Appendix 14.2: Aviation Lighting and Mitigation Report

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Wind Power Aviation Consultants Ltd

Wind Farm Aviation Lighting and Mitigation Report for Loch Liath Wind Farm V2.0

Our Reference: WPAC 076/22
Your Reference: Loch Liath LUC 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 (to be released shortly)
C. Air Navigation Order (ANO) Article 222
D. 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
E. NatureScot General pre-application and scoping advice for onshore wind farms dated Sep 2020
F. International Civil Aviation Organisation (ICAO) Annex 14 Vol 1 Chapter 6

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 as proposed by NatureScot in their response to a recent Wind Farm Inquiry.

Part 1 Turbine Lighting Layout Design

Introduction

2. WPAC have designed a number of CAA and MOD compliant lighting layouts for wind farms and have also been in constant dialogue with the CAA regarding the proposed change 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. Discussions with the CAA have clarified that the draft regulations 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. Statkraft has proposed a 13-turbine wind farm on the Balmacaan Estate located seven kilometres to the north-west of Loch Ness between the Balmacaan and Levishie Forests.

4. The proposed turbine site is within MOD Low Flying Area (LFA) 14. LFA 14 is the largest LFA, it includes the Highlands Restricted Area (HRA) and offers the greatest training utility in the UK. Accordingly, it is used for both in-house MOD low flying training and large multi-national (NATO) air exercises. At night this area converts to Night Allocated Region (NAR) 1BE. Although NAR 1BE is primarily reserved for low flying fast jet aircraft in the hours of darkness, the extended airspace offered means it is also used for low flying training by all aircraft/helicopter types. In addition, the area around Loch Ness is frequented by Coast Guard, Police, Air Ambulance and Commercial Helicopters by day and night.

5. As a result, Loch Liath will require a comprehensive obstruction lighting arrangement that includes both visible (CAA ANO) and infra-red (MOD IR) lights

Note: Loch Liath is located in an area that has other existing and proposed turbine sites.

Lighting Assessment Overview

- From a CAA perspective, Loch Liath is located in Class G 'en-route' airspace and will require lighting in-accordance-with CAP 764 advice.
- To accommodate MOD requirements, the site will be assessed for NVG compatible lighting in accordance with MOD published obstruction lighting specifications.
- The recommended final lighting configuration has been optimised to minimise light impact on the local area.
- The Loch Liath wind turbine proposal is for 13 turbines: ten at 200m and three at 180m to tip.

