Appendix 13.1: 2021 Aviation Lighting Report

Wind Power Aviation Consultants Ltd

Wind Farm Aviation Lighting Report for Energy Isles Shetland Ltd

Our Reference: WPAC/027/21
Your Reference: CON004828

Authors: Commander John Taylor, RN (Ret)
Squadron Leader Mike Hale MBE MSc CFS RAF (Ret)
Light Modelling, GIS and Mapping – Sam Taylor BA (Hons) MSc

Wind Power Aviation Consultants Ltd, Company No.: 6811887
[redacted] [redacted]
www.wpac.co.uk

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 selected by the LVIA consultant after consultation with the relevant stakeholders. Part 2 of the report identifies and explains those mitigation measures that can be utilised to minimise the environmental effect of the lights including an assessment of the historical meteorological data from which to predict the luminous intensity requirements for the lights. The entire report can be considered to fulfil the requirements for an Aviation Lighting Landscape and Visual Impact Mitigation Plan (ALLVIMP) as proposed by NatureScot in their response to the on going Claughrie 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. Recent discussions with the CAA 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 UK Ltd has proposed an 18 turbine wind farm with turbines having a tip height of 180 metres. Aviation stakeholder requirements in this location will include the following:

- CAA: The CAA will require statutory Medium Intensity Lighting on behalf of local aviation stakeholders. This requirement includes both Commercial Aviation and General Aviation and is enshrined in UK law. The closest commercial airport, Scatsta, was 31km to the south of the Energy Isles site and it has now closed. The unlicensed and mothballed (emergency services only) Baltasound Airstrip (Unst Airport) is 14km to the NE and the closest grass strip airfield, Fetlar, is 16km to the SE. Accordingly, the CAA ask for en-route lighting only.

- Military: The Energy Isles site is located in MOD Low Flying Area 14 (LFA 14). This is a very large and valuable piece of training airspace which stretches from the Scottish Central Belt up to the Shetland Isles. At night LFA 14 converts into dedicated Fixed Wing (Fast Jet & Tactical Transport) Areas, Rotary Wing (Helicopter) dedicated Training Areas, Maritime Patrol Areas (MPAs) and Coast Guard Training Areas (CGSAR). At night military, and many civilian public services, aircraft and helicopters use Night Vision Goggles and/or Devices (NVG/D). It is important that any obstruction lighting fitted to turbines is compatible with these devices, i.e. has an Infra Red (IR) component.

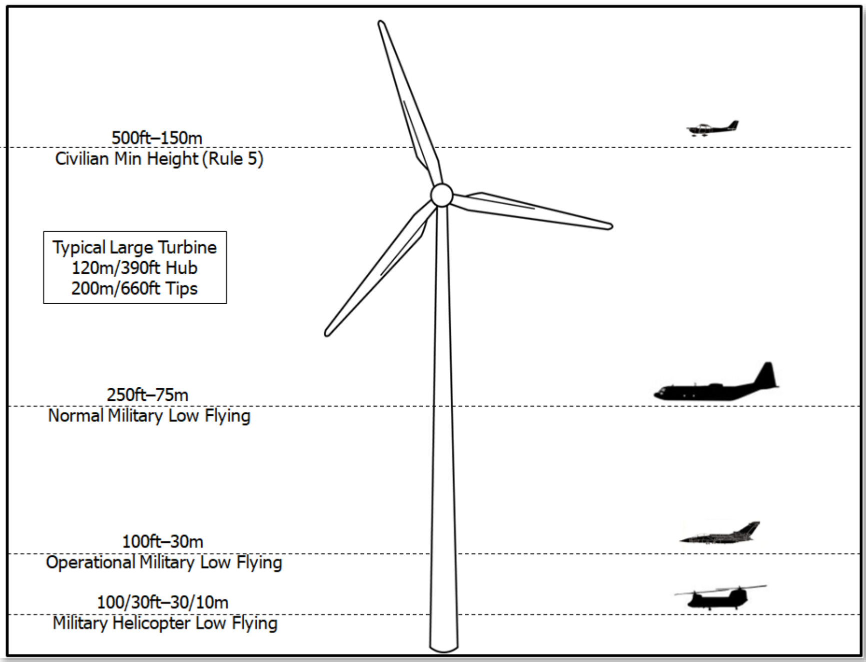

Figure 1 MOD Low Flying Vs Wind turbines in context

- Coastguard, HEMS, Police etc: Public service aviation such as HEMS (Heli-Med) and Coastguard already have, or will, convert to NVG/D capability. The closest Coastguard facility to Energy Isles is operated by Bristows Helicopters at Sumburgh Airport on the southern tip of the Shetland Isles. Although such services are not expected to routinely operate in the immediate area of Energy Isles at night, they will benefit from IR lighting on the turbines should the need arise.

- Commercial and General Aviation: Commercial aviation stakeholders operating to/from the local airports at night will be under an advisory or procedural ATC service. Accordingly, red obstruction lighting on turbines will increase their situational awareness and aid safe navigation. At night, General Aviation aircraft will normally seek an ATC service and/or operate above Sector Safety Altitude. Again, red obstruction lighting will increase their situational awareness and aid safe navigation.

- Extensive MOD trials over 5 years resulted in a NVG obstruction light specification that is carefully 'tuned' to NVG operating spectrums. The result is a unit that emits IR light at 600mW/sr over 750-900nm (ideally concentrated over 800-850nm). In addition, to further aid detection by NVGs, the unit will flash at 1Hz for a 200-500ms flash duration. Cognisant that military aircraft and helicopters climb and descend rapidly/steeply, the MOD IR beam pattern is much wider than the ANO visible lights. The IR units cover +30° to -15°.

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 1 MOD Specification for IR Lights

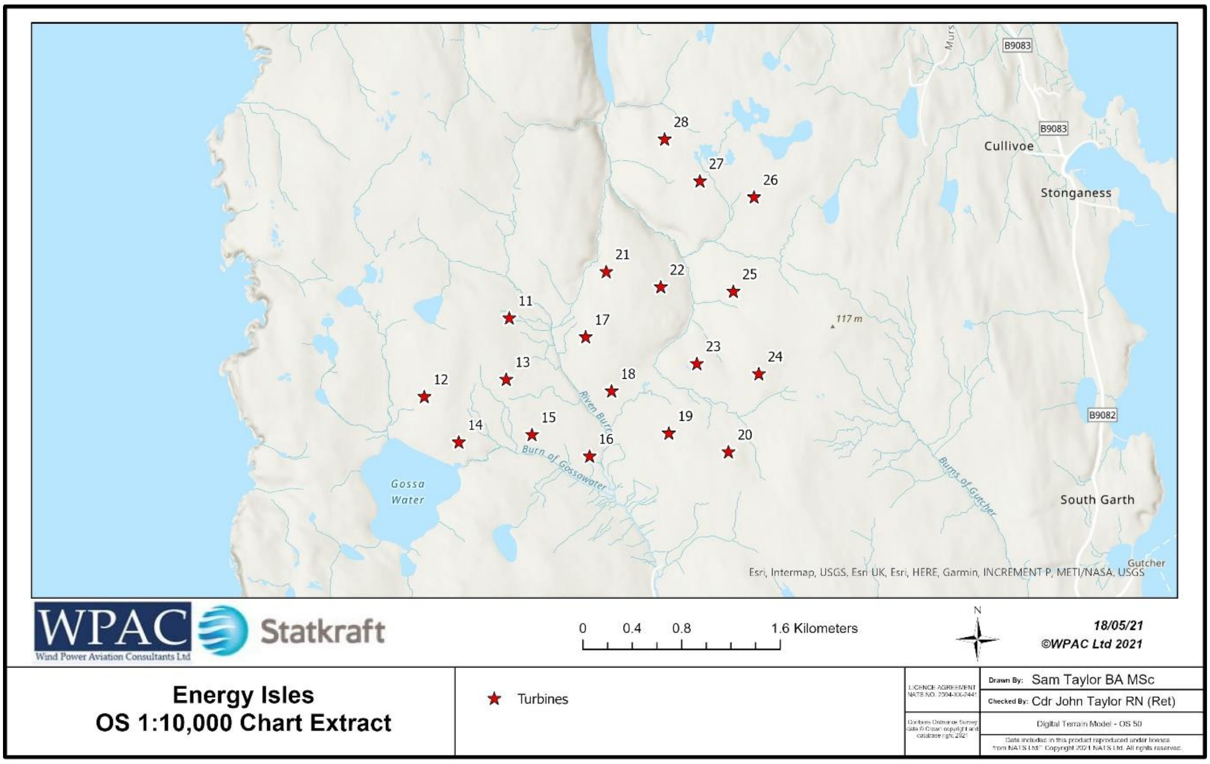

Figure 2 Energy Isles Wind Farm Turbine Site

Visible Lighting Scheme – ANO Visible Red Lights

4. The CAA requires:

- That all perimeter turbines be lit unless removing one will leave a gap of less than 900m between the remaining turbines (either side).

