1.7	X
18	11.63	-0.5	1697	170	12.6	1.3	X
19	11.85	-2.1	378	38	2.7	0.3	X
22	13.06	-0.1	1984	198	11.6	1.2	X

Viewpoint 7 Ardnagowan

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	9.19	0.1	2064	206	24.4	2.4	X
2	10.2	-1.4	706	71	6.8	0.7	X
6	9.58	-2.6	262	26	2.9	0.3	
9	11.18	-2.1	378	38	3.0	0.3	X
12	9.11	-2.2	350	35	4.2	0.4	
18	10.93	-1.8	488	49	4.1	0.4	X
19	8.83	-2.4	304	30	3.9	0.4	
22	10.87	-1.9	448	45	3.8	0.4	X

Viewpoint 8 Leanach

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	8.55	-0.1	1984	198	27.1	2.7	X
2	9.42	-2.7	245	24	2.8	0.3	X
6	9.56	-1.9	448	45	4.9	0.5	X
9	11.08	-1.1	949	95	7.7	0.8	X
12	10.18	-0.7	1451	145	14.0	1.4	X
18	11.53	-0.4	1790	179	13.5	1.4	X
19	10.74	-2.5	284	28	2.5	0.3	
22	12.4	-1.9	488	49	3.2	0.3	X

Viewpoint 9 Strachur

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	9.37	-1.3	776	78	8.8	0.9	
2	9.36	-1.7	535	54	6.1	0.6	
6	10.67	-1.6	584	58	5.1	0.5	
9	11.19	-1.5	642	64	5.1	0.5	X
12	12.56	-1.0	1055	106	6.7	0.7	
18	12.56	0.5	2142	214	13.6	1.4	X
19	14.04	-0.8	1314	131	6.7	0.7	X
22	14.53	-0.8	1314	131	6.2	0.6	X

Viewpoint 10 Dun na Cuaiche

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	14.47	-0.4	1790	179	8.6	0.9	X
2	14.25	-1.0	1055	106	5.2	0.5	X
6	13.12	-1.7	535	54	3.1	0.3	X
9	12.37	-2.3	324	32	2.1	0.2	
12	11.65	-0.9	1181	118	8.7	0.9	X
18	11.07	-1.7	535	54	4.4	0.4	X
19	10.81	-1.4	706	71	6.0	0.6	X
22	9.4	-2.3	324	32	3.7	0.4	X

Viewpoint 11 Ford

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	14.22	0.0	2028	203	10.0	1.0	X
2	15	-0.7	1580	158	7.0	0.7	X
6	13.65	-1.4	706	71	3.8	0.4	X
9	14.72	-2.1	378	38	1.7	0.2	X
12	11.88	-2.0	409	41	2.9	0.3	X
18	13.53	-0.8	1451	145	7.9	0.8	X
19	10.39	-2.6	262	26	2.4	0.2	
22	11.95	-1.3	858	86	6.0	0.6	X

Viewpoint 12 Loch Fyne Waters

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	10.26	-1.8	488	49	4.6	0.5	X
2	10.38	-2.1	378	38	3.5	0.4	X
6	11.59	-2.3	324	32	2.4	0.2	X
9	12.27	-1.9	448	45	3.0	0.3	X
12	13.39	-0.7	1451	145	8.1	0.8	X
18	13.58	0.5	2142	214	11.6	1.2	X
19	14.78	0.1	2064	206	9.4	0.9	X
22	15.46	-1.0	1055	106	4.4	0.4	X

Viewpoint 13 A83 Old Military Road

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	10.71	-2.3	324	32	2.8	0.3	X
2	11	-2.6	262	26	2.2	0.2	M
6	12.06	-2.6	262	26	1.8	0.2	
9	12.95	-2.1	378	38	2.3	0.2	X
12	13.68	0.0	2028	203	10.8	1.1	X
18	14.13	0.6	2142	214	10.7	1.1	X
19	14.94	-0.3	1867	187	8.4	0.8	X
22	15.85	-0.8	1314	131	5.2	0.5	X

