Technical Appendix 4.6: Aviation Lighting and Mitigation Report

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Wind Power Aviation Consultants Ltd

Wind Farm Aviation Lighting and Mitigation Technical Appendix for Appin Wind Farm V2.0

Our Reference: WPAC 010/25
Your Reference: Appin EIA Technical Appendix

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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. NatureScot Guidance on Aviation Lighting Impact Assessment dated November 2024
G. International Civil Aviation Organisation (ICAO) Annex 14 Vol 1 Chapter 6
H. MOD Obstruction Lighting Guidance Document 01 Jan 2020

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 D and F as discussed with the CAA and the MOD. It explains the rationale behind the lighting design taking into account 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 including NatureScot and the Local Planning Authority. 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 required under 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

Lighting Layout Starting Point and Assumptions

3. Stakraft are proposing a nine-turbine wind farm named Appin to be located 7km NW of Moniaive between the Dalwhat and Shinnel Waters in East Ayrshire. The turbines will be situated on Colt, Black Craig, Lamgarroch, Mullwhanny and Cormunnoch Hills. All turbines will be 200m to tip.

4. From a civilian aviation perspective the Appin site is located 42km southeast of Prestwick Airport. Importantly, Appin is clear of Controlled Airspace (CTA) associated with Prestwick, Glasgow and Edinburgh Airports. The airspace around Appin is designated Class G by the CAA (open-unrestricted airspace). Conversely, from a military perspective, the turbines will be located in Low Flying Area (LFA) 16; one of the busiest LFAs in the UK. In addition, the Appin turbines will be in the co-located Tactical Training Area (TTA) 20 where military fast jet aircraft operate down to 100ft (30m) day and night.

5. In the hours of darkness (evening civil twilight to morning civil twilight) this area converts to Night Allocated Region (NAR) 2B. Although primarily a fast jet training area, the airspace is also used by MOD and NATO tactical transport aircraft and helicopters for day and night training.

6. In addition, this area will be frequented by CSAR, Police, HEMs and Air Ambulance helicopters (Some operating from Prestwick and Glasgow) as well as military craft by day and night. This type of activity will dictate that the site will require both visible red and infra-red obstruction lighting on its turbines.

Lighting Assessment Overview

- Appin will be assessed as below/in Class G ‘en route’ airspace insofar as visible obstruction lighting is concerned.
- Local airspace constraints will be considered for their potential impact on the site.
- Expected CAA and MOD dispensations will be assessed for the site.
- The visible lighting component of the lighting proposal will be developed in accordance with the latest (still draft) CAA CAP 764.
- To accommodate MOD requirements, and other lower airspace night operators, the site will be assessed for Night Vision Equipment compatible lighting in accordance with MOD published obstruction lighting specifications.
- Where possible, the recommended lighting configuration will be optimised to reduce light impact on the local area.
- The Appin wind farm proposal is for nine turbines at 200m to tip.