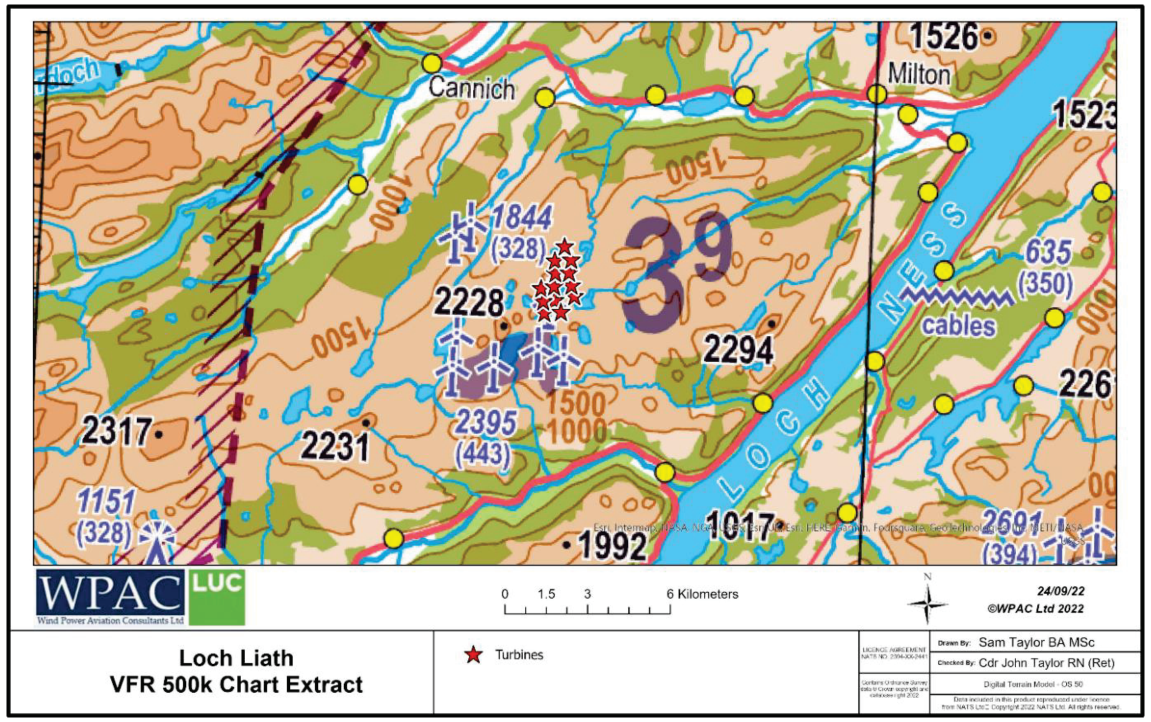

Figure 1 Loch Liath on an aviation chart

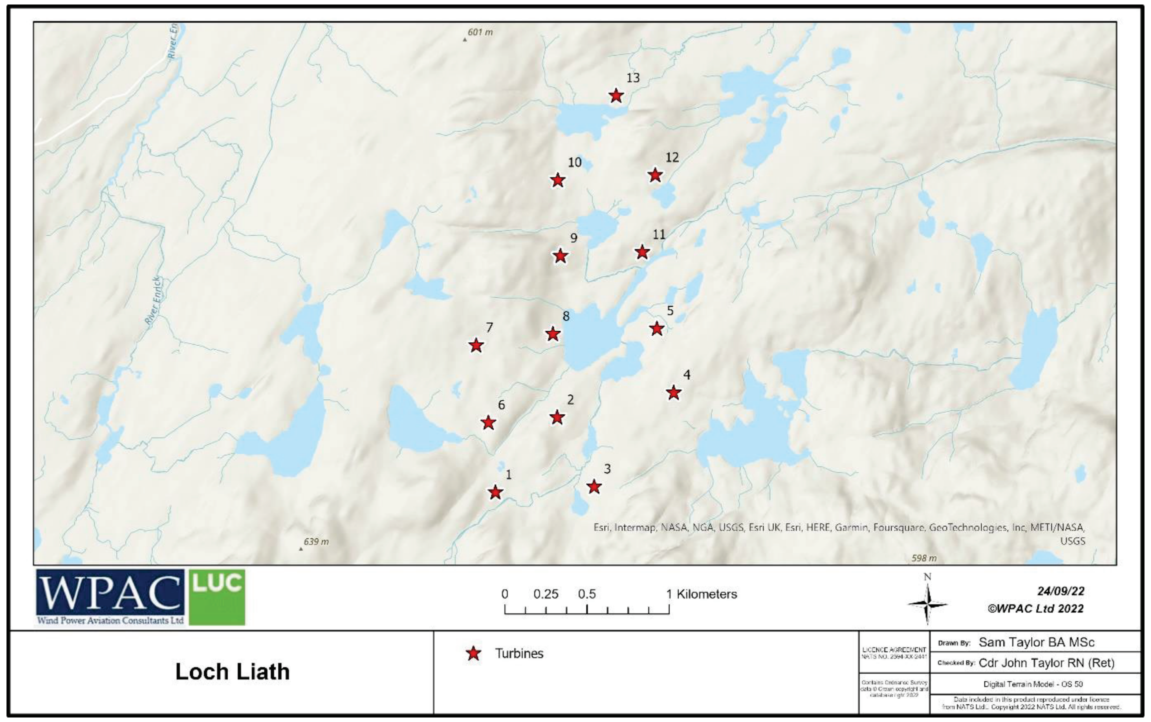

Figure 2 Loch Liath Wind Farm

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

6. 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.
- That any turbine within 200m of a 'string perimeter' be lit unless the distance between adjacent turbines is less than 900m total.
- That any unlit turbine does not exceed a 10° up-slope from adjacent lit turbines.

Applying these criteria dictates that nine perimeter turbines of the Loch Liath site will require ANO visible red lighting. This gives nine of the thirteen total turbines carrying visible ANO lights.

Turbines with 2000/200cd Lights: T1, T3, T4, T7, T9, T10, T11, T12 and T13

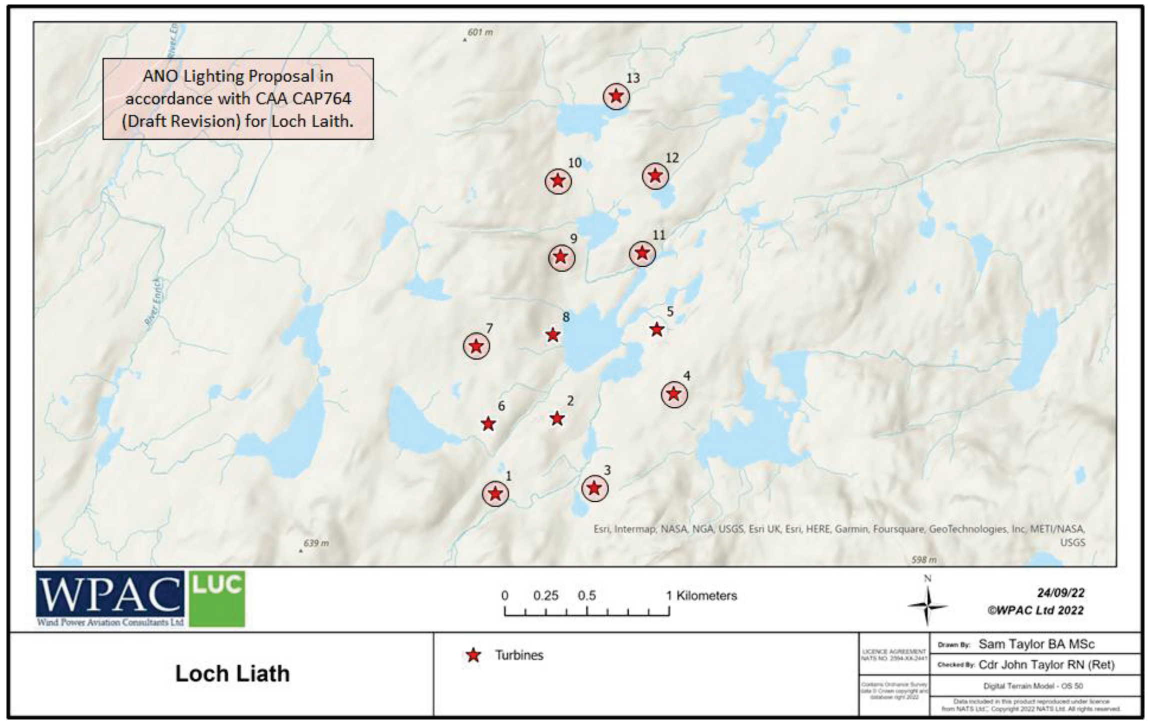

Figure 3 CAA-ANO CAP764 Compliant Lighting Arrangement

CAA-ANO Red 2000/200cd Lighting. (Reduced Lighting using CAA Dispensations)

7. The CAP 764 (Draft) compliant visible lighting proposal at Figure 3 results in a relatively high visual lighting density. Accordingly, in line with lighting proposals accepted by the CAA in recent years, a reduced lighting proposal has been generated based upon the following:

- That all perimeter turbine light spacing be extended from a maximum of 900m to a maximum of 1300m.
- Because Loch Liath is in an active night area, that is a mix of hills and existing turbines, it is important that enough lights remain to clearly identify the Loch Liath turbines quickly and safely thus allowing approaching craft to manoeuvre effectively. Accordingly, the proposal will retain around half of the total turbines as lit.
- The presence of existing wind turbine sites to the immediate south of the Loch Liath windfarm should allow the removal of the visible light from T3 (a potential slight outlier).

Applying these criteria dictates that six perimeter turbines of the Loch Liath site will require ANO visible red lighting. This gives six of the thirteen total turbines carrying visible ANO lights