Viewpoint 14 St Catherine’s

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	17.01	-0.2	1934	193	6.7	0.7	X
2	17.03	-0.7	1451	145	5.0	0.5	
6	15.7	-0.9	1181	118	4.8	0.5	
9	15.35	-1.0	1055	106	4.5	0.5	
12	13.87	-0.2	1934	193	10.1	1.0	X
18	13.87	-0.7	1451	145	7.5	0.8	
19	12.59	-0.8	1451	145	9.2	0.9	
22	11.84	-0.9	1181	118	8.4	0.8	

Viewpoint 15 Beinn Bhan

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	13.67	-0.1	1984	198	10.6	1.1	X
2	12.73	-1.7	535	54	3.3	0.3	X
6	13.92	-0.8	1314	131	6.8	0.7	X
9	12.78	-2.2	378	38	2.3	0.2	
12	15.63	0.4	2132	213	8.7	0.9	X
18	14.06	-1.6	584	58	3.0	0.3	
19	17.16	-0.6	1580	158	5.4	0.5	X
22	15.96	-1.5	642	64	2.5	0.3	

Viewpoint 16 Minor Road at Fernoch Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	17.76	1.5	1743	174	5.5	0.6	X
2	17.22	0.2	2093	209	7.1	0.7	X
6	16.51	-0.7	1580	158	5.8	0.6	
9	15.27	-0.8	1314	131	5.6	0.6	
12	15.66	-0.4	1790	179	7.3	0.7	
18	14.42	-0.5	1697	170	8.2	0.8	
19	15.38	-0.4	1790	179	7.6	0.8	
22	13.49	-0.5	1697	170	9.3	0.9	

Viewpoint 17 Tom Soilleir

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	14.63	-1.2	858	86	4.0	0.4	
2	14.92	-1.4	706	71	3.2	0.3	
6	15.98	-1.4	706	71	2.8	0.3	
9	16.86	-1.4	706	71	2.5	0.3	
12	17.59	0.3	2117	212	6.8	0.7	X
18	18.05	0.6	2142	214	6.6	0.7	X
19	18.81	-0.6	1580	158	4.5	0.5	X
22	19.77	-0.7	1451	145	3.7	0.4	X

Viewpoint 18 Hell’s Glen Road (B839)

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	15.51	0.9	2092	209	8.7	0.9	
2	16.21	0.6	2142	214	8.2	0.8	
6	16.7	0.5	2142	214	7.7	0.8	
9	18.07	0.4	2132	213	6.5	0.7	
12	17.61	0.8	2117	212	6.8	0.7	
18	18.77	0.6	2142	214	6.1	0.6	
19	18.28	0.7	2134	213	6.4	0.6	
22	19.86	0.6	2142	214	5.4	0.5	

Viewpoint 19 Beinn Lochain

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	15.95	-1.6	584	58	2.3	0.2	
2	16.11	-1.8	488	49	1.9	0.2	
6	17.29	-1.8	488	49	1.6	0.2	
9	18.01	-1.7	535	54	1.7	0.2	X
12	19.03	-0.5	1697	170	4.7	0.5	X
18	19.3	0.4	2132	213	5.7	0.6	X
19	20.36	-0.3	1867	187	4.5	0.5	X
22	21.14	-0.9	1181	118	2.6	0.3	X

Viewpoint 20 Ardkinglas Woodland Garden

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	23.24	-0.3	1867	187	3.5	0.4	X
2	23.98	-1.2	858	86	1.5	0.2	X
6	22.59	-1.4	706	71	1.4	0.1	
9	23.53	-1.4	706	71	1.3	0.1	
12	20.71	-1.3	776	78	1.8	0.2	
18	22.22	-0.5	1697	170	3.4	0.3	X
19	19.13	-1.5	642	64	1.8	0.2	
22	20.4	-1.1	949	95	2.3	0.2	X

Viewpoint 21 Otter Ferry (B8000)