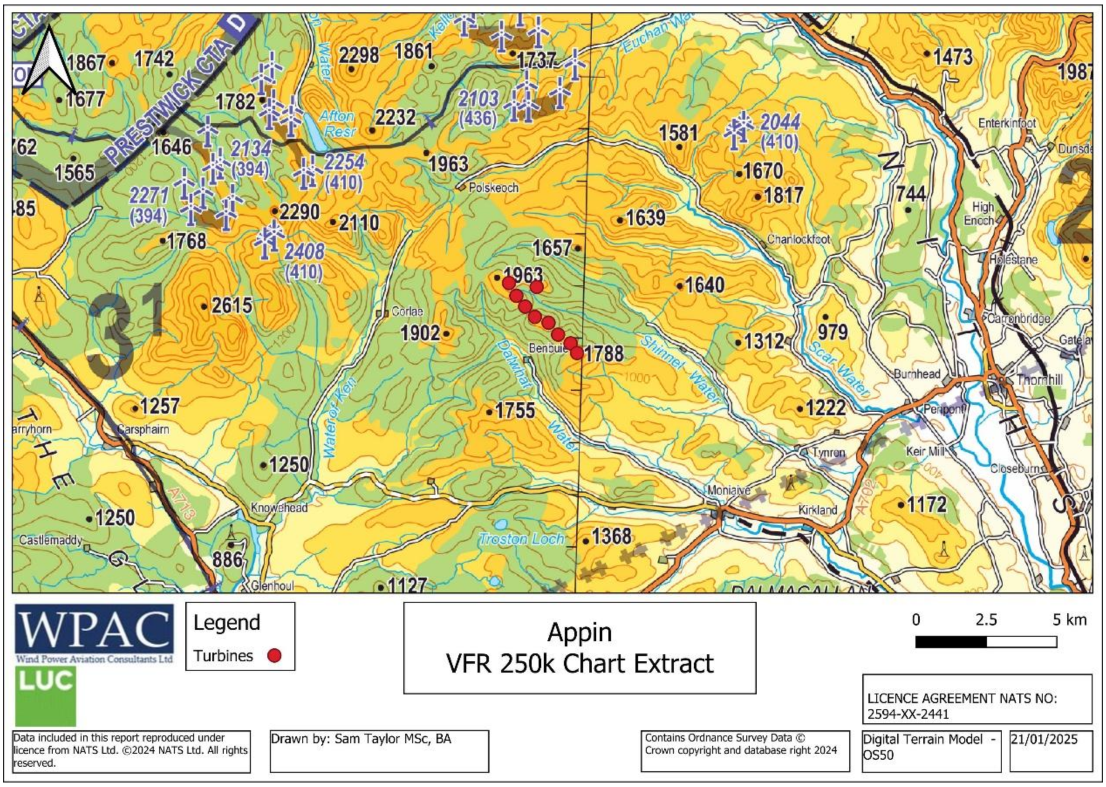

Figure 1 Appin on an aviation chart

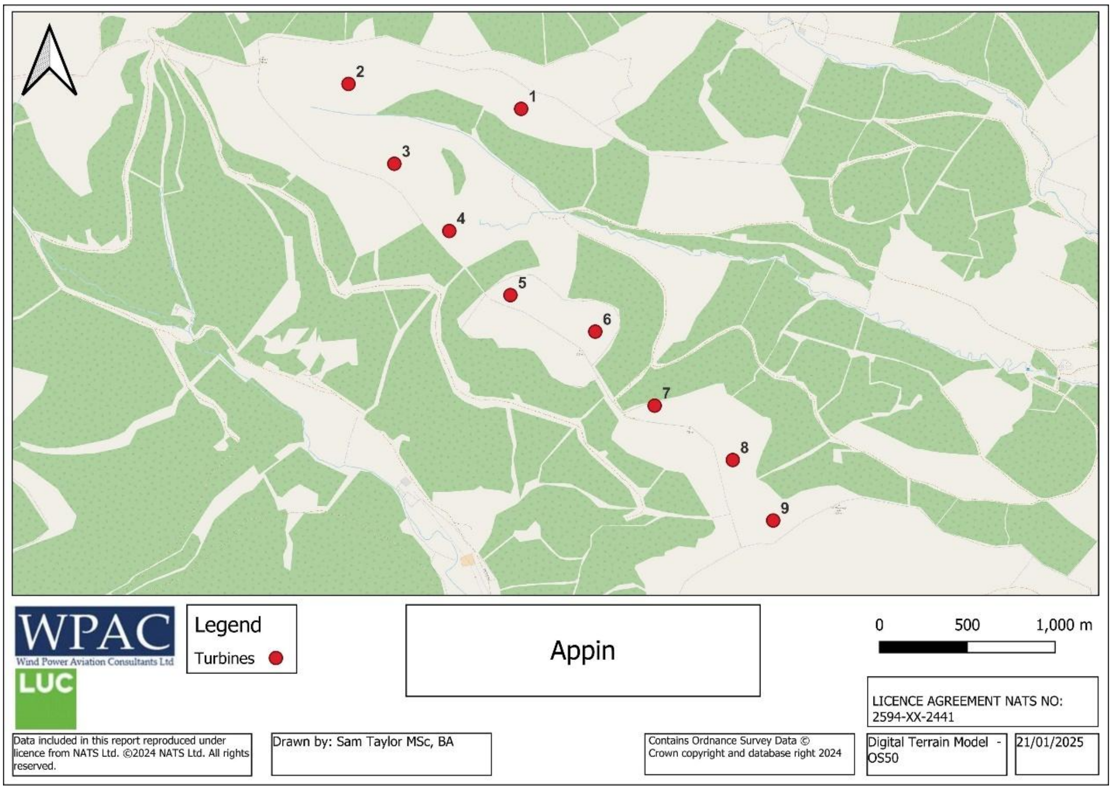

Figure 2 Appin Wind Farm

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

7. 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 distance is negotiable/extendable by application to the CAA).

- That any turbine within 200m of the perimeter be lit unless the distance between adjacent turbines is less than 900m total (Again, this distance/requirement is negotiable by application to the CAA).

- That any unlit turbine does not exceed a 10° up-slope from adjacent lit turbines. All perimeter turbines are lit and conform to this requirement.

Applying these criteria, without expected CAA dispensations, dictates that all 9 turbines will require ANO visible red lighting.

Turbines with 2000/200cd Lights: T1, T2, T3, T4, T5, T6, T7, T8 and T9

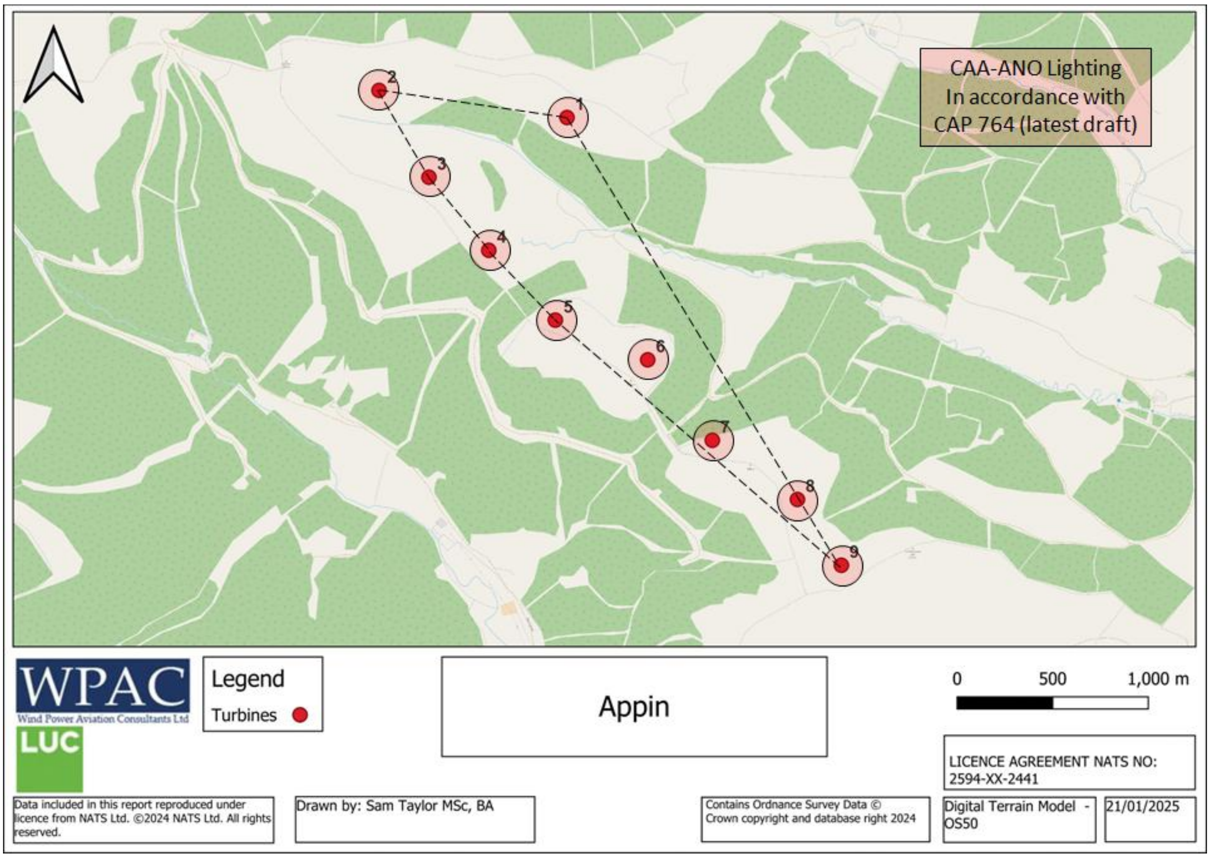

Figure 3 Lighting Layout without CAA Dispensations

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

CAA-ANO Red 2000/200cd Lighting – Reduced and Balanced Option

8. The military have operated at low level at night for many decades now using night vision equipment. In more recent times, an increasing number of 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. 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.

9. When aircraft are operating at safety altitude or above, 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 including turbine tip heights. Aircraft/helicopters flying as such, will only need enough visible lights to define the wind farm and its size/shape/perimeter.

10. Accordingly, the regular outline of the Appin turbine site could be identified with four visible red lights on turbines T2, T5, and T9 to indicate the ‘line’ of turbines and another light on the outlier T1.