- 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° slope from adjacent lit turbines.

- Applying these criteria dictates that all of the 'string' perimeter and four internal turbines require lighting

  Turbines with 2000/200cd Lights: T11,12,14,16,19,20,21,24,25,26,28

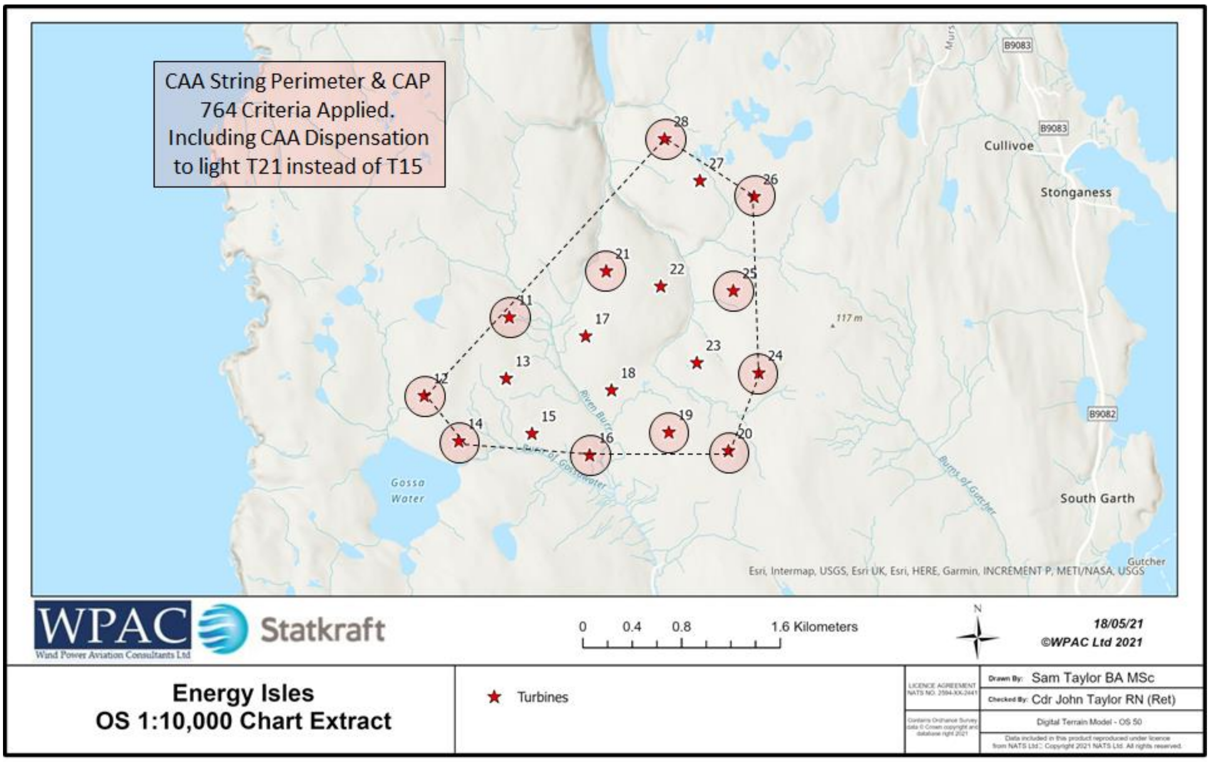

Figure 3 CAA-ANO CAP 764 Compliant Lighting Arrangement.

IR Lighting Scheme – Infra-Red Night Vision Device Compatible Lighting

5. The MOD Guidance for turbine obstruction lighting requires the fitting of Infra Red lights that can be seen by military pilots operating on NVD/Gs.

   The MOD requires:

   - That all 'compound-perimeter' (see Figure 4) turbines be lit unless removing a light will leave a gap of less than 500m between the remaining perimeter lit turbines (either side).
   - That any dominant turbine, by location or height, be lit.
   - That a central turbine be lit to provide 'depth perception' to approaching aircraft. Note: this is not required for the smaller sites that fit inside a one sq nautical mile footprint (approx 4 sq km).

   Applying these criteria dictates that the Energy Isles Wind Farm site will require lighting with 12 turbines lit with infra-red lights in total.

Turbines with Infra-Red: 11,12,14,15,16,19,20,21,24,25,26,28

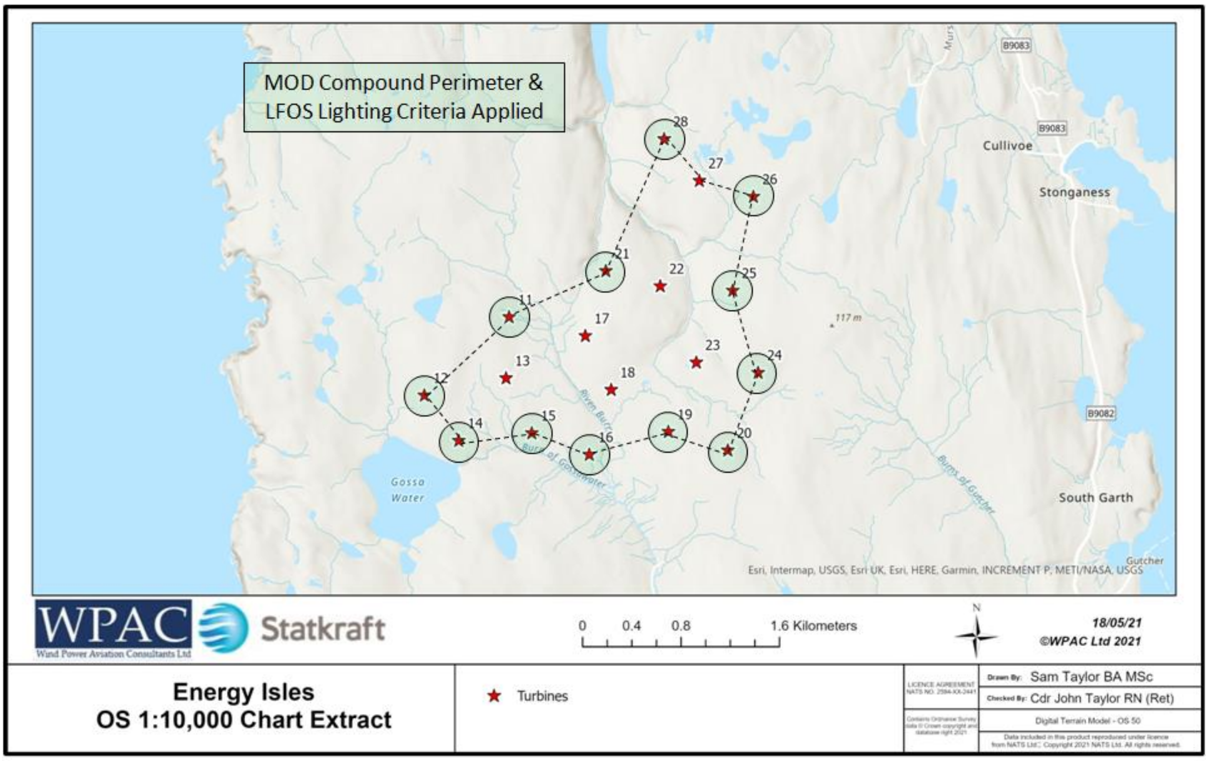

Figure 4 MOD IR Guidance Compliant Lighting Arrangement.