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	24.96	-0.6	1580	158	2.5	0.3	M
2	25.26	-0.8	1314	131	2.1	0.2	
6	23.79	-0.9	1181	118	2.1	0.2	
9	23.9	-0.9	1181	118	2.1	0.2	
12	21.76	-0.7	1451	145	3.1	0.3	
18	22.35	-0.5	1697	170	3.4	0.3	X
19	20.18	-0.8	1314	131	3.2	0.3	
22	20.19	-0.8	1314	131	3.2	0.3	

Viewpoint 22 Cruach Mor Dunardry

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	22.61	1.2	1955	195	3.8	0.4	
2	22.42	1.0	2054	205	4.1	0.4	
6	23.84	0.9	2092	209	3.7	0.4	
9	24.05	0.8	2117	212	3.7	0.4	
12	25.83	1.0	2054	205	3.1	0.3	
18	25.54	1.0	2054	205	3.2	0.3	
19	27.37	0.9	2092	209	2.8	0.3	
22	27.63	0.9	2092	209	2.7	0.3	

Viewpoint 23 Beinn Bhuidhe

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	24.1	1.2	1955	195	3.4	0.3	
2	24.4	1.1	2006	201	3.4	0.3	
6	25.45	1.0	2054	205	3.2	0.3	
9	26.34	0.9	2092	209	3.0	0.3	
12	27	1.1	2006	201	2.8	0.3	
18	27.53	1.0	2054	205	2.7	0.3	
19	28.14	1.0	2054	205	2.6	0.3	
22	29.21	0.9	2092	209	2.5	0.3	

Viewpoint 24 Beinn Ìme

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	24.94	1.4	1827	183	2.9	0.3	
2	24.11	1.4	1827	183	3.1	0.3	
6	25.46	1.2	1955	195	3.0	0.3	
9	24.52	1.2	1955	195	3.3	0.3	
12	27.32	1.3	1895	190	2.5	0.3	
18	25.9	1.3	1895	190	2.8	0.3	
19	28.92	1.2	1955	195	2.3	0.2	
22	27.89	1.2	1955	195	2.5	0.3	

Viewpoint 25 Ben Cruachan

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	31.55	-0.7	1451	145	1.5	0.2	X
2	32.19	-0.8	1314	131	1.3	0.1	X
6	30.72	-1.0	1055	106	1.1	0.1	X
9	31.42	-1.1	949	95	1.0	0.1	
12	28.73	-0.7	1451	145	1.8	0.2	X
18	29.98	-1.0	1055	106	1.2	0.1	
19	27.08	-1.1	949	95	1.3	0.1	
22	27.96	-1.0	1055	106	1.4	0.1	X

Viewpoint 26 A83 South of Inverneill

Appendix B – Abbreviations and Definitions

ADSB…………………………………..………Automatic Dependent Surveillance Broadcast
AGL..Above Ground Level (Height)
ANO...Air Navigation Order
AMSL..Above Mean Sea Level (Elevation)
ASG...Aviation Steering Group
CAA..Civil Aviation Authority
CAP..Civil Aviation Publication (Referrers to Specific Documents)
cd...Candela, a measure of light intensity
DIO..Defence Infrastructure Organisation
HNTA...Helicopter Night Training Area
In Flight Visibility....................The distance a pilot can see ahead to fly & navigate the aircraft
IR...Infrared
Kts..Knots: a measure of airspeed (10 kts = 12mph = 19 kph)
LED..Light Emitting Diode
MOD...Ministry of Defence
mW/sr..............milliWatts per steradian: electromagnetic energy output related to solid angle
Nm...Nautical Mile
NVD ....Night Vision Devices - Aircraft Mounted
NVG..Night Vision Goggles - Operator Worn
Radar Altimeter........An altimeter that uses radar to accurately measure height above ground
QFE ....Setting on Altimeter that gives Height above Airfield
RoAR...Rules of the Air Regulations
Rule 5...The Low Flying Rule – part of RoAR
Rule 28...VFR Rules Outside Controlled Airspace – part of the RoAR
ReUK...Renewables UK – The UK Wind Industry Body
SAR Box..Night Training Area for Search and Rescue Helicopter Units
SSA...Sector Safety Altitude
SSR……………………………………………………………Secondary Surveillance Radar
UKAB...............................United Kingdom Air Prox Board – Investigates Aircraft Near Misses
VFR....................................Visual Flight Rules (Flight without ATC on a see-and-be-seen basis)
VMC..................................Visual Meteorological Conditions (Weather suitable for VFR flight)