Turbines with 2000/200cd ANO Visible Red Lights: T1, T2, T5 and T9

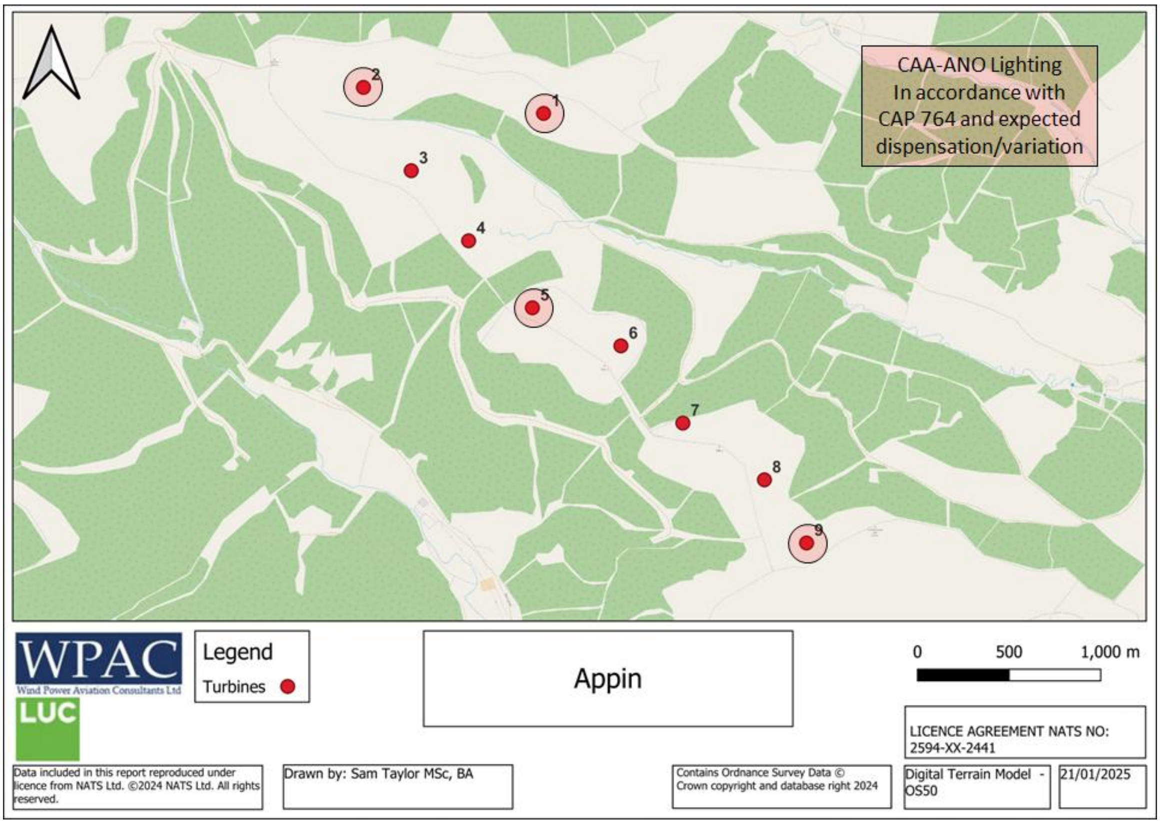

Figure 4 Lighting Layout with CAA Dispensations

MOD Lighting Requirements

11. 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.

12. 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.

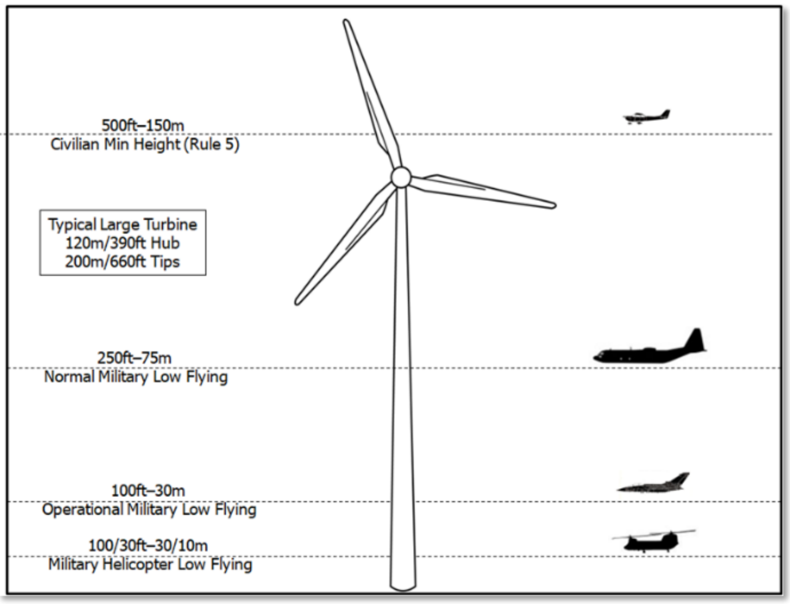

Figure 5 Wind turbine in context with MOD Low Flying

MOD Infra-Red Lighting Layout

13. 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. Note: At this site, the CAA string and MOD compound perimeters are generally similar.
- That any dominant turbine, by location or height, be lit. Note: here, all turbines are lit.
- Appin does not meet the MOD small site criteria (red dotted circle). This allows for non-perimeter turbines to not carry an IR light. However, all Appin turbines are considered perimeter turbines so all must retain their IR light.

Applying the MOD criteria dictates that all turbines of the Appin site will require IR lighting. Nine hub mounted IR lights in total.