Visible & IR Lighting Scheme – ANO Visible Red Lights & MOD IR Lights

Turbine No	Easting	Northing	Height	ANO Lights	MOD Lights	Mid Mast
11	449777	1201270	180m	2000/200cd	600mW/sr	
12	449088	1200632	180m	2000/200cd	600mW/sr	32cd
13	449752	1200772	180m			
14	449368	1200263	180m	2000/200cd	600mW/sr	
15	449961	1200325	180m		600mW/sr	
16	450428	1200150	180m	2000/200cd	600mW/sr	32cd
17	450396	1201116	180m			
18	450606	1200678	180m			
19	451071	1200336	180m	2000/200cd	600mW/sr	
20	451554	1200185	180m	2000/200cd	600mW/sr	32cd
21	450563	1201645	180m	2000/200cd	600mW/sr	
22	451005	1201521	180m			
23	451298	1200900	180m			
24	451800	1200817	180m	2000/200cd	600mW/sr	
25	451594	1201485	180m	2000/200cd	600mW/sr	
26	451762	1202249	180m	2000/200cd	600mW/sr	32cd
27	451323	1202379	180m			
28	451037	1202718	180m	2000/200cd	600mW/sr	32cd

Table 2 Combined CAA & MOD Lighting Table.

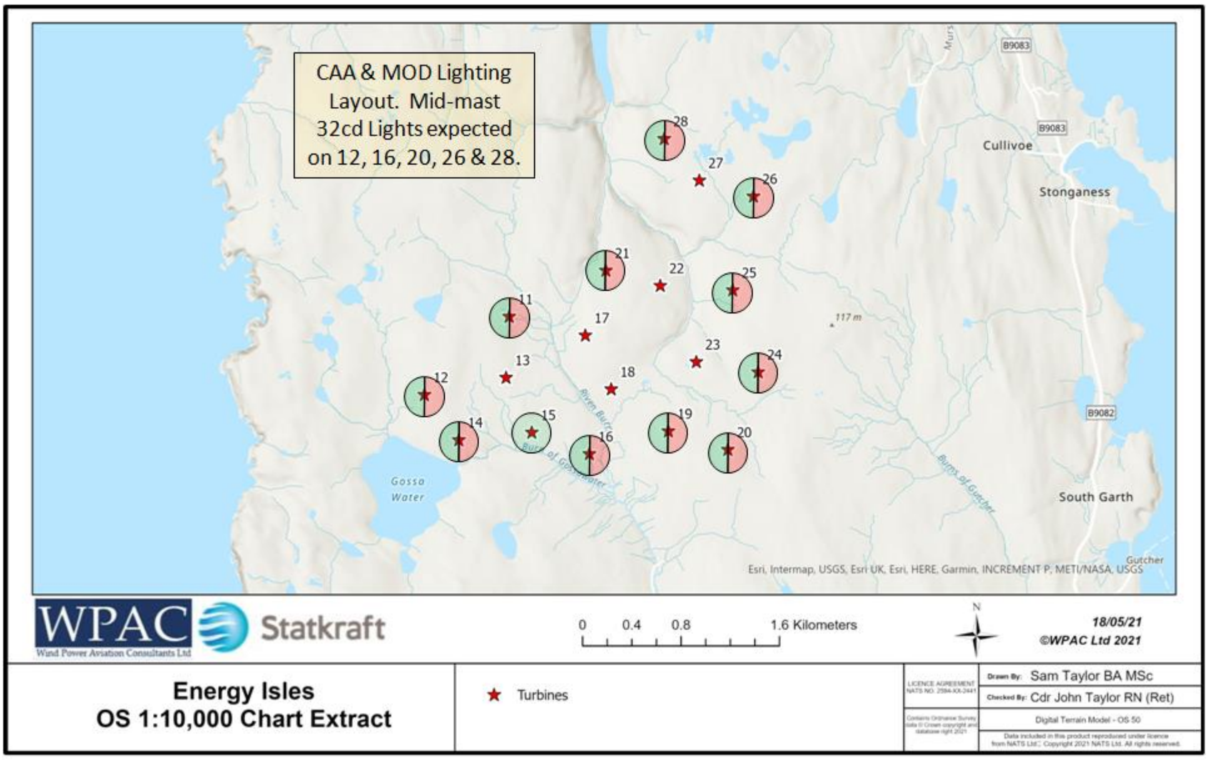

Figure 5 Combined CAA & MOD Lighting Diagram.

6. In addition, the CAA has confirmed the requirement for mid-mast 32cd red lights on selected turbines.

   - Commercial versions of these lights typically emit a 40-50cd beam that is less well focussed than the medium intensity hub lights, peaking up to 70cd. As such under some conditions, in certain locations they can appear to be brighter than the hub mounted focused 2000/200cd lights.

   - The site will require mid-mast lights on turbines: **T12, T16, T20, T26 and T28.**

   - Finally, the CAA confirmed approval of the lighting layouts proposed above in their letter Reference '*Safety and Airspace Regulation Group -Windfarms/Energy Isles dated 13 August 2021*, which is attached to the end of this report as Appendix A.

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

7. Having defined a layout of turbines to be lit 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. 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-2KR[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.

8. Figure 6 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.

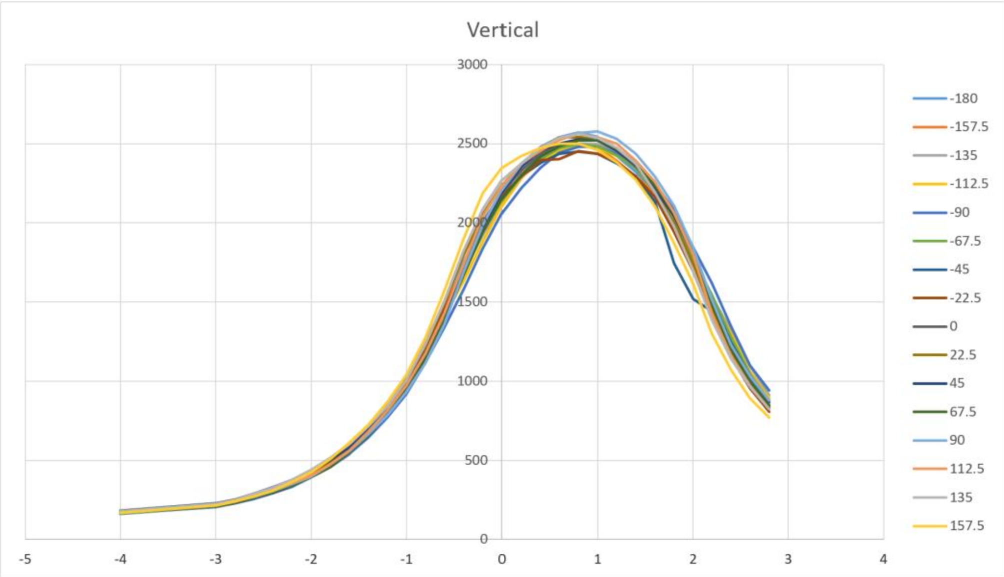

Figure 6 (MI GAM Light Measurement Results)

9. 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 100 metres. 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 Energy Isles Wind Farm viewpoints. The locations of the viewpoints are shown in Figure 7 and Table 3.