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Appendix C CAA Response

Strategy and Policy Group
Windfarm Policy

UK Civil Aviation Authority

Mike Hale
Aviation Consultant
Wind Power Aviation Consultants Ltd.
38 Hadrian Way
Chilworth
Southampton
SO16 7HX

27 October 2025
Ref Windfarms / Eredine

Dear Mike,

Proposed Obstacle Lighting Scheme for Eredine Wind Farm

Reference: Eredine Wind Farm Brief dated 15 July 2025 Amendment Level 3

1. Thank you for the lighting brief at reference. The report discusses the proposed obstacle lighting plan for the Eredine Wind Farm at the Eredine Forest between Loch Awe and Loch Fyne. The wind farm sits on two hills and a ridge line that straddle the Abhainn-a'-Bhealaich and Ally-nan-Sacs river valleys.

2. The proposed Eredine Wind Farm consists of 17 turbines, with tip heights 200m above ground level. This brings them within scope of the Air Navigation Order (ANO) Article 222 obstacle lighting requirements.

3. We have considered the report carefully and take note of the intent to address 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.

4. We note the proposed lighting scheme identifies the perimeter outline and that some mitigation is proposed to be provided by the provision of infra-red lighting for those operators who carry Night Vision Device capability.

5. Under provisions given in the Air Navigation Order (ANO) Article 222 section 6, the CAA provides for the following variation:

- medium intensity steady red (2000 candela) lights on the nacelles of turbines T01, T02, T06, T09, T12, T18, T19 and T22;

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• a second 2000 candela light on the nacelles of the above turbines to act as alternates in the event of a failure of the main light (note that both lights should not be lit at the same time);

• the lights on these turbines to be capable of being dimmed to 10% of peak intensity when the lowest visibility as measured at suitable points around the wind farm by visibility measuring devices exceeds 5km;

• infra-red lights to MoD specification installed on the nacelles of turbines T01, T02, T04, T06, T08, T09, T10, T12, T13, T14, T15, T16, T17, T18, T19, T21 and T22 (note that dimming permission is applicable only to visible lights, not infra-red lighting).

6. Intermediate level 32 candela lights are not required to be fitted on the turbine towers.

7. If the proposed design of the wind farm changes (other than variations due to micrositing etc.) this is likely to require a revision to this aviation obstacle lighting variation.

8. This letter supersedes my previous letter dated 29 September 2025 following changes to the layout of the turbines.

Yours sincerely,

AWells

Andy Wells
Manager Aviation and Wind Turbine Policy

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Appendix D CEL-WT-MIC Specification

cel
AVIATION LIGHTING

DATASHEET

05 Dec 2024

Medium Intensity Red 2,000cd Light

230VAC - LED Aircraft Warning Light

CEL-WT-MIC - StandAlone / Modbus

Medium intensity stand-alone 2,000cd red model is designed for Wind Turbine Installations. This intelligent light offers unique features such as incorporated fault monitoring, photocell, GPS synchronisation, adjustable luminosity and supports both stand-alone and Modbus operation as a part of a larger CEL aviation light system network.

Key features
- 2,000cd (effective) RED fixed or flashing modes
- Extremely reliable - long lifetime
- Supports both stand-alone and Modbus operations
- Suitable for Ofsh ore environment
- Incorporated GPS synchronisation
- Adjustable luminous output levels 10%, 30%, and 100%
- Incorporated photocell and fault monitoring
- WIFI interface
- Design lifetime more than 20 years
- 5yr warranty- the longest in the industry

Specifications met
- ICAO International Standards and Recommended Practices: Aerodromes Annex 14 Volume 1, 8th Edition, July 2018,
- Chapter 6: Medium-intensity Type B/C Fixed Obstacle Light
- European Aviation Safety Agency - Chapter Q – Visual Aids for Denoting Obstacles CS-ADR-DSN.Q.848
- FAA Advisory Circular 150/534543F 09/12/06: L-864 and L-885
- CEL-WT-MIC - light measurement chart table - DEC2024