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

Turbines with Infra-Red Lighting: T1, T2, T3, T4, T5, T6, T7, T8 and T9

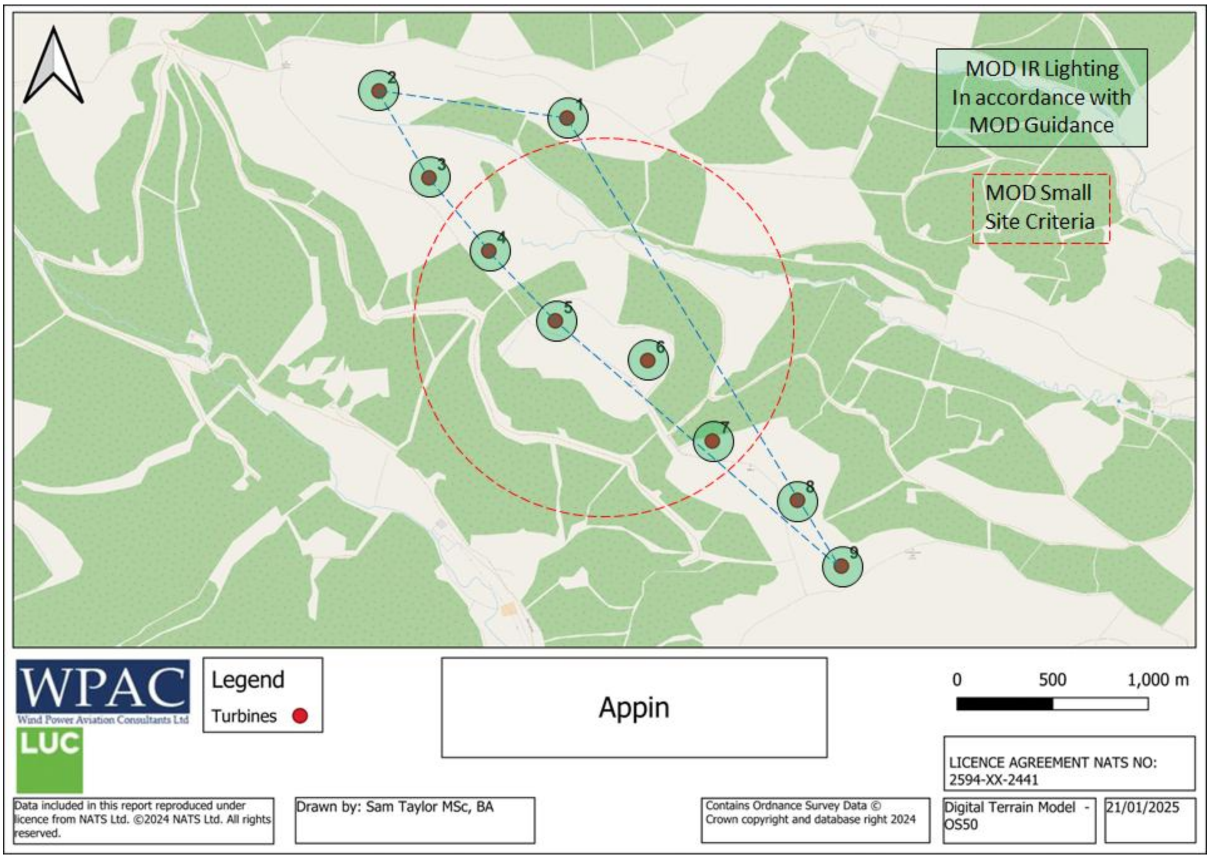

Figure 6 Proposed MOD Infra-Red Lighting Arrangement

Combined CAA Visible Lighting and MOD Infra-Red Lighting

Appin Turbine Lightning Table							
Turbine	Easting	Northing	Hub Ht	Tip Ht	Disc Dia	CAA-ANO	MOD-IR
1	271329	598727	119m	200m	162m	2000/200cd	600mW/sr
2	270343	598414[1]	119m	200m	162m	2000/200cd	600mW/sr
3	270607	598414	119m	200m	162m		600mW/sr
4	270920	598031	119m	200m	162m		600mW/sr
5	271268	597665	119m	200m	162m	2000/200cd	600mW/sr
6	271751	597457	119m	200m	162m		600mW/sr
7	272089	597035	119m	200m	162m		600mW/sr

[1] Turbine 2 has moved approximately 16 metres since the assessment but will make no substantive difference to the results

8	272534	596725	119m	200m	162m		600mW/sr
9	272764	596380	119m	200m	162m	2000/200cd	600mW/sr

Table 1 CAA and MOD Lighting Table

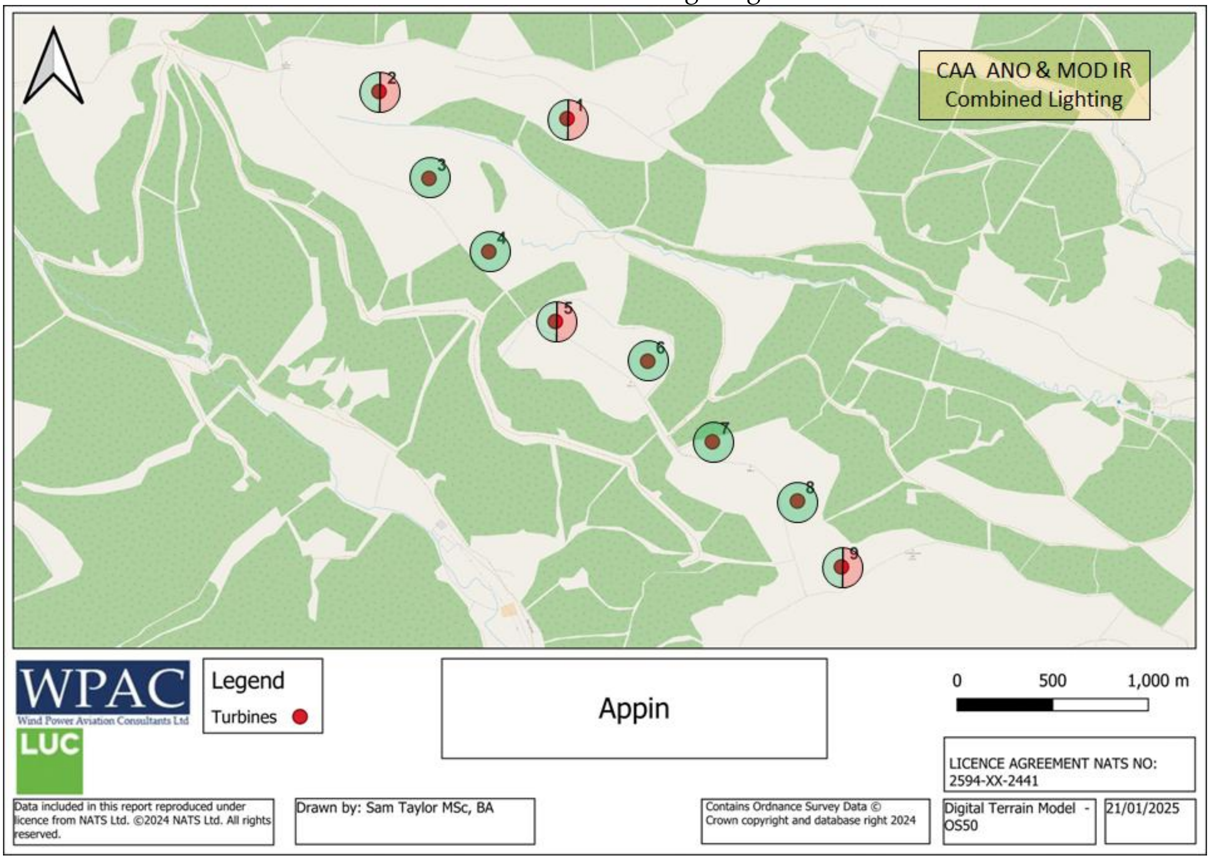

Figure 7 CAA-ANO Visible Red and MOD Infra-Red Lighting Arrangement

ANO Light Specifications

14. 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 met 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 or 25cd 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.

15. <u>**Low Intensity Mid Mast Lights**</u> – 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.

16. 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. As a result, 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 Appin. This was approved as shown in the CAA letter at Appendix C.

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

17. 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

18. 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. Additionally, the lights can be switched on by a suitable Lux Meter when the sunlight falling on a vertical surface drops below 500 Lux. This second option would be suitable to activate the lights in poor day-time weather conditions.

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

19. Having defined a layout of turbines to be fitted with visible lighting, an assessment has been undertaken to calculate the brilliance of the 2000cd red 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[2] 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

[2] Candela is the SI Unit of luminous intensity and refers to the amount of light emitted in a particular direction.

CEL-WT-MIC[3] 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.

20. 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.