10. 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 that will be experienced by the human eye at the viewpoint. The figure produced is in micro-lumens per square metre or

[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.contarnex.com/led-obstruction-lighting/medium-intensity-led-obstacle-warning-lighting.php

lumen(10^{-6})/m^2). These are perfect clear-air figures and therefore are 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% can be as high as 75% at the more distant observation ranges. The results for all of the lit turbines are shown in the following tables. Results for the mid-mast lights are also included. **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 inaccuracies within the terrain model we have highlighted in purple any viewpoints where the line of sight is under 5 metres above ground level and may therefore be marginally visible.**

Viewpoint Number	Viewpoint Name	Easting	Northing
1	Tittyans Hill, Yell	452077	1200014
2	Fishermen's Memorial, Gloup	450642	1204526
3	Haa of Houlland	452972	1204399
4	Cullivoe	454022	1203033
5	Sands of Breckon	452742	1205341
6	A968 / NCR 1 Colvister	451109	1196952
7	Cunnister, Basta Voe	452370	1197640
8	Nev of Stuis, Yell	446317	1197331
9	Belmont Lodge, Unst	456488	1200934
10	Westing, Unst	457180	1206109
11	Grimster, Whale Firth, Yell	446787	1193284
12	Brough Lodge Fetlar	458059	1192659
13	A968 NCR1, Mid Yell	446431	1190356
14	Wood Wick, Unst	458032	1211716
15	B9081, Hill of Reafirth	451204	1188319
16	Point of Fethaland, North Roe	437888	1195114
17	Loch of Houllsquey, North Roe	437804	1191161
18	Hermaness Hill	460635	1217655
19	Settlement at Burra Voe, A970, North Roe	436736	1188328
20	Ronas Hill	430565	1183449
21	A968 / NCR1 Hill of Swinster	444634	1172972

Table 3 Viewpoint Locations

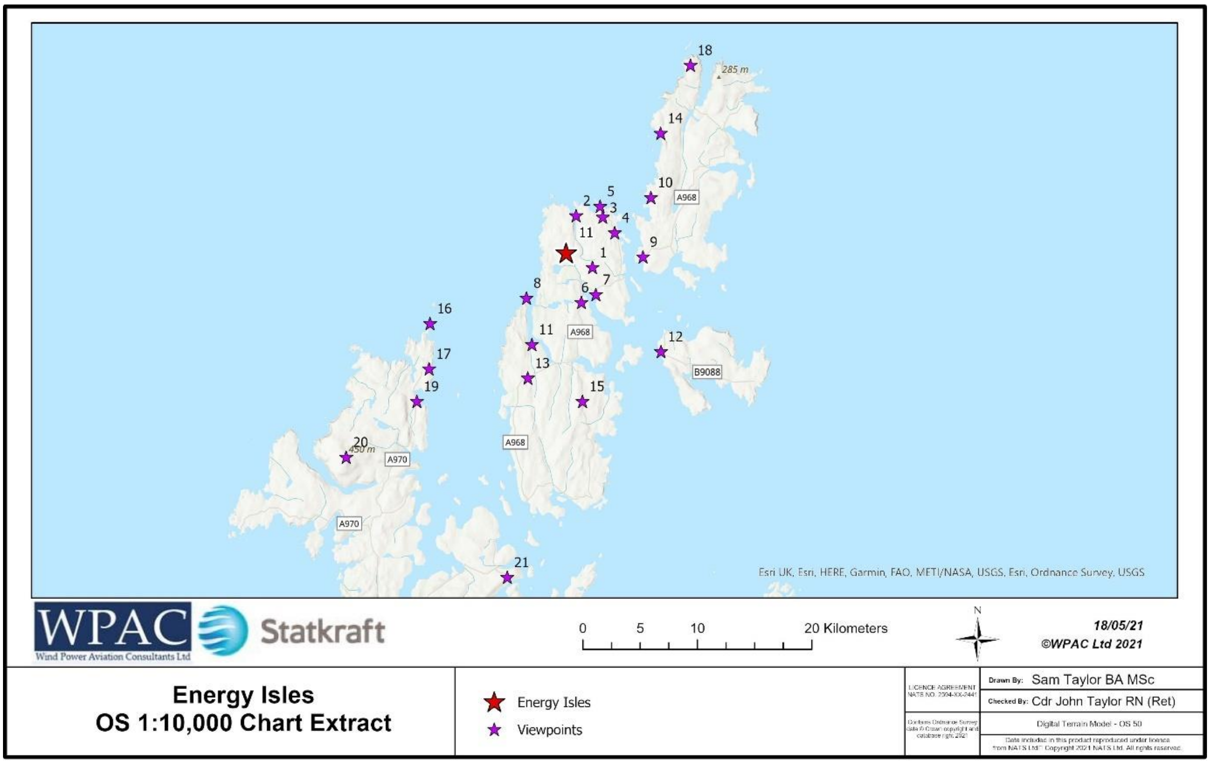

Figure 7 Viewpoint Locations

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	2.621	-1.4	691	69	101	10.6	
T12	3.052	-1.3	756	76	81	8.1	
T14	2.72	-1.1	902	90	122	12.2	
T16	1.655	-1.0	982	98	359	35.9	
T19	1.056	-2.8	239	24	214	21.4	
T20							
T21	2.25	-1.9	448	45	90.5	9	
T24							
T25	1.548	-3.0	217	22	91	9.1	
T26	2.257	-2.5	291	29	57	5.7	
T28	2.897	-1.8	484	48	58	5.8	

Viewpoint 1

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	3.369	-2.2	357	36	31	3.1	
T12	4.193	-1.4	691	69	39	3.9	X
T14	4.449	-1.2	822	82	42	4.2	X
T16	4.381	-1.2	822	82	43	4.3	
T19	4.212	-1.1	902	90	51	5.1	X
T20	4.436	-1.1	902	90	46	4.6	X
T21	2.882	-2.8	239	24	28.8	2.9	
T24	3.886	-1.3	756	76	50	5.0	X
T25	3.187	-1.6	576	58	57	5.7	X
T26	2.538	-2.7	254	25	39	3.9	X
T28	1.851	-4.5	119	12	35	3.5	X

Viewpoint 2

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	4.472	-1.1	902	90	45	4.5	X
T12	5.411	-0.9	1087	109	37	3.7	X
T14	5.486	-0.7	1317	132	44	4.4	X
T16	4.952	-0.4	1721	172	70	7.0	X
T19	4.486	-0.9	1087	109	54	5.4	X
T20	4.446	-1.2	822	82	42	4.2	X
T21	3.659	-1.8	484	48	36.2	3.6	
T24	3.769	-1.7	530	53	37	3.7	X
T25	3.223	-2.0	413	41	40	4.0	X
T26	2.467	-3.1	418	42	42	4.2	
T28	2.563	-2.9	228	23	35	3.5	

Viewpoint 3

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	4.597	-1.2	822	82	39	3.9	X
T12	5.487	-1.1	902	90	30	3.0	X
T14	5.416	-0.8	1192	119	41	4.1	X
T16	4.607	-0.2	1982	198	93	9.3	X
T19	3.998	-1.2	822	82	51	5.1	X
T20	3.769	-1.9	448	45	32	3.2	X
T21	3.727	-1.9	448	45	32.3	3.2	X
T24	3.138	-2.7	254	25	26	2.6	
T25	2.879	-2.8	239	24	29	2.9	
T26	2.392	-3.7	244	24	46	4.6	
T28	3.002	-2.8	239	24	27	2.7	X