Turbines with 2000/200cd Lights: T1, T4, T7, T10, T12 and T13

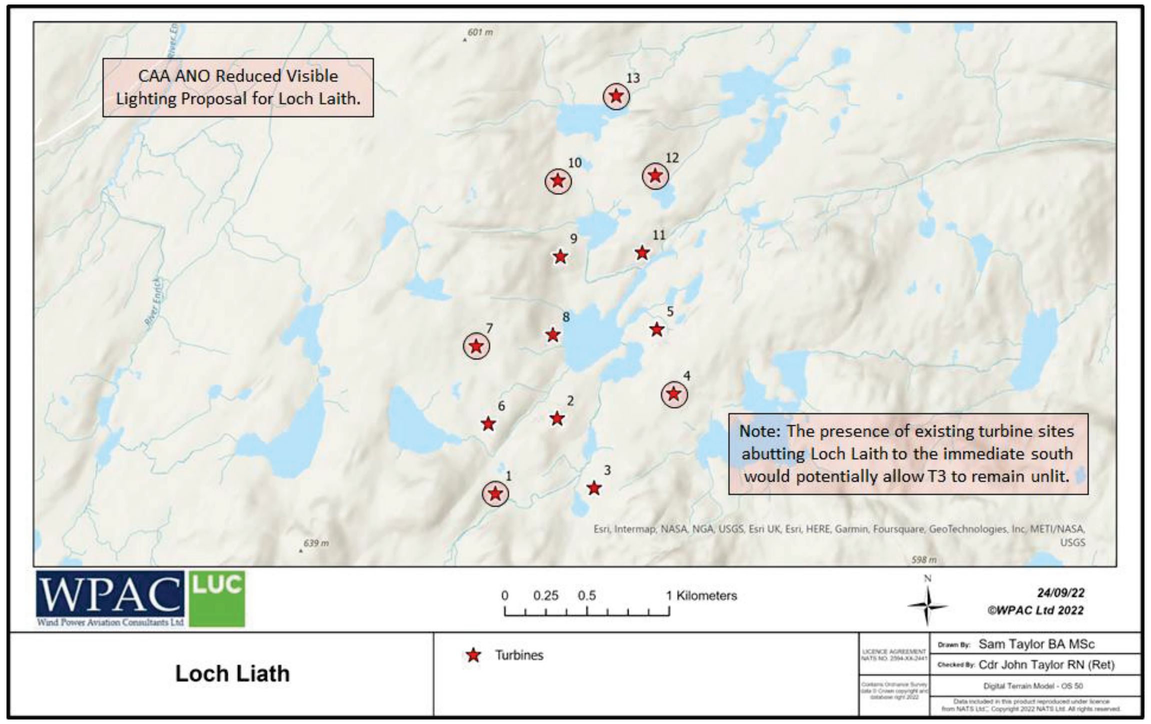

Figure 4 CAA-ANO CAP 764 Modified Lighting Arrangement

MOD Lighting Requirements

8. 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.

9. 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.

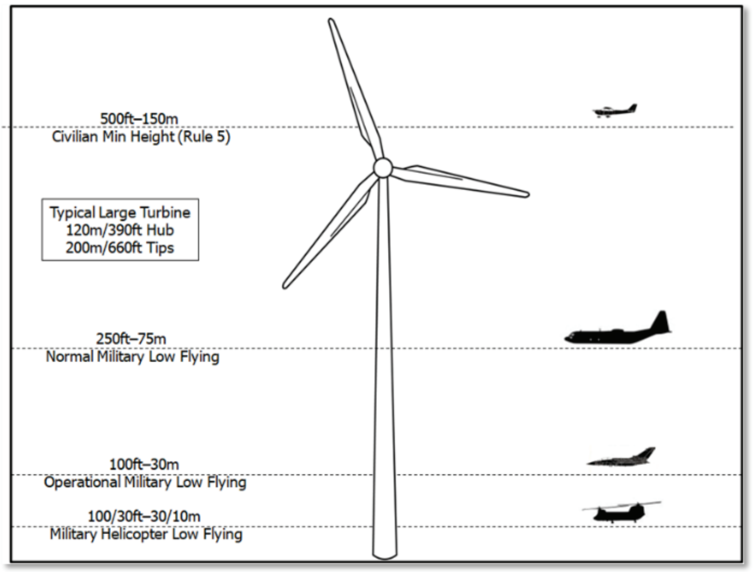

Figure 5 Wind turbine in context with MOD Low Flying

MOD Infra-Red Lighting Layout

10. The MOD requires:

- That all 'compound-perimeter' turbines 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, the corner and highest turbines are lit.
- In addition to the perimeter turbines, the MOD requires that central turbines also be lit to provide depth-perception for approaching pilots. This requirement is dropped if the site meets the MOD small site criteria. The blue circle below shows that the site does not quite meet this criterion.

Applying the MOD requirement dictates that all of the perimeter and central turbines of the Loch Liath site will require IR lighting. Thirteen turbine IR hub lights in total.

Turbines with Infra-Red: T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12 and T13

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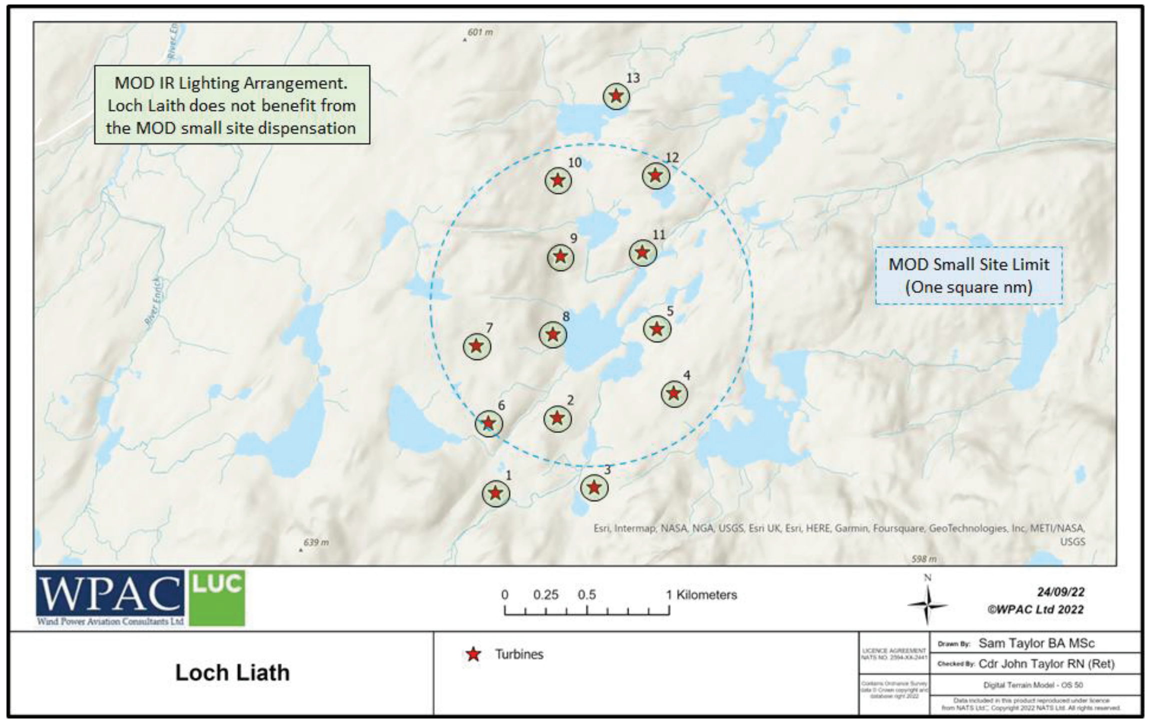