Optical characteristics
- 2,000cd (effective)
- Colour aviation RED
- NVG compliant infrared (850nm)
- Horizontal beam 360°
- Vertical beam 3°
- Maximum intensity at -1° is less than 1,110cd
- Maximum intensity at -10° is less than 56cd

Electrical characteristics
- Operating voltage 90-265VAC
- Constant power input at 95% by active PFC
- Flash rates: 20/30/40/60fpm
- Meets standards
  EMC (Emissions): EN 61000-6-4
  EMC (Immunity): EN 61000-6-2

Electrical characteristics - continued
- Power consumption
  17W @Night (RED, 40fpm)
  20W @Night (RED+IR, 40fpm)
  25W @Night (RED, fixed)
  30W @Night (RED+IR, fixed)
- Recommended cables (Outdoor):
  Power (L-N-PE): 3x1,5mm"or 3x2,5mm"
  Data: CAT 7
  Alarm: CAT 7, 3x1,5mm or 3x2,5mm"
  Power + Data: 6x1,5mm"or 6x2,5mm"
- Input/Output terminals can be used to daisy chain power and data to additional lightheads

Mechanical characteristics
Painted marine grade aluminium body (C5MHigh)
Glass cover
Degree of protection IP66
Operating temperature range -40...+55°C
Mounting 240x240mm
Height 333mm, diameter 270mm
Weight 11kg

Additional Factory-Installed Options
Cold-climate version (CCV)
NVG compliant infrared (IR)

OPERATING VOLTAGE
230 VAC
CAUTION / LED RADIATION

EASA
Wifi

Contarnex Europe Limited
252 Martin Way,
Morden, Surrey SM4 4AW
United Kingdom

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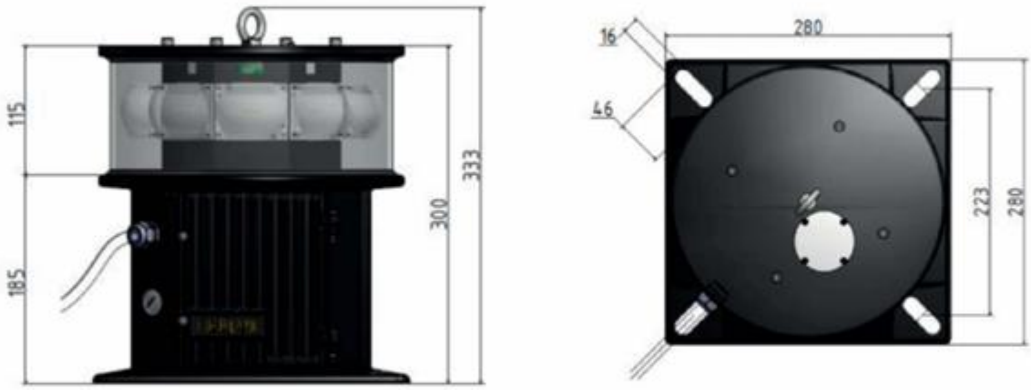
Medium Intensity Red 2,000cd Light

230VAC - LED Aircraft Warning Light

CEL-WT-MIC - StandAlone / Modbus

CEL-WT-MIC

Light unit with mounting dimensions



CEL-WT Versions

CEL-WT-MIB	Medium-intensity Type B (flashing) obstruction light, 2,000cd Red, GPS sync, Photocell, Alarm, 100-240VAC Supports stand-alone and Modbus Network operation.
CEL-WT-MIC	Medium-intensity Type C (steady burn) obstruction light, 2,000cd Red, infrared, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.
CEL-WT-MIB-IR	Medium-intensity Type B (flashing) obstruction light, 2,000cd Red, Infrared 850nm, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.
CEL-WT-MIC-IR	Medium-intensity Type C (steady burn) obstruction light, 2,000cd Red, Infrared 850nm, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.

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