Viewpoint 4

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	5.036	-1.1	902	90	36	3.6	X
T12	5.96	-1.0	982	98	28	2.8	X
T14	6.097	-0.6	1443	144	39	3.9	X
T16	5.683	-0.3	1851	185	57	5.7	X
T19	5.277	-0.9	1087	109	39	3.9	X
T20	5.291	-1.3	756	76	27	2.7	X
T21	4.291	-1.7	530	53	28.8	2.9	X
T24	4.621	-1.9	448	45	21	2.1	X
T25	4.023	-2.2	357	36	22	2.2	X
T26	3.244	-3.2	362	36	25	2.5	X
T28	3.128	-3.3	366	37	25	2.5	

Viewpoint 5

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	4.519	-1.6	576	58	28	2.8	
T12	4.198	-1.8	484	48	27	2.7	
T14	3.741	-1.8	484	48	35	3.5	
T16	3.27	-1.6	576	58	54	5.4	
T19	3.384	-1.9	448	45	39	3.9	
T20	3.263	-2.3	333	33	31	3.1	
T21	4.725	-1.7	530	53	23.7	2.4	
T24	3.926	-2.2	357	36	23	2.3	
T25	4.559	-1.8	484	48	23	2.3	
T26	5.337	-1.7	530	53	19	1.9	
T28	5.766	-1.5	622	62	19	1.9	

Viewpoint 6

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	4.461	-1.7	530	53	27	2.7	
T12	4.441	-1.8	484	48	25	2.5	
T14	3.986	-1.8	484	48	30	3.0	
T16	3.174	-1.7	530	53	53	5.3	
T19	2.993	-2.3	333	33	37	3.7	
T20	2.673	-3.0	217	22	30	3.0	
T21	4.394	-1.9	448	45	23.2	2.3	
T24	3.228	-2.8	239	24	23	2.3	
T25	3.923	-2.2	357	36	23	2.3	
T26	4.649	-2.0	413	41	19	1.9	
T28	5.25	-1.7	530	53	19	1.9	

Viewpoint 7

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	5.243	-1.4	691	69	25	2.5	X
T12	4.31	-2.1	385	39	21	2.1	
T14	4.231	-1.9	448	45	25	2.5	
T16	4.985	-0.8	1192	119	48	4.8	X
T19	5.624	-1.1	902	90	29	2.9	X
T20	5.964	-1.3	756	76	21	2.1	X
T21	6.053	-1.3	756	76	20.6	2.1	X
T24	6.497	-1.4	691	69	16	1.6	X
T25	6.716	-1.2	822	82	18	1.8	X
T26	7.337	-1.2	822	82	15	1.5	X
T28	7.162	-1.2	822	82	16	1.6	X

Viewpoint 8

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	6.719	-1.1	902	90	20	2.0	X
T12	7.406	-0.9	1087	109	20	2.0	X
T14	7.152	-0.7	1317	132	26	2.6	X
T16	6.111	-0.5	1582	158	42	4.2	X
T19	5.45	-1.1	902	90	30	3.0	X
T20	4.991	-1.7	530	53	21	2.1	
T21	5.968	-1.5	622	62	17.5	1.7	
T24	4.689	-2.0	413	41	19	1.9	
T25	4.925	-1.9	448	45	18	1.8	
T26	4.906	-2.1	385	39	16	1.6	
T28	5.736	-1.7	530	53	16	1.6	

Viewpoint 9

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	8.844	-0.8	1192	119	15	1.5	
T12	9.771	-0.7	1317	132	14	1.4	
T14	9.757	-0.6	1443	144	15	1.5	
T16	9.006	-0.4	1721	172	21	2.1	X
T19	8.405	-0.7	1317	132	19	1.9	
T20	8.17	-0.9	1087	109	16	1.6	
T21	7.982	-0.9	1087	109	17.1	1.7	
T24	7.547	-1.1	902	90	16	1.6	
T25	7.252	-1.1	902	90	17	1.7	
T26	6.652	-1.3	756	76	17	1.7	
T28	7.017	-1.2	822	82	17	1.7	

Viewpoint 10

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	8.527	-0.6	1443	144	20	2.0	X
T12	7.7	-0.8	1192	119	20	2.0	X
T14	7.441	-0.5	1582	158	29	2.9	X
T16	7.772	-0.2	1982	198	33	3.3	X
T19	8.251	-0.4	1721	172	25	2.5	X
T20	8.387	-0.5	1582	158	22	2.2	X
T21	9.174	-0.5	1582	158	18.8	1.9	X
T24	9.049	-0.6	1443	144	18	1.8	X
T25	9.506	-0.6	1443	144	16	1.6	X
T26	10.253	-0.7	1317	132	13	1.3	X
T28	10.347	-0.6	1443	144	13	1.3	X

Viewpoint 11

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	11.947	-0.7	1317	132	9	0.9	
T12	12.002	-0.7	1317	132	9	0.9	
T14	11.548	-0.7	1317	132	10	1.0	
T16	10.693	-0.6	1443	144	13	1.3	
T19	10.381	-0.7	1317	132	12	1.2	
T20	9.948	-0.9	1087	109	11	1.1	
T21	11.702	-0.8	1192	119	8.7	0.9	
T24	10.282	-0.9	1087	109	10	1.0	
T25	10.94	-0.8	1192	119	10	1.0	
T26	11.473	-0.9	1087	109	8	0.8	
T28	12.268	-0.8	1192	119	8	0.8	

Viewpoint 12

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	11.415	-0.5	1582	158	12	1.2	X
T12	10.614	-0.6	1443	144	13	1.3	X
T14	10.333	-0.5	1582	158	15	1.5	X
T16	10.578	-0.1	2083	208	19	1.9	X
T19	11.006	-0.4	1721	172	14	1.4	X
T20	11.084	-0.5	1582	158	13	1.3	X
T21	12.021	-0.5	1582	158	10.9	1.1	X
T24	11.758	-0.6	1443	144	10	1.0	X
T25	12.268	-0.6	1443	144	10	1.0	X
T26	13.033	-0.6	1443	144	8	0.8	X
T28	13.192	-0.5	1582	158	9	0.9	X

Viewpoint 13

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	13.314	-0.5	1582	158	9	0.9	
T12	14.243	-0.5	1582	158	8	0.8	
T14	14.361	-0.4	1721	172	8	0.8	
T16	13.842	-0.4	1721	172	9	0.9	
T19	13.34	-0.5	1582	158	9	0.9	
T20	13.226	-0.6	1443	144	8	0.8	
T21	12.538	-0.6	1443	144	9.2	0.9	
T24	12.555	-0.7	1317	132	8	0.8	
T25	12.088	-0.6	1443	144	10	1.0	
T26	11.355	-0.8	1192	119	9	0.9	
T28	11.397	-0.7	1317	132	10	1.0	

Viewpoint 14

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	13.029	-0.2	1982	198	12	1.2	
T12	12.493	-0.2	1982	198	13	1.3	
T14	12.084	-0.1	2083	208	14	1.4	
T16	11.856	0.0	2185	219	16	1.6	
T19	12.018	-0.1	2083	208	14	1.4	
T20	11.871	-0.2	1982	198	14	1.4	
T21	13.341	-0.2	1982	198	11.1	1.1	
T24	12.512	-0.3	1851	185	12	1.2	
T25	13.172	-0.2	1982	198	11	1.1	
T26	13.941	-0.3	1851	185	10	1.0	
T28	14.4	-0.3	1851	185	9	0.9	

Viewpoint 15

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	13.388	-0.7	1317	132	7	0.7	
T12	12.486	-0.8	1192	119	8	0.8	
T14	12.582	-0.7	1317	132	8	0.8	
T16	13.513	-0.6	1443	144	8	0.8	
T19	14.18	-0.6	1443	144	7	0.7	
T20	14.577	-0.7	1317	132	6	0.6	
T21	14.259	-0.7	1317	132	6.5	0.6	
T24	15.036	-0.7	1317	132	6	0.6	
T25	15.114	-0.7	1317	132	6	0.6	
T26	15.601	-0.8	1192	119	5	0.5	
T28	15.189	-0.7	1317	132	6	0.6	