Figure 6 Proposed MOD Infra-Red Lighting Arrangement

Combined CAA Visible Lighting and MOD Infra-Red Lighting

Loch Liath Turbine Data Table							
Turbine	Easting	Northing	AMSL	Hub Ht	Tip Ht	CAA ANO	MOD IR
1	237585	822647	520	102.5	180	2000/200cd	600mW/sr
2	237961	823103	527	122.5	200		600mW/sr
3	238186	822681	503	122.5	200		600mW/sr
4	238670	823253	514	122.5	200	2000/200cd	600mW/sr
5	238568	823643	499	122.5	200		600mW/sr
6	237542	823071	538	102.5	180		600mW/sr
7	237468	823541	552	102.5	180	2000/200cd	600mW/sr
8	237935	823610	497	122.5	200		600mW/sr
9	237981	824085	532	122.5	200		600mW/sr
10	237965	824546	528	122.5	200	2000/200cd	600mW/sr
11	238479	824108	504	122.5	200		600mW/sr
12	238558	824577	529	122.5	200	2000/200cd	600mW/sr
13	238320	825060	513	122.5	200	2000/200cd	600mW/sr

Table 1 Proposed and agreed CAA and MOD Lighting Arrangement

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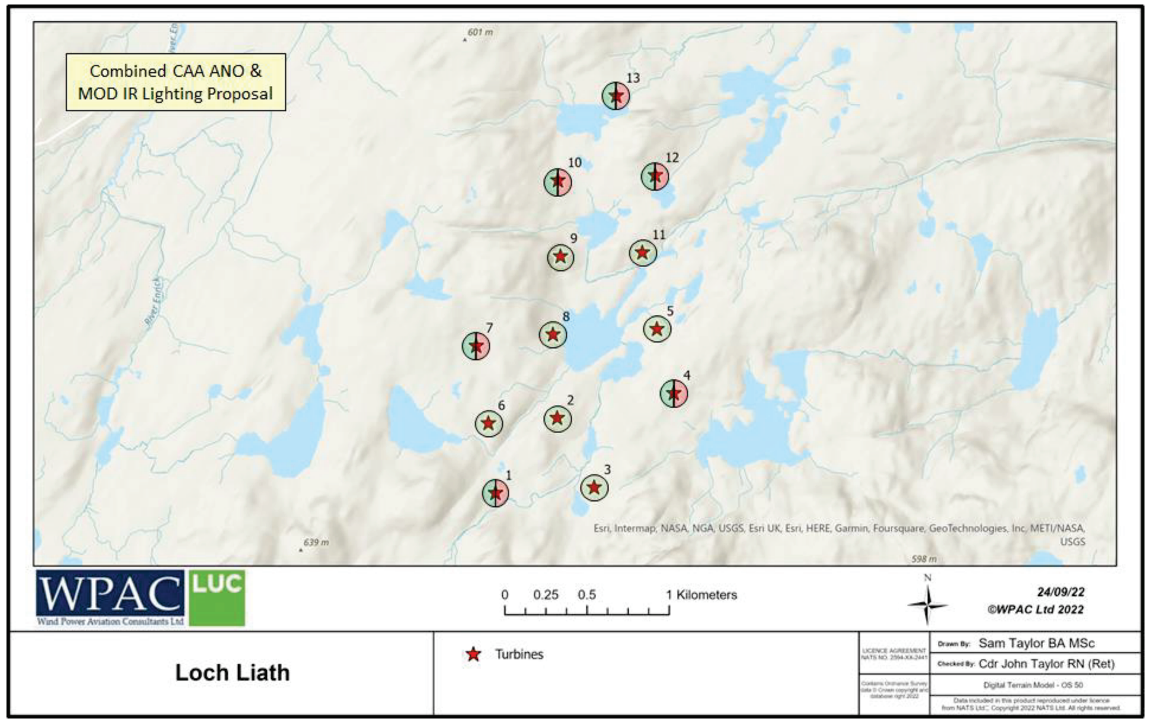

Figure 7 CAA-ANO Visible Red and MOD Infra-Red Lighting Arrangement

ANO Light Specifications

11. 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.

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.

12. **<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.

13. 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 requested that the CAA guidance requirement for 32cd (Type B) mid mast lights be removed for Loch Liath and they have confirmed in their response at Appendix C that mid mast lighting is not required in this location.

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

14. 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

15. 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

16. 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 MI-ACWGAM[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 provided to every 0.1°. These lights are already fitted in a number of locations around the UK.

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

[2] The Technical Specification is at: https://www.aircraftwarninglights.co.uk/datasheets/CEL-MI-ACWGAM - datasheet rev10.pdf

17. 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.

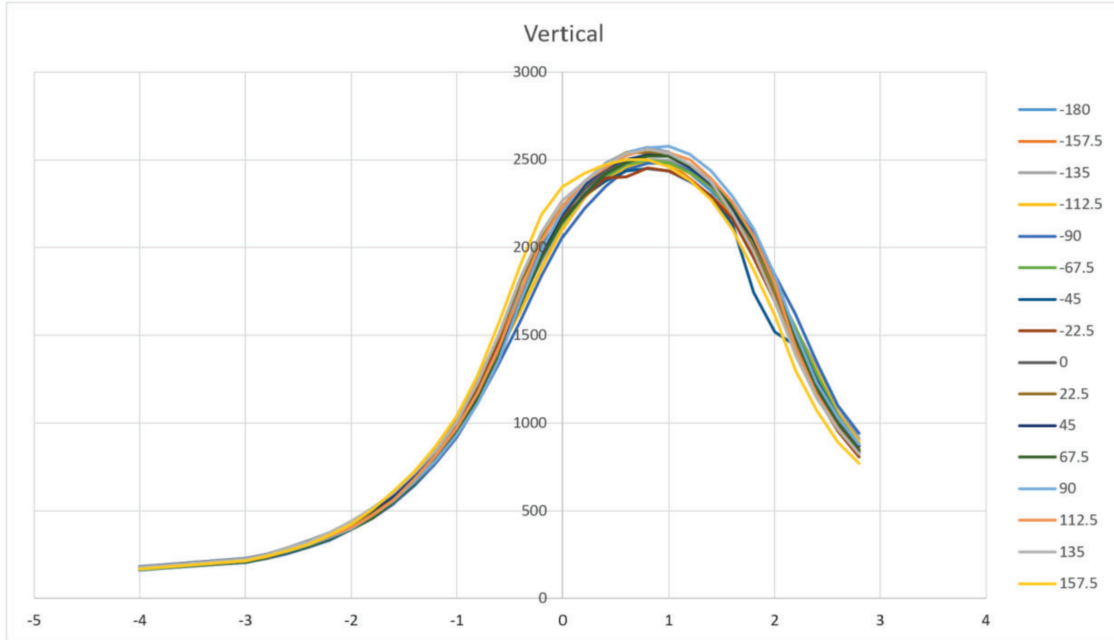

Figure 8 (MI ACWGAM Light Measurement Results)

18. 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 or 102.5 metres as appropriate. 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 Loch Liath Wind Farm viewpoints. The locations of the viewpoints are shown in Figure 9 and Table 5. The assessment has been undertaken utilizing the turbine lighting layout shown in Figure 4 and Table 1. It is possible that one or two viewpoint locations may be moved very slightly when the on site photography is undertaken, but for all practical considerations, the results for each point will remain the same.