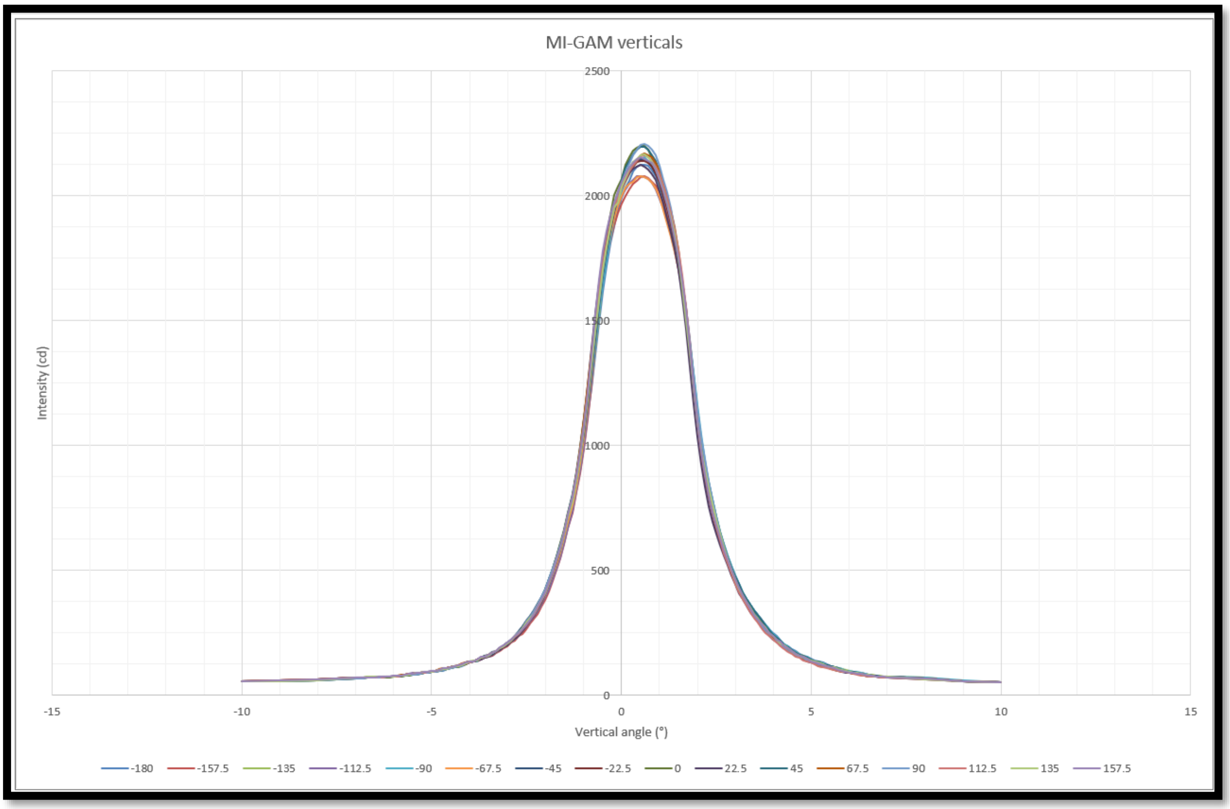

Figure 8 CEL-WT-MIC Light Measurement Results

21. 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 119 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 Appin Wind Farm viewpoints. The locations of the viewpoints are shown in Figure 9 and Table 5.

[3] CEL-WT-MIC - rev1.pdf

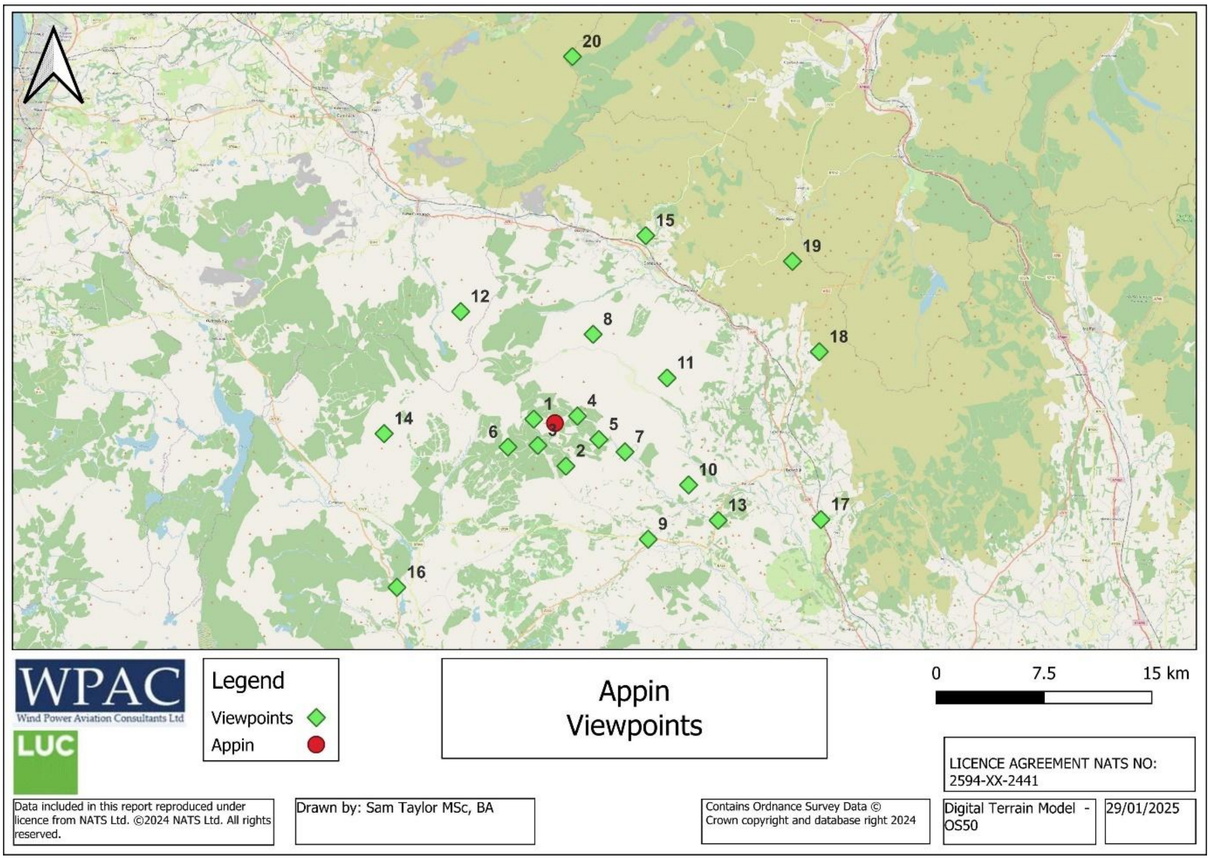

Figure 9 Viewpoint Locations

22. 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$^{(10\text{-}6)}$/m^2) or lux$^{(10\text{-}6)}$. 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.