Viewpoint 16

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	15.67	-0.4	1721	172	7	0.7	
T12	14.732	-0.5	1582	158	7	0.7	
T14	14.716	-0.4	1721	172	8	0.8	
T16	15.497	-0.3	1851	185	8	0.8	
T19	16.131	-0.4	1721	172	7	0.7	
T20	16.447	-0.4	1721	172	6	0.6	
T21	16.514	-0.4	1721	172	6.3	0.6	
T24	17.004	-0.5	1582	158	5	0.5	
T25	17.226	-0.5	1582	158	5	0.5	
T26	17.826	-0.5	1582	158	5	0.5	
T28	17.569	-0.5	1582	158	5	0.5	

Viewpoint 17

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	19.656	0.0	2185	219	6	0.6	
T12	20.57	0.0	2185	219	5	0.5	
T14	20.723	0.1	2257	226	5	0.5	
T16	20.263	0.1	2257	226	5	0.5	
T19	19.784	0.1	2257	226	6	0.6	
T20	19.689	0.0	2185	219	6	0.6	
T21	18.915	0	2185	219	6.1	0.6	
T24	19.015	0.0	2185	219	6	0.6	
T25	18.526	0.0	2185	219	6	0.6	
T26	17.778	0.0	2185	219	7	0.7	
T28	17.755	0.0	2185	219	7	0.7	

Viewpoint 18

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	18.373	-0.5	1582	158	5	0.5	
T12	17.434	-0.6	1443	144	5	0.5	
T14	17.378	-0.5	1582	158	5	0.5	
T16	18.09	-0.2	1982	198	6	0.6	X
T19	18.7	-0.3	1851	185	5	0.5	X
T20	18.978	-0.4	1721	172	5	0.5	X
T21	19.197	-0.6	1443	144	3.9	0.4	
T24	19.568	-0.5	1582	158	4	0.4	X
T25	19.846	-0.5	1582	158	4	0.4	X
T26	20.484	-0.6	1443	144	3	0.3	
T28	20.288	-0.6	1443	144	4	0.4	

Viewpoint 19

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	26.205	0.5	2452	245	4	0.4	
T12	25.266	0.5	2452	245	4	0.4	
T14	25.224	0.6	2475	248	4	0.4	
T16	25.951	0.6	1443	144	2	0.2	
T19	26.564	0.6	2475	248	4	0.4	
T20	26.845	0.5	2452	245	3	0.3	
T21	27.037	0.5	2452	245	3.4	0.3	
T24	27.433	0.5	2452	245	3	0.3	
T25	27.704	0.5	2452	245	3	0.3	
T26	28.333	0.4	2429	243	3	0.3	
T28	28.114	0.4	2429	243	3	0.3	

Viewpoint 20

Turbine	Distance	Elevation	Candela	Candela at 10%	Microlumens	Microlumens at 10%	Obscured
T11	28.762	-0.1	2083	208	3	0.3	X
T12	28.016	-0.1	2083	208	3	0.3	X
T14	27.699	-0.1	2083	208	3	0.3	X
T16	27.789	0.1	2257	226	3	0.3	X
T19	28.111	-0.1	2083	208	3	0.3	X
T20	28.079	-0.2	1982	198	3	0.3	
T21	29.28	-0.1	2083	208	2.4	0.2	X
T24	28.752	-0.3	1851	185	2	0.2	
T25	29.35	-0.2	1982	198	2	0.2	X
T26	30.132	-0.3	1851	185	2	0.2	
T28	30.427	-0.1	2083	208	2	0.2	X

Viewpoint 21

Interpreting the Results

11. 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, the distance between the light and the viewpoint is the dominant factor and the resultant figure in micro-lumens is the most relevant figure to consider. Assessing the effect of lighting of various intensity on the population at varying distances is beyond our expertise. We report the facts and anticipate that the Landscape and Visual Impact Assessment consultants will be able to put the results into the correct context in terms of background environmental lighting, atmospheric conditions such as pollution and haze and human perception at various distances. Table 4 shows the turbine with the greatest potential perceived luminous intensity expressed in micro-lumens at each viewpoint.

Viewpoint	Brightest Lit Turbine	Distance (km)	Microlumens	Microlumens at 10%
1	T16	1.655	359	35.9
2	T16	4.381	43	4.3
3	T26	2.467	42	4.2
4	T21	3.727	32.3	3.2
5	T28	3.128	25	2.5
6	T21	4.725	23.7	2.4
7	T16	3.174	53	5.3
8	T14	4.231	25	2.5
9	T20	4.991	21	2.1
10	T21	7.982	17.1	1.7
11				
12	T16	10.693	13	1.3
13				
14	T21	12.538	9.2	0.9
15	T16	11.856	16	1.6
16	T16	13.513	8	0.8
17	T16	15.497	8	0.8
18	T21	18.915	6.1	0.6
19	T14	17.378	5	0.5
20	T14	25.224	4	0.4
21	T20	28.079	3	0.3

Table 4 Brightest Turbine Hub Light from each Viewpoint (measured in micro-lumens)

12. In order to place the values in microlumens in context, Table 5 provides some examples of approximate values placed on a number of environmental comparators.

Comparison Object	**Approximate Illuminance (micro-lumens per m²)**
Car Halogen main beam approaching 1km	Up to 1,000,000
International Space Station (400km up)	1000
Car Brake Lights at 1km distance	100
Brightest Star in the Sky	13
Car Brake Lights at 10km distance	1
Typical bright star (eg Orion)	0.5
Faintest light visible from street lit area	0.4
Visible limit for fully dark-adapted eyes	0.02

Table 5 Comparisons of micro-lumens values

13. If there is a requirement to consider the brightest turbine in terms of emitted candela rather than micro-lumens, Table 6 provides data on which turbine emits the most candela towards each viewpoint but takes no account of distance between light and viewpoint.

Viewpoint	Brightest Lit Turbine	Distance (km)	Candela Emitted	Candela at 10%
1	T16	1.655	982	98
2	T16	4.381	822	82
3	T26	2.467	827	83
4	T21	3.727	448	45
5	T21	4.291	530	53
6	T28	5.766	622	62
7	T16	3.174	530	53
8	T21	6.053	756	76
9	T21	5.968	622	62
10	T14	9.757	1443	144
11				
12	T21	11.702	1192	119
13				
14	T16	13.842	1721	172
15	T16	11.856	2185	219
16	T16	13.513	1443	144
17	T16	15.497	1851	185
18	T19	19.784	2257	226
19	T14	17.378	1582	158
20	T14	25.224	2475	248
21	T20	28.079	1982	198

Table 6 Brightest Turbine Hub Light measured in Candela emitted towards a viewpoint
NB – where candela results are the same, the closest turbine has been selected as the brightest.

Mid-Mast Lights

Visibility Tables for the Mid-Tower lights

14. The CAA have clarified their position in relation to the requirement for lights at the mid point between the turbine hub and the ground. A small number of the turbines identified as requiring hub lights will also require 32 candela red lights as described in paragraph 7. Commercially available 32cd mid-mast lights are over engineered and emit considerably more light than the minimum required by ICAO Annex E. Lighting manufacturers are working on a new generation of 32cd lights that carefully match the ICAO Annex E requirement without excessive light intensity or light that 'spills' downward.