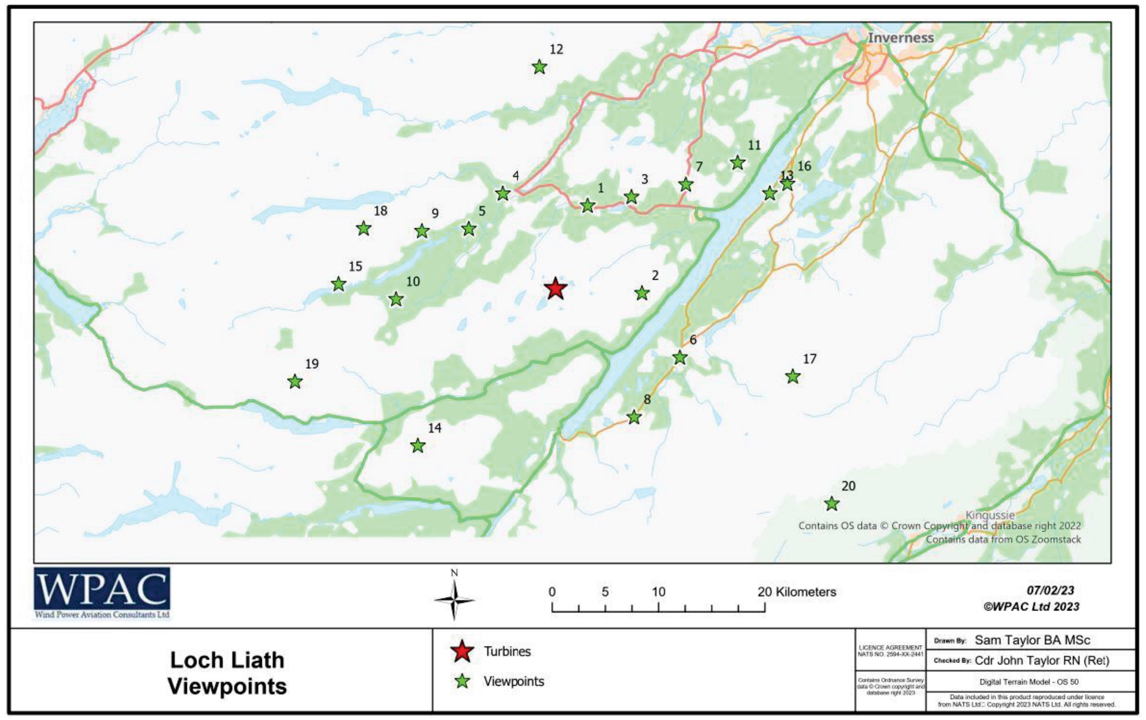

Figure 9 Viewpoint Locations

19. 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.

20. 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**.

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Viewpoint Number	Viewpoint Name	Easting	Northing
1	Affric Kintail Way near Braefield	240594	830432
2	Meall Fuar-mhonaidh	245705	822209
3	Balbeg	244713	831254
4	Affric Kintail Way West of Cannich	232532	831570
5	Coire Loch Trail Glen Affric	229330	828255
6	B862 near Whitebridge	249265	816161
7	A833 near Balnagrantach	249825	832423
8	B862 Suidhe Viewpoint	244958	810548
9	Meall Mor, above Glen Affric	224928	828045
10	Creag Dhubh	222497	821647
11	Carn na Leitire	254693	834470
12	Beinn a' Bha'ach Ard	236046	843310
13	B852 Erchite Wood east of Loch Ness picnic area	257717	831590
14	Meall Dubh	224533	807889
15	Core Path at Loch Affric	217092	823063
16	B862 South of Dores	259368	832481
17	Carn na Saobhaidhe	259881	814377
18	Toll Creagach	219446	828294
19	Sgurr nan Conbhairean	212975	813887
20	Carn Dearg	263560	802406

Table 5 Viewpoints

Interpreting the Results

21. 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 m^2 (Lux $^{(10\text{-}6)}$) at each viewpoint.

Viewpoint	Brightest Lit Turbine	Distance (km)	microlumens per m² (lux$^{10-6}$)	Microlumens at 10%	Obscured
1	12	6.2	3.81	0.4	
2	4	7.1	48.0	4.8	
3					X
4	13	8.7	2.8	0.3	
5	12	9.9	2.8	0.3	
6					X
7	12	13.7	3.1	0.3	
8	1	14.2	4.9	0.5	
9	7	13.3	12.7	1.3	
10	1	15.1	7.5	0.8	
11	4	19.6	3.4	0.3	
12	13	18.4	7.2	0.7	
13	12	20.4	1.2	0.1	
14	1	19.7	6.3	0.6	
15	7	20.4	2.2	0.2	
16	12	22.3	1.7	0.2	
17	4	23.0	4.6	0.5	
18	7	18.6	7.0	o.7	
19	7	26.3	3.6	0.4	
20	4	32.5	2.3	0.2	

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

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22. In order to place the values in microlumens per m² (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

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23. 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	Brightest Lit Turbine	Distance (km)	Candela	Candela at 10%	Obscured
1	12	6.2	145.0	14.5	
2	1	8.1	2452.1	245.2	
3					X
4	13	8.7	212.3	21.2	
5	12	6.2	145	14.5	
6					X
7	12	13.7	576.0	57.6	
8	13	16.0	1087.1	108.7	
9	13	13.7	2330.0	233.0	
10	1	15.1	1721.2	172.1	
11	1	20.8	1442.9	144.3	
12	13	18.4	2452.1	245.2	
13	1	22.0	576.0	57.6	
14	1	19.7	2428.8	242.9	
15	13	21.3	982.0	98.2	
16	1	23.9	902.2	90.2	
17	4	23.0	2428.8	242.9	
18	12	19.5	2471.1	247.1	
19	10	27.2	2514.7	251.5	
20	4	32.5	2428	242.9	

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

Part 2 Mitigation

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

24. 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.

25. 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'.*

26. 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, which is covered separately.

27. It will be necessary to calculate how much time the lights would spend at 2000cd and at 200cd. To assess historical visibility in this Highland region, the closest meteorological station to Loch Liath is at Inverness Airport. Note: there are no meteorological stations that provide historical data closer to Loch Liath. 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 Inverness Airport which are averaged over a 30-year period.