23. The results for every medium intensity 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	Colt Hill, Striding Arch	NX 69856 99004
2	Bail Hill, Striding Arch	NX 72094 95735
3	Cairnhead, Striding Arch	NX 70140 97177
4	Shinnelhead	NX 72893 99216
5	High Appin	NX 74382 97583
6	Benbrack, Striding Arch	NX 68058 97062
7	Shinnel Water Valley near Craigencon	NX 76204 96725
8	SUW near Cloud Hill	NS 73984 04910
9	Moniaive	NX 77819 90644
10	Auchengibbert Hill	NX 80627 94423
11	Cairnkinna Hill	NS 79129 01870
12	Blackcraig Hill	NS 64770 06492
13	A702, Shinnel Water Valley	NX 82686 91955
14	Cairnsmore of Carsphairn	NX 59441 97995
15	Crawick Multiverse	NS 77646 11783
16	A713, near Stroangassel	NX 60330 87294
17	A76, south of Closeburn	NX 89836 92013
18	Durisdeer Rig	NS 89724 03699
19	East Mount Lowther	NS 87855 09990
20	Cairn Table	NS 72543 24246

Table 5 Viewpoints

Interpreting the Results

24. 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 whilst following the guidelines in GLVIA3 or other relevant guidance. Table 6 shows the turbine with the greatest potential perceived luminous intensity expressed in micro-lumens per m^2 (Lux $^{(10^{-6})}$) at each viewpoint.

Viewpoint	Turbine	Distance (KM)	Microlumens per m2 (lux10-6)	Microlumens at 10%	Obscured
1	5	1.95	278.7	27.9	
2	5	2.1	42.2	4.2	
3	5	1.23	49.7	5.0	
4	1	1.64	27.9	2.8	
5	9	2.02	18.5	1.9	
6	5	3.27	110.7	11.1	
7	9	3.46	6.3	0.6	
8	5	7.74	10.7	1.1	
9	9	7.65	2.3	0.2	
10	9	8.1	6.8	0.7	
11	9	8.41	22.4	2.2	M
12	2	9.44	23.1	2.3	
13	9	10.86	2.0	0.2	
14	2	10.94	17.9	1.8	
15	1	14.5	2.3	0.2	
16	1	15.86	1.6	0.2	M
17	9	17.62	1.4	0.1	
18	5	19.42	2.3	0.2	
19	1	20	4.8	0.5	
20	2	25.47	2.9	0.3	

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

25. 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 m^2)
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

26. 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	9	3.92	1580	158	
2	2	3.59	262	26	
3	5	1.23	75	8	
4	1	1.64	75	8	
5	2	4.24	108	11	
6	9	4.76	1451	145	
7	2	6.24	114	11	
8	9	8.62	706	71	
9	9	7.65	133	13	
10	5	9.9	584	58	
11	5	8.92	1697	170	M
12	5	10.96	2117	212	
13	2	14.14	324	32	
14	2	10.94	2142	214	
15	1	14.5	488	49	
16	1	15.86	409	41	M
17	5	19.41	535	54	
18	5	19.42	858	86	
19	9	20.32	1984	198	
20	5	26.61	1934	193	

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

Part 2 Mitigation

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

27. 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.

28. 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'.*

29. 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 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. Note: This concession is not applicable to MOD specification IR lighting or the 25cd red lights, which are covered separately.

30. It will be necessary to calculate how much time the lights would spend at 2000cd and at 200cd. To assess historical visibility in this region the closest meteorological station to Appin is at Prestwick. However, although the visibility will not be identical at these two locations, it will be in the same air-mass for the majority of the time and will give similar observations. Table 9 below is a Met Office table of visibilities throughout the year for Prestwick Airport which are averaged over a 30-year period.

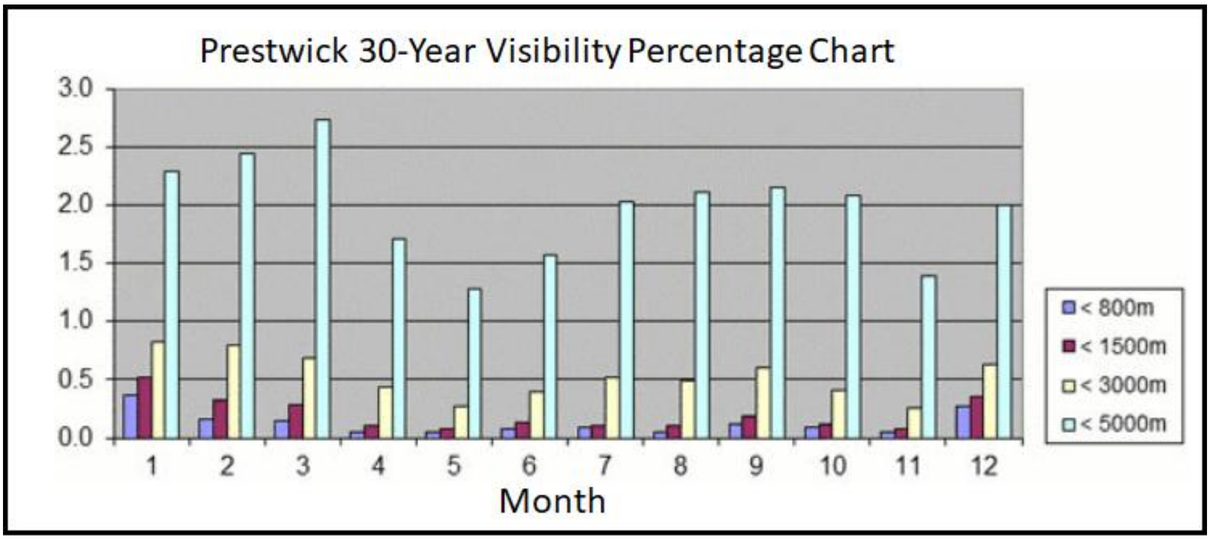

Table 9 Prestwick Visibility Table

31. These Met Office records show that the visibility is below 5km (light blue bar) for an average of 2% of the time. This suggests that the lights at Appin will be set at **2000cd for 2% of the time (visibility below 5km) and set at 200cd for 98% of the time (visibility above 5km)**.

32. Whilst Prestwick is not Appin, it will be in the same air mass. In addition, 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 Appin visibility would be better than that at Prestwick.

In addition, cloud will play its part in the observability of the obstruction lights at Appin. This can also be obtained from Met Office data.

Obstruction Light Weather Obscuration.

33. On occasion, the visibility in the area of Appin will reduce significantly due to the presence of cloud on the hills. If the Appin turbines are in cloud, then the obstruction lights will not be seen. The turbines will carry the CAA/ANO lights on the turbine hub. The average height at the base of these turbines is around 1700-2000ft above mean sea level (amsl). The hub heights, for the proposed turbines will be around 400ft above ground level (agl) giving hub heights averaging around 2100-2400ft amsl. For aeronautical reasons, meteorological cloud bases are quoted in feet (ft). The hub mounted CAA visible red lights will be at these heights: 2100-2400 amsl.

34. Using these heights, it is possible to compare the light altitudes amsl with the actual cloud bases recorded by the Met Office at Prestwick (over a 30-year period) as shown below in Table 10.