15. The calculations for the mid-mast lights are based upon the parameters of the CEL -LI-32-230-F LED red low intensity aircraft warning light manufactured by Contarnex Europe Ltd . The full technical specification is available at https://www.contarnex.com/led-obstruction-lighting/datasheets/Low-Intensity/1-READY%20-%202nd%20Generation/CEL-LI-32-230-F-low-intensity-led-obstruction-warning-light.pdf The light has been tested in a calibrated test chamber and the results are shown in the graph below at Figure 9 and the manufacturer has provided the

luminous intensity figures for every 0.5° in elevation. Although less precise than the 2000cd medium intensity red lights referred to in the main report, there is still some reduction in intensity the further below horizontal the viewpoint is in relation to the light. It should be noted that although classified as a 32cd low intensity red light, the maximum output peaks at around 74cd at an elevation angle of +4.0°, however, this is likely to be well above the elevation angle between any light and any potential viewpoint. The concession to reduce light intensity in good visibility does not apply to these lights. Finally it should also be noted that due to the lower elevation of the mid mast light (half hub height), there is more opportunity for terrain screening between the light and a viewpoint.

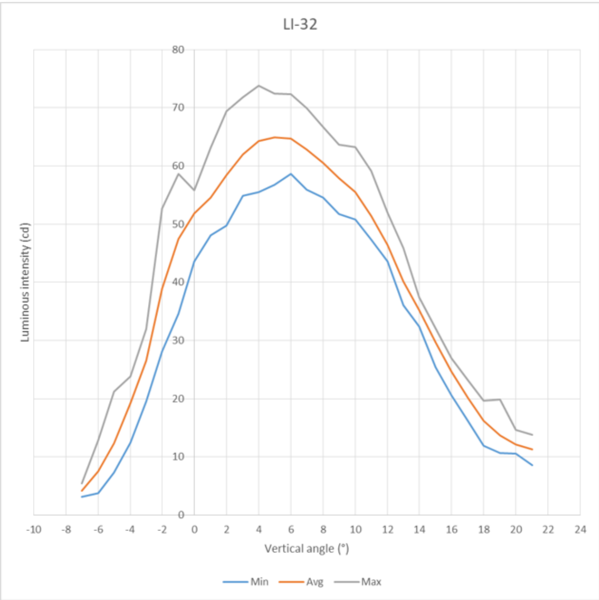

Figure 9

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	3.052	-0.4	50	5.4	
T16	1.655	0.8	54	19.7	
T20					
T26	2.257	-1.2	47	9.2	
T28	2.897	-0.8	47	5.6	

Viewpoint 1

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	4.193	-0.4	50	2.8	X
T16	4.381	-0.1	52	2.7	X
T20	4.436	-0.3	50	2.5	X
T26	2.538	-1.0	47	7.3	X
T28	1.851	-2.0	39	11.4	X

Viewpoint 2

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	5.411	-0.1	52	1.8	X
T16	4.952	0.5	53	2.2	X
T20	4.446	-0.4	50	2.5	X
T26	2.467	-2.0	39	6.4	
T28	2.563	-1.7	43	6.5	

Viewpoint 3

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	5.487	-0.3	50	1.7	X
T16	4.607	0.9	54	2.5	X
T20	3.769	-0.1	52	3.7	X
T26	2.392	-2.5	33	5.8	
T28	3.002	-1.6	43	4.8	X

Viewpoint 4

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	5.96	-0.2	52	1.5	X
T16	5.683	0.6	53	1.6	X
T20	5.291	-0.3	50	1.8	X
T26	3.244	-2.1	39	3.7	X
T28	3.128	-1.7	43	4.4	X

Viewpoint 5

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	4.198	-0.8	47	2.7	X
T16	3.27	-0.7	50	4.7	
T20	3.263	-1.5	43	4.0	
T26	5.337	-1.2	47	1.7	
T28	5.766	-1.0	47	1.4	

Viewpoint 6

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	4.441	-1.2	47	2.4	
T16	3.174	-0.7	50	5.0	X
T20	2.673	-1.9	39	5.5	
T26	4.649	-1.2	47	2.2	X
T28	5.25	-1.1	47	1.7	X

Viewpoint 7

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	4.31	-1.0	47	2.5	X
T16	4.985	0.4	53	2.1	X
T20	5.964	-0.6	50	1.4	X
T26	7.337	-0.7	50	0.9	X
T28	7.162	-0.6	50	1.0	X

Viewpoint 8

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	7.406	-0.3	50	0.9	X
T16	6.111	0.3	53	1.4	X
T20	4.991	-0.7	50	2.0	X
T26	4.906	-1.5	43	1.8	
T28	5.736	-1.2	47	1.4	

Viewpoint 9

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	9.771	-0.2	52	0.5	X
T16	9.006	0.8	54	0.7	X
T20	8.17	-0.3	50	0.7	X
T26	6.652	-0.9	47	1.1	
T28	7.017	-0.8	47	1.0	

Viewpoint 10

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	7.7	-0.2	52	0.9	X
T16	7.772	0.3	53	0.9	X
T20	8.387	-0.1	52	0.7	X
T26	10.253	-0.3	50	0.5	X
T28	10.347	-0.2	52	0.5	X

Viewpoint 11

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	12.002	-0.5	50	0.3	
T16	10.693	-0.1	52	0.5	X
T20	9.948	-0.6	50	0.5	
T26	11.473	-0.6	50	0.4	
T28	12.268	-0.6	50	0.3	

Viewpoint 12

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	10.614	-0.1	52	0.5	X
T16	10.578	0.4	53	0.5	X
T20	11.084	-0.1	52	0.4	X
T26	13.033	-0.3	50	0.3	X
T28	13.192	-0.2	52	0.3	X

Viewpoint 13

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	14.243	-0.2	52	0.3	X
T16	13.842	0.5	53	0.3	X
T20	13.226	-0.1	52	0.3	X
T26	11.355	-0.5	50	0.4	
T28	11.397	-0.5	50	0.4	

Viewpoint 14

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	12.493	0.0	52	0.3	
T16	11.856	0.2	52	0.4	
T20	11.871	0.0	52	0.4	
T26	13.941	-0.1	52	0.3	
T28	14.4	-0.1	52	0.3	

Viewpoint 15

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	12.486	-0.6	50	0.3	
T16	13.513	0.1	52	0.3	X
T20	14.577	-0.5	50	0.2	
T26	15.601	-0.6	50	0.2	
T28	15.189	-0.6	50	0.2	

Viewpoint 16

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	14.732	-0.3	50	0.2	
T16	15.497	0.4	53	0.2	X
T20	16.447	-0.1	52	0.2	X
T26	17.826	-0.3	50	0.2	
T28	17.569	-0.3	50	0.2	

Viewpoint 17

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	20.57	0.2	52	0.1	
T16	20.263	0.5	53	0.1	X
T20	19.689	0.2	52	0.1	
T26	17.778	0.1	52	0.2	
T28	17.755	0.1	52	0.2	

Viewpoint 18

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	17.434	-0.4	50	0.2	
T16	18.09	0.2	52	0.2	X
T20	18.978	0.0	52	0.1	X
T26	20.484	-0.5	50	0.1	
T28	20.288	-0.4	50	0.1	

Viewpoint 19

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	25.266	0.7	53	0.1	
T16	25.951	0.7	53	0.1	
T20	26.845	0.6	53	0.1	
T26	28.333	0.5	53	0.1	
T28	28.114	0.5	53	0.1	

Viewpoint 20

Turbine	Distance	Elevation	Candela	Microlumens	Obscured
T12	28.016	0.1	52	0.1	X
T16	27.789	0.4	53	0.1	X
T20	28.079	0.0	52	0.1	X
T26	30.132	-0.1	52	0.1	X
T28	30.427	0.1	52	0.1	X

Viewpoint 21

Part 2 Mitigation

16. 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'.

17. 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. It should be noted that this does not apply to the low intensity 32cd lights installed halfway up the turbine towers.

Historical Visibility Tables for Energy Isles Wind Farm

18. It is considered useful to estimate how much time the lights would spend at 2000cd and at 200cd. To assess historical visibility on the Shetland Isle, the closest meteorological station is at Unst Airport. The visibility will not be identical at the two locations but similar. Below is a Met Office table of visibilities at Unst throughout the year and averaged over a 30 year period (Ref K). Note: the tables for Scatsta are very similar.