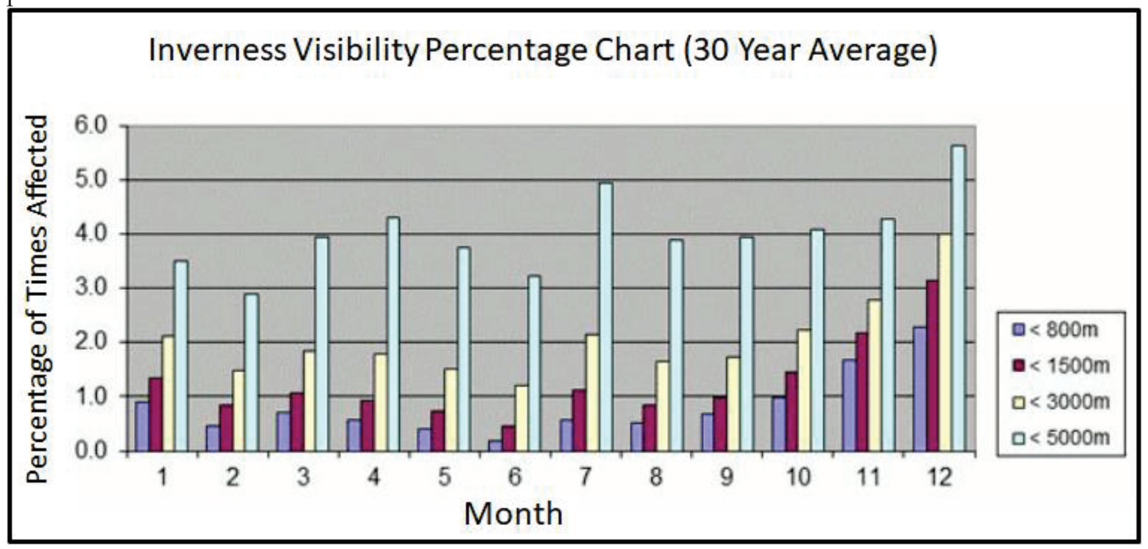

Table 9 Inverness Visibility Table

28. These Met Office records show that the visibility is below 5km (light blue bar) for an average of 4% of the time at Inverness Airport. This suggests that the lights at Loch Liath will be set at **2000cd for 4% of the time (visibility below 5km) and set at 200cd for 96% of the time (visibility above 5km)**.

29. Whilst Inverness Airport is not Loch Liath, the figures will be a reasonably accurate representation of the visibility throughout the year. Indeed, met visibility improves with height since the concentration of particles (dust, haze) and liquid droplets (water, aerosols) reduces with height and the air also becomes thinner. It could be argued that the Loch Liath visibility, on a 500m hill, will be better than that at Inverness Airport and the lights will spend even less time at the 2000cd higher setting.

Obstruction Light Weather Obscuration.

30. On occasion, the visibility in the area of Loch Liath will reduce significantly due to the presence of cloud on the hills. If the Loch Liath turbines are in cloud, then the obstruction lights will not be seen. The average height of the turbine hubs (where the lights are mounted) will be around 600m amsl. (Note: all the turbines are sited on similar height terrain of 500m). For aeronautical reasons, meteorological cloud bases are quoted in feet (ft) so measurements will now be given in feet. Converting 600m gives 1950ft.

31. It is now possible to compare the average **turbine hub/light** height of **1950ft** amsl with the actual cloud bases recorded by the Met Office at Inverness Airport, again, over a 30-year period as shown in Table 10. The maroon bars show when the cloud-base first drops below 1000ft and therefore low enough below the turbine red light for the light to be significantly obscured, or more probably, invisible to the human eye.

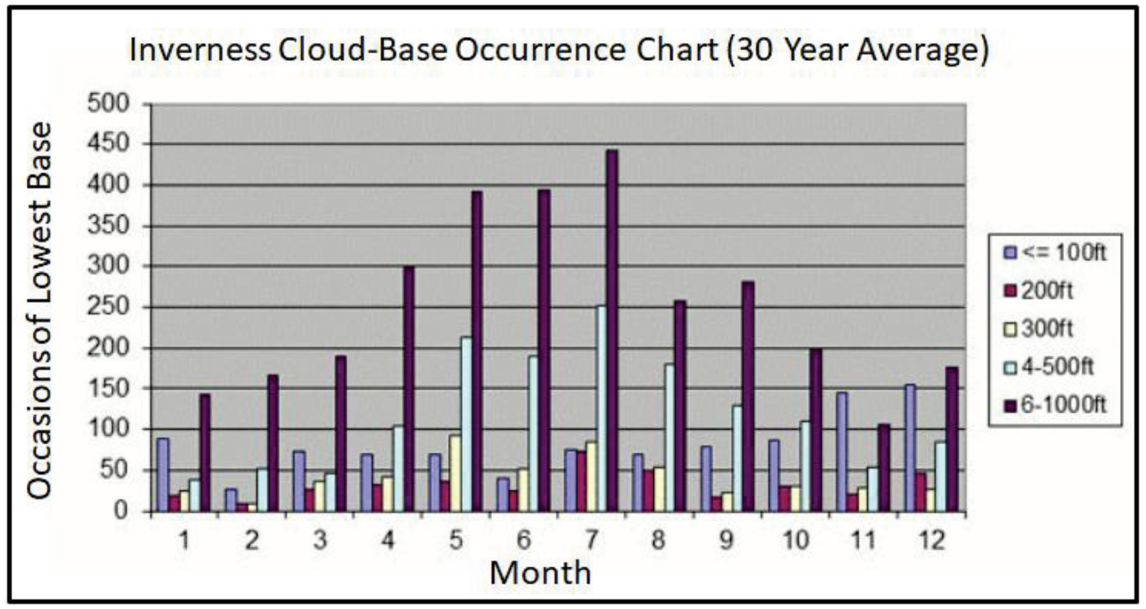

Table 10 Inverness Cloud Base Table.

32. The burgundy columns (600-1000ft) indicate that the cloud base will be comfortably below turbine hub heights (1950ft) on around 250 occasions a month. At this distance below the turbine hubs the lights will be obscured to the general public.

33. The other columns (light blue in particular: 400-500ft) indicate that on a further 150 or so occasions a month, the lights will be obscured by cloud. Note: met office statistics report cloud base in occurrences as opposed to total duration. The remaining columns on the chart (blue, red, cream – representing very low cloud bases) suggest that the lights will be obscured on an additional 100 or more occasions a month.

34. Again, whilst Inverness Airport is not Loch Liath, Met Office statistics show that the cloud-base reduces in the region of hills. It could be argued that at Loch Liath, located on a 500m hill, the cloud-base would be lower than at Inverness thus providing even greater degree of obstruction light obscuration than calculated here.

Weather Obscuration Conclusion

35. 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 Loch Liath, so gathered, should be presented as follows:

> *Meteorological observations suggest that the turbine hubs will be obscured on more than five 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 96% of the time.* *(Obstruction lights switched down to 200cd)*

Conclusion/Notes

36. The Loch Liath site does not benefit appreciably from the draft revision of the latest CAA CAP 764 resulting in a relatively high density of visible obstruction lighting. To further reduce the number of visible obstruction lights required at the turbine site, WPAC proposed a reduced lighting scheme which is in concert with recent CAA lighting approvals at other wind turbine sites resulting in a proposal to light 6 out of 13 turbines with ANO 2000/200cd lights and all turbines with IR lights. This lighting layout has now been approved by the CAA as shown in their response at Appendix C.