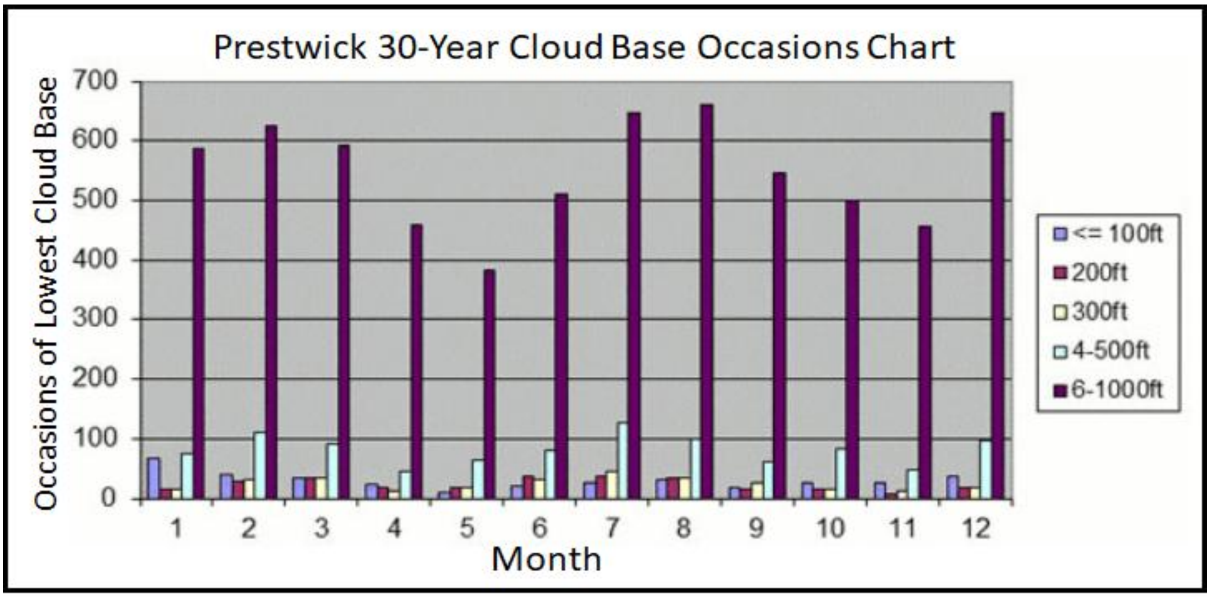

Table 10 Prestwick Cloud Base Table.

35. The darker red columns (600-1000ft amsl) indicate that, on around 550 occasions a month, the cloud-base will be below the turbine hub heights. In addition, the combined blue, red and yellow

columns indicate that on a further 200 times a month the weather would be such that the cloud would be so low that the turbines/lights would only be visible to people on the hills when very close to the turbines.

36. Again, Prestwick is not Appin, meteorological statistics and science show that cloud-bases reduce in the region of hills. It could be argued that at Appin, the cloud-base would on the whole, be lower than at Prestwick thus providing an even greater degree of turbine light obscuration on more occasions per month.

Weather Obscuration Conclusion

37. 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 Appin, so gathered, should be presented as follows:

> *Meteorological observations suggest that the turbine hubs/lights will be obscured on over 750 occasions a month by cloud.*
>
> *When not obscured by cloud, the visibility in the area of the turbines can be expected to exceed 5km for 98% of the time and the 2000cd lights will be switched down to 200cd.*

Visibility Meter Locations

38. The CAA currently state that visibility should be measured at suitable points around the wind farm. In the case of Appin turbines, visibility meters on T2, T5 and T9 will meet this requirement.

Conclusion/Notes

39. The purpose of this Lighting Brief is to identify an obstruction lighting arrangement that minimizes any environmental effects 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.

40. Applying the CAP 764 draft criteria for visible red obstruction lighting, results in a solution that requires all-bar-one turbine to carry an ANO 2000cd visible red light. By initially applying current CAA dispensations, and then matching the lighting to the night operators' requirements, an environmentally friendly, but aviation safe, layout has been achieved. This results in a total of:

4 x ANO Visible Red 2000cd lights and 9 x MOD IR 600mW/sr lights.

41. Furthermore, the site is in an area where it will benefit from both the dimming of the visible red lights in good-weather and regular obscuration of both turbines and the visible red light by cloud.

The lights will be regularly obscured by cloud and when not obscured set at the lower 200cd for approximately 98% of the time.

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Technical Mitigation

42. 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.

43. 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

44. 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 recent 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.*

45. 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.'*

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46. 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

47. 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.

48. 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 Appin. 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 operations are taking place within the activation zone for the system. The infra-red 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

49. 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.

50. 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.

51. 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.

52. 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

53. This report has assessed the requirements for both visible, CAA approved aviation lighting and MOD approved Infra-Red lighting for the Appin 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 were sent to the CAA and MOD DIO for approval. The MOD will approve the IR lighting layout as there is no concession required and the CAA have considered the proposal and responded, their approval letter is attached at Appendix C to this report.

54. 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 98% of the time, the 2000cd 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.

55. 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

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 (lux10-6) at 10%	Obscured
1	1.5	-2.9	218	22	97.0	9.7	
2							
5	1.95	-1.0	1055	106	278.7	27.9	
9	3.92	-0.6	1580	158	103.0	10.3	

Viewpoint 1 Colt Hill, Striding Arch

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	3.09	-3.0	206	21	21.6	2.2	
2	3.59	-2.6	262	26	20.4	2.0	
5	2.1	-3.2	186	19	42.2	4.2	
9							

Viewpoint 2 Bail Hill, Striding Arch

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	1.95	-9.6	75	8	19.6	2.0	X
2	1.7	-9.7	75	8	25.8	2.6	X
5	1.23	-15.3	75	8	49.7	5.0	
9	2.74	-7.2	75	8	10.0	1.0	

Viewpoint 3 Cairnhead, Striding Arch

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	1.64	-13.5	75	8	27.9	2.8	
2	2.57	-7.6	75	8	11.4	1.1	X
5	2.25	-8.7	75	8	14.9	1.5	M
9	2.84	-6.2	74	7	9.1	0.9	X

Viewpoint 4 Shinnelhead

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	3.26	-6.0	75	8	7.1	0.7	
2	4.24	-4.6	108	11	6.0	0.6	
5	3.12	-5.5	85	8	8.7	0.9	
9	2.02	-8.6	75	8	18.5	1.9	

Viewpoint 5 High Appin

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	3.67	-1.5	642	64	47.6	4.8	
2	2.92	-1.8	488	49	57.4	5.7	
5	3.27	-0.9	1181	118	110.7	11.1	
9	4.76	-0.7	1451	145	64.2	6.4	

Viewpoint 6 Benbrack, Striding Arch

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	5.27	-5.2	91	9	3.3	0.3	
2	6.24	-4.4	114	11	2.9	0.3	
5	5.02	-5.0	94	9	3.7	0.4	
9	3.46	-7.3	75	8	6.3	0.6	

Viewpoint 7 Shinnel Water Valley near Craigencon

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	6.73	-2.1	378	38	8.4	0.8	
2	7.05	-2.0	409	41	8.2	0.8	
5	7.74	-1.5	642	64	10.7	1.1	
9	8.62	-1.4	706	71	9.5	1.0	

Viewpoint 8 SUW near Cloud Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	10.37	-3.0	206	21	1.9	0.2	X
2	11.11	-2.1	378	38	3.1	0.3	X
5	9.6	-2.5	284	28	3.1	0.3	X
9	7.65	-4.0	133	13	2.3	0.2	

Viewpoint 9 Moniaive

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	10.25	-1.7	535	54	5.1	0.5	
2	11.2	-1.6	584	58	4.7	0.5	
5	9.9	-1.6	584	58	6.0	0.6	
9	8.1	-1.9	448	45	6.8	0.7	

Viewpoint 10 Auchengibbert Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	8.41	-0.9	1181	118	16.7	1.7	M
2	9.28	-0.8	1314	131	15.3	1.5	M
5	8.92	-0.6	1697	170	21.4	2.1	M
9	8.41	-0.6	1580	158	22.4	2.2	M

Viewpoint 11 Cairnkinna Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	10.16	0.1	2064	206	20.0	2.0	
2	9.44	0.1	2064	206	23.1	2.3	
5	10.96	0.3	2117	212	17.6	1.8	
9	12.89	0.2	2093	209	12.6	1.3	

Viewpoint 12 Blackcraig Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	13.22	-2.5	284	28	1.6	0.2	
2	14.14	-2.3	324	32	1.6	0.2	
5	12.77	-2.4	304	30	1.9	0.2	
9	10.86	-2.8	232	23	2.0	0.2	

Viewpoint 13 A702, Shinnel Water Valley

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	11.91	0.5	2142	214	15.1	1.5	
2	10.94	0.6	2142	214	17.9	1.8	
5	11.83	0.8	2117	212	15.1	1.5	
9	13.42	0.6	2142	214	11.9	1.2	

Viewpoint 14 Cairnsmore of Carsphairn

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	14.5	-1.9	488	49	2.3	0.2	
2	14.83	-1.8	488	49	2.2	0.2	
5	15.49	-1.4	706	71	2.9	0.3	X
9	16.16	-1.2	858	86	3.3	0.3	X

Viewpoint 15 Crawick Multiverse

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Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	15.86	-2.1	409	41	1.6	0.2	M
2	15.31	-2.1	378	38	1.6	0.2	M
5	15.07	-2.0	409	41	1.8	0.2	X
9	15.4	-1.6	584	58	2.5	0.3	X

Viewpoint 16 A713, near Stroangassel

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	19.69	-1.8	488	49	1.3	0.1	
2	20.66	-1.7	535	54	1.3	0.1	
5	19.41	-1.7	535	54	1.4	0.1	
9	17.62	-1.9	448	45	1.4	0.1	

Viewpoint 17 A76, South of Closeburn

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	19.06	-1.4	706	71	2.0	0.2	
2	19.97	-1.3	776	78	2.0	0.2	
5	19.42	-1.3	858	86	2.3	0.2	
9	18.47	-1.3	776	78	2.3	0.2	

Viewpoint 18 Durisdeer Rig

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	20	-0.2	1934	193	4.8	0.5	
2	20.74	-0.2	1934	193	4.5	0.5	
5	20.66	-0.1	1984	198	4.7	0.5	
9	20.32	-0.1	1984	198	4.8	0.5	

Viewpoint 19 East Mount Lowther

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	25.55	-0.3	1867	187	2.9	0.3	
2	25.47	-0.3	1867	187	2.9	0.3	
5	26.61	-0.2	1934	193	2.7	0.3	
9	27.87	-0.2	1934	193	2.5	0.3	

Viewpoint 20 Cairn Table

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...Infra-Red
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)

Appendix C CAA Response

OFFICIAL - Named Parties Only. This information is intended for Wind Power Aviaton Consultants Ltd. only

Strategy and Policy Group
Windfarm Policy

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

10 February 2025
Ref Windfarms / Appin

Dear Mike,

Proposed Obstacle Lighting Scheme for Appin Wind Farm

Reference: Appin Wind Farm Lighting report dated 21 January 2025

1. Thank you for the lighting brief at reference. The report discusses the proposed obstacle lighting plan for the Appin Wind Farm, located approximately 7km NW of Moniaive between the Dalwhat and Shinnel Waters in East Ayrshire.

2. The proposed Appin Wind Farm consists of 9 turbines, with heights 200m ground to tip. This brings the turbines 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, T05 and T09;
- 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);

Civil Aviation Authority
2E Aviation House Beehive Ring Road Crawley West Sussex RH6 0YR www.caa.co.uk
Telephone 0330 138 3166 [redacted]

OFFICIAL - Named Parties Only

• 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, T03, T04, T05, T06, T07, T08 and T09 (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.

Yours sincerely,

[redacted]

Andy Wells
Manager Aviation and Wind Turbine Policy

Appendix D Lighting 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 Offshore 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 measurements and table - Dec 2024

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

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

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EASA Wifi

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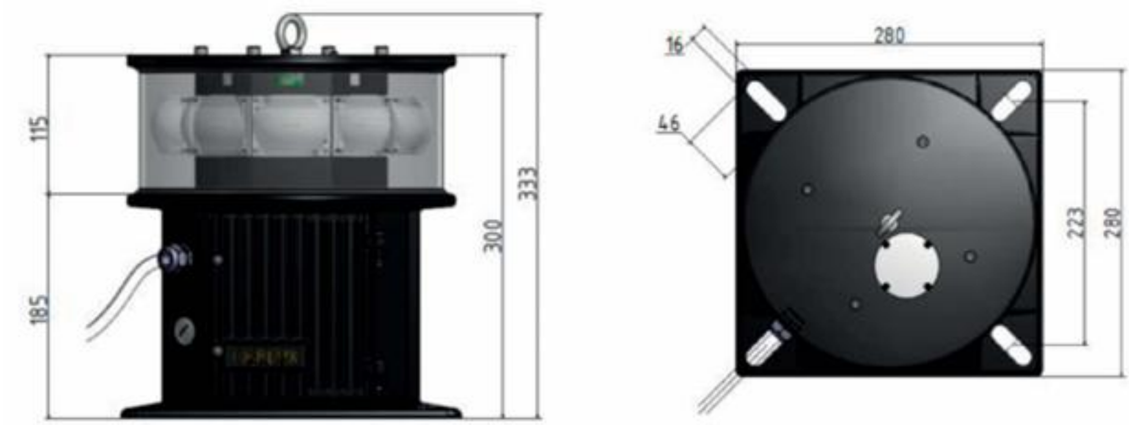
Medium Intensity Red 2,000cd Light

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/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 B/C obstruction light, 2,000cd Red, CINfrared 850nm, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.

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CEL AVIATION LIGHTING