37. In addition, the site is in an area where it will positively benefit from the weather obscuration of its visible ANO lighting. This obscuration benefit is potentially quite significant. Moreover, when the lights are not obscured by cloud, they can expect to be set at the lower 200cd for 96% of the time.

Technical Mitigation

38. 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.

39. 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

40. 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

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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.*

41. 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, nothing can be done 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.

42. What is clear is that once the carriage of compatible transponders is 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.

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Figure 11 ADSB/SSR Passive Aerial

43. Bearing the above in mind, it would 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. It may therefore be suitable for use as the basis of a planning condition requiring the activation of the system once the regulatory and equipage hurdles have been overcome.

44. An ADSL 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, however, in a location like Loch Liath, with limited night low level civilian traffic, the lights will rarely be activated. 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

45. 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.

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46. 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.

47. 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.

48. 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

49. This report has assessed the requirements for both visible, CAA approved aviation lighting and MOD approved Infra-Red lighting for the Loch Liath 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 responded approving the reduced lighting design as shown in Appendix C .

50. 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 96% 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.

51. 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 rare occasions in this location when an aircraft activates the system. A suitably worded planning condition may enable the future lighting effects to be mitigated to the extent of becoming almost non-existent.

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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 (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	8.3	-1.6	576.0	57.6	8.3	0.8	X
4	7.4	-3.2	207.8	20.8	3.8	0.4	X
7	7.6	-2.3	332.9	33.3	5.8	0.6	X
10	6.4	-3.2	207.8	20.8	5.0	0.5	X
12	6.2	-4.4	145.0	14.5	3.8	0.4	
13	5.8	-4.5	138.4	13.8	4.1	0.4	M

Viewpoint 1 Affric Kintail Way near Braefield

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	8.1	0.5	2452.1	245.2	37.1	3.7	
4	7.1	0.4	2428.8	242.9	48.0	4.8	
7	8.3	0.3	2379.4	237.9	34.2	3.4	
10	8.1	0.3	2379.4	237.9	36.4	3.6	
12	7.5	0.3	2379.4	237.9	42.0	4.2	
13	7.9	0.4	2428.8	242.9	38.8	3.9	

Viewpoint 2 Meall Fuar-mhonaidh

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	11.2	-0.8	1192.2	119.2	9.5	1.0	X
4	10.0	-1.7	529.8	53.0	5.3	0.5	X
7	10.6	-1.7	529.8	53.0	4.7	0.5	X
10	9.5	-2.1	384.9	38.5	4.3	0.4	X
12	9.1	-2.2	356.7	35.7	4.3	0.4	X
13	8.9	-2.5	291.3	29.1	3.7	0.4	X

Viewpoint 3 Balbeg – NB all hubs are screened by terrain and line of sight is between 37 and 245 metres AGL. Moving the VP north-east would bring some turbine hubs into view

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	10.3	-1.1	902.2	90.2	8.6	0.9	X
4	10.3	-1.1	902.2	90.2	8.4	0.8	X
7	9.4	-2.6	273.5	27.4	3.1	0.3	X
10	8.9	-2.8	239.3	23.9	3.0	0.3	X
12	9.2	-2.8	239.3	23.9	2.8	0.3	X
13	8.7	-3.1	212.3	21.2	2.8	0.3	

Viewpoint 4 Affric Kintail Way West of Cannich

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	10.0	-2.4	309.1	30.9	3.1	0.3	M
4	10.6	-1.4	690.6	69.1	6.2	0.6	X
7	9.4	-2.8	239.3	23.9	2.7	0.3	
10	9.4	-2.8	239.3	23.9	2.7	0.3	
12	9.9	-2.6	273.5	27.4	2.8	0.3	
13	9.5	-2.2	356.7	35.7	3.9	0.4	X

Viewpoint 5 Coire Loch Trail Glen Affric

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	13.4	-0.9	1087.1	108.7	6.1	0.6	X
4	12.8	-1.5	633.3	63.3	3.9	0.4	X
7	13.9	-1.6	576.0	57.6	3.0	0.3	X
10	14.1	-1.1	902.2	90.2	4.6	0.5	X
12	13.6	-1.3	756.5	75.7	4.1	0.4	X
13	14.1	-0.8	1192.2	119.2	6.0	0.6	X

Viewpoint 6 B862 near Whitebridge – all turbine hubs are screened by terrain. Line of sight is between 32 and 250 metres AGL

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	15.7	-0.9	1087.1	108.7	4.4	0.4	X
4	14.4	-1.1	902.2	90.2	4.3	0.4	X
7	15.2	-1.4	690.6	69.1	3.0	0.3	X
10	14.2	-1.6	576.0	57.6	2.8	0.3	
12	13.7	-1.6	576.0	57.6	3.1	0.3	
13	13.7	-1.6	576.0	57.6	3.1	0.3	

Viewpoint 7 A833 near Balnagrantach

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	14.2	-1.0	982.0	98.2	4.9	0.5	
4	14.2	-1.1	902.2	90.2	4.5	0.4	
7	15.0	-1.1	902.2	90.2	4.0	0.4	
10	15.6	-1.0	982.0	98.2	4.0	0.4	
12	15.4	-1.0	982.0	98.2	4.1	0.4	
13	16.0	-0.9	1087.1	108.7	4.3	0.4	

Viewpoint 8 B862 Suidhe Viewpoint

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	13.8	0.2	2330.0	233.0	12.3	1.2	
4	14.6	0.1	2257.6	225.8	10.7	1.1	
7	13.3	0.1	2257.6	225.8	12.7	1.3	
10	13.5	0.1	2257.6	225.8	12.4	1.2	
12	14.1	0.1	2257.6	225.8	11.4	1.1	
13	13.7	0.2	2330.0	233.0	12.4	1.2	

Viewpoint 9 Meall Mor, above Glen Affric

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	15.1	-0.4	1721.2	172.1	7.5	0.8	
4	16.3	-0.4	1721.2	172.1	6.5	0.7	
7	15.1	-0.5	1582.1	158.2	6.9	0.7	
10	15.7	-0.5	1582.1	158.2	6.4	0.6	
12	16.3	-0.5	1582.1	158.2	5.9	0.6	
13	16.2	-0.4	1721.2	172.1	6.6	0.7	

Viewpoint 10 Creag Dhubh

Turbine	**Distance (km)**	**Elevation Angle**	**Candela**	**Candela at 10%**	**Microlumens per square metre (lux$^{10-6}$)**	**Microlumens per square metre (lux$^{10-6}$) at 10%**	**Obscured**
1	20.8	-0.6	1442.9	144.3	3.3	0.3	
4	19.6	-0.7	1317.5	131.8	3.4	0.3	
7	20.4	-0.7	1317.5	131.8	3.2	0.3	
10	19.5	-0.7	1317.5	131.8	3.5	0.3	
12	18.9	-0.7	1317.5	131.8	3.7	0.4	
13	18.9	-0.7	1317.5	131.8	3.7	0.4	

Viewpoint 11 Carn na Leitire

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	20.7	0.4	2428.8	242.9	5.7	0.6	
4	20.2	0.4	2428.8	242.9	5.9	0.6	
7	19.8	0.4	2428.8	242.9	6.2	0.6	
10	18.9	0.4	2428.8	242.9	6.8	0.7	
12	18.9	0.4	2428.8	242.9	6.8	0.7	
13	18.4	0.5	2452.1	245.2	7.2	0.7	

Viewpoint 12 Beinn a' Bha'ach Ard

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	22.0	-1.6	576.0	57.6	1.2	0.1	
4	20.8	-1.8	483.7	48.4	1.1	0.1	
7	21.8	-1.7	529.8	53.0	1.1	0.1	
10	21.0	-1.6	576.0	57.6	1.3	0.1	X
12	20.4	-1.8	483.7	48.4	1.2	0.1	M
13	20.5	-1.4	690.6	69.1	1.6	0.2	X

Viewpoint 13 B852 Erchite Wood east of Loch Ness picnic area

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	19.7	0.4	2428.8	242.9	6.3	0.6	
4	20.9	0.3	2379.4	237.9	5.5	0.5	
7	20.3	0.3	2379.4	237.9	5.8	0.6	
10	21.4	0.3	2379.4	237.9	5.2	0.5	
12	21.8	0.3	2379.4	237.9	5.0	0.5	
13	22.0	0.3	2379.4	237.9	4.9	0.5	

Viewpoint 14 Meall Dubh

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	20.5	-0.8	1192.2	119.2	2.8	0.3	X
4	21.6	-1.0	982.0	98.2	2.1	0.2	X
7	20.4	-1.1	902.2	90.2	2.2	0.2	
10	20.9	-1.1	902.2	90.2	2.1	0.2	
12	21.5	-1.0	982.0	98.2	2.1	0.2	
13	21.3	-1.0	982.0	98.2	2.2	0.2	

Viewpoint 15 Core Path at Loch Affric

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	23.9	-1.1	902.2	90.2	1.6	0.2	
4	22.7	-1.2	822.4	82.2	1.6	0.2	
7	23.7	-1.2	822.4	82.2	1.5	0.1	
10	22.8	-1.2	822.4	82.2	1.6	0.2	
12	22.3	-1.2	822.4	82.2	1.7	0.2	
13	22.3	-1.2	822.4	82.2	1.7	0.2	

Viewpoint 16 B862 South of Dores

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	23.8	0.4	2428.8	242.9	4.3	0.4	
4	23.0	0.4	2428.8	242.9	4.6	0.5	
7	24.2	0.3	2379.4	237.9	4.1	0.4	
10	24.2	0.3	2379.4	237.9	4.1	0.4	
12	23.6	0.3	2379.4	237.9	4.3	0.4	
13	24.1	0.3	2379.4	237.9	4.1	0.4	

Viewpoint 17 Carn na Saobhaidhe

Turbine	**Distance (km)**	**Elevation Angle**	**Candela**	**Candela at 10%**	**Microlumens per square metre (lux$^{10-6}$)**	**Microlumens per square metre (lux$^{10-6}$) at 10%**	**Obscured**
1	19.0	1.2	2439.4	243.9	6.8	0.7	
4	19.9	1.1	2471.1	247.1	6.3	0.6	
7	18.6	1.2	2439.4	243.9	7.0	0.7	
10	18.9	1.2	2439.4	243.9	6.8	0.7	
12	19.5	1.1	2471.1	247.1	6.5	0.7	
13	19.1	1.2	2439.4	243.9	6.7	0.7	

Viewpoint 18 Toll Creagach

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	26.1	1.6	2205.4	220.5	3.2	0.3	X
4	27.3	0.8	2514.7	251.5	3.4	0.3	
7	26.3	0.9	2508.8	250.9	3.6	0.4	
10	27.2	0.8	2514.7	251.5	3.4	0.3	
12	27.7	0.8	2514.7	251.5	3.3	0.3	
13	27.7	0.8	2514.7	251.5	3.3	0.3	

Viewpoint 19 Sgurr nan Conbhairean

Turbine	**Distance (km)**	**Elevation Angle**	**Candela**	**Candela at 10%**	**Microlumens per square metre (lux$^{10-6}$)**	**Microlumens per square metre (lux$^{10-6}$) at 10%**	**Obscured**
1	32.9	0.4	2428.8	242.9	2.2	0.2	
4	32.5	0.4	2428.8	242.9	2.3	0.2	
7	33.6	0.4	2428.8	242.9	2.2	0.2	
10	33.8	0.4	2428.8	242.9	2.1	0.2	
12	33.4	0.4	2428.8	242.9	2.2	0.2	
13	33.9	0.4	2428.8	242.9	2.1	0.2	

Viewpoint 20 Carn Dearg

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)

Wind Power Aviation Consultants Ltd
Wind Farm Aviation Lighting and Mitigation Report for Loch Liath Wind Farm V2.0
Our Ref: WPAC/076/22 Date: 08/02/23

Appendix C CAA Response

Safety and Airspace Regulation Group
Safety and Business Delivery

Civil Aviation Authority

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

21 December 2022
Ref Windfarms/Loch Liath

Dear Mike,

Proposed Obstacle Lighting Scheme for Loch Liath Wind Farm

Reference: Loch Liath Wind Farm Abridged Brief, dated 12 December 2022

1. Thank you for the e-mail at reference. The attached report discusses the proposed obstacle lighting plan for the Loch Liath Wind Farm.

2. The proposed Loch Liath Wind Farm consists of 13 turbines, with three turbines having proposed tip heights of 180m above ground level (AGL) and the other 10 turbines having proposed tip heights of 200m AGL, which 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 local terrain aspects and some mitigation provided by the provision of infra-red lighting for those operators who carry Night Vision Device capability.

5. In your brief, you note that "the presence of existing wind turbine sites to the immediate south of the Loch Liath windfarm should allow the removal of the visible light from T3 (a potential slight outlier)." This development, the existing Bhlaraidh wind farm, is shown on the map at Annex A to this letter, with turbine tip heights of 120m and 135 m AGL.

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

Civil Aviation Authority
1W Aviation House Beehive Ring Road Crawley West Sussex RH6 0YR www.caa.co.uk
Telephone 0330 138 3166 andy.wells@caa.co.uk

- medium intensity steady red (2000 candela) lights on the nacelles of turbines T01, T04, T07, T10, T12, and T13;
- 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;
- 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, T09, T10, T11, T12, and T13.

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. Please let me know if you have any further queries.

Yours sincerely,

[redacted]

Andy Wells, Manager Rulemaking and Safety Publications