19. The Met Office table in Figure 10 shows that the visibility is below 5km for an average of 8% of the time. This suggests that:
    - Obstruction Lighting will be at 2000cd for only 8% of the time; and
    - Obstruction Lighting will be at 200cd for 92% of the time.

    A parallel analysis at Scatsta Airport gives similar figures showing:
    - Obstruction Lighting will be at 2000cd for only 6% of the time; and
    - Obstruction Lighting will be at 200cd for 94% of the time.

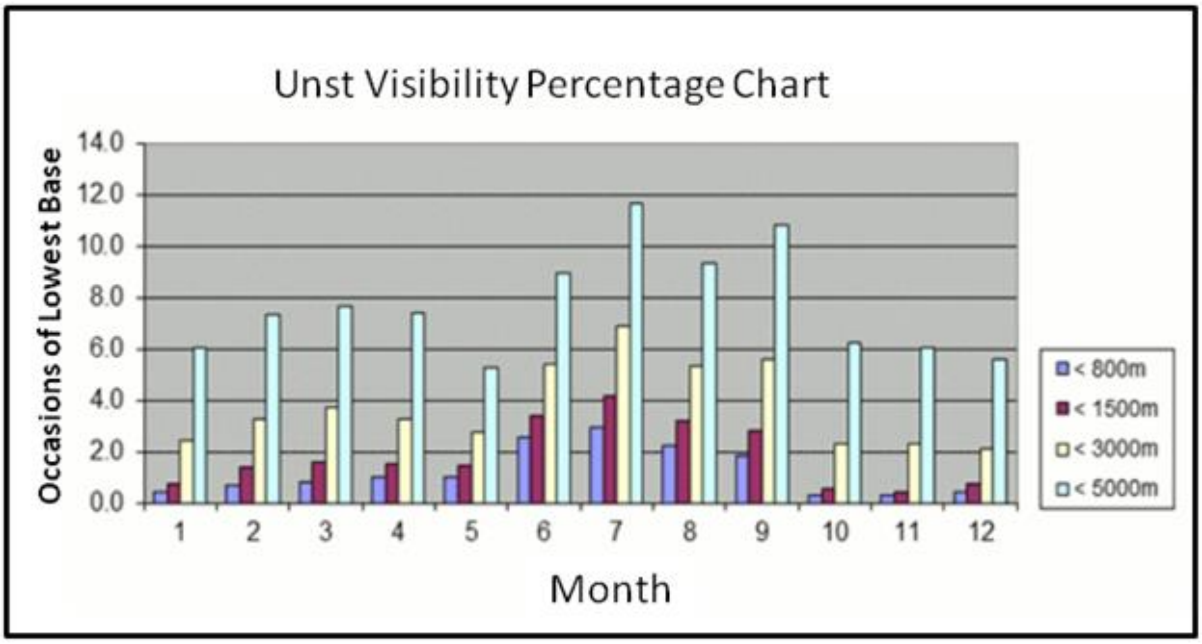

Figure 10 Visibility Table for Unst Airport (Light Blue is 5km Indicator)

20. Whilst Unst and Scatsta aerodromes are not directly adjacent to the Energy Isles site, meteorological 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 visibility would be better than that at Unst. In addition cloud will play its part in the observability of the obstruction lights at Energy Isles. This will now be investigated.

Obstruction Light – Cloud Base Implications

21. On occasion, the visibility in the area of Energy Isles will drop significantly due to the presence of cloud on or close to the hills. If the Energy Isles turbines are in cloud, then the obstruction lights will not be visible. In a similar vein, if the turbines are partially shrouded in cloud then the light intensity will be much reduced. The base of the turbines is around 40-80m above mean sea level (amsl); this equates to 130-260ft amsl. Although, the overall height and rotor size of the turbines may vary, the hub heights will be around 100m/330ft above ground level (agl). Adding the height of the ground gives hub heights of 460-600ft amsl. This is the height at which the turbine obstruction lighting will be fitted.

22. It is now possible to compare these two heights: turbine base 130-260ft amsl and turbine hub 460-600ft amsl with the actual cloud bases recorded by the Met Office, at Unst airport, over a 30 year period as shown in Figure 11 on the following page.

The light blue columns (400-500ft) indicate that:

- Between 300 and 700 occasions a month (time of year depending), the cloud-base will be below the turbine hub heights (460-6000ft), and;

- The hub lights will be completely or partially obscured.

The yellow and red columns (200-300ft) indicate that:

- Between 100 and 400 occasions a month, the cloud base will range around the turbine base heights, and;

- The cloud would obscure the lighting at hub height.

Note a similar analysis at Scatsta Airport gives slightly lower averages for cloud

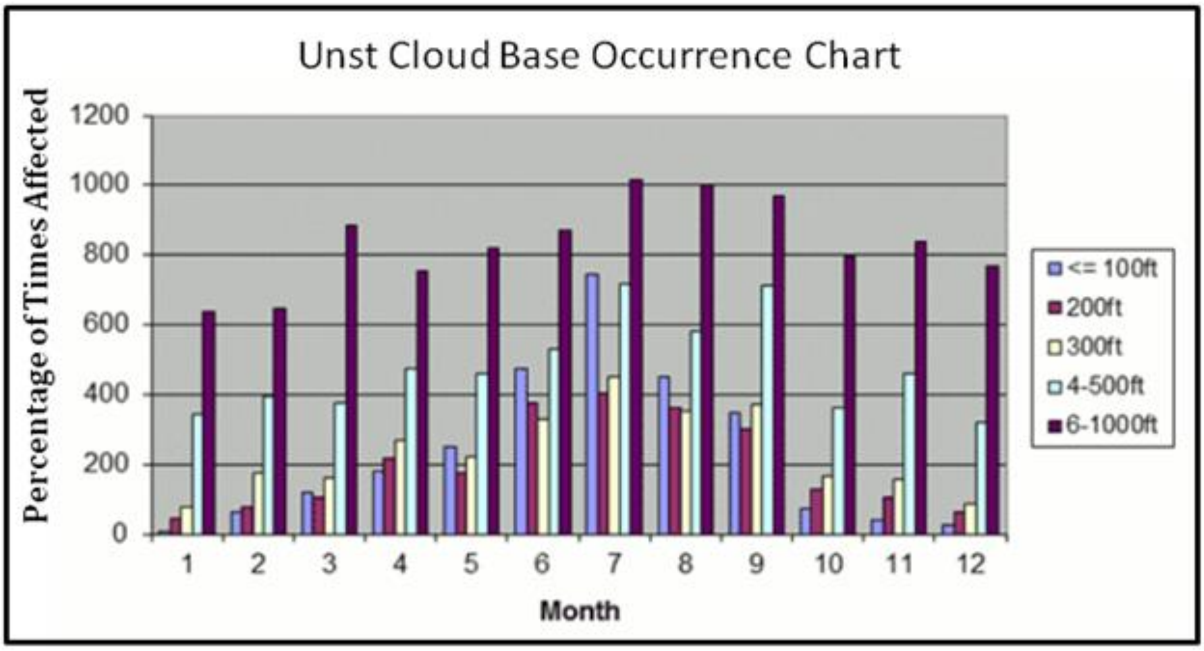

Figure 11 Thirty Year Average Cloud Base Table for Unst Airport Weather Station

23. Again, whilst Unst is not directly adjacent to the Energy Isles site, it is a meteorological reality that the cloud-base tends to lower over hills. This would suggest that the cloud-base would obscure the turbines on more occasions per month than the analysis suggests.

Technical Mitigation

24. 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. There are some significant technical and regulatory issues to be overcome before any such system can be installed and operated.

25. 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 12 below. The main regulatory constraint is that although such systems are in use in Europe, in the UK 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 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 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 to 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 12 Terma 5002 Radar at a Wind Farm

26. 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.*

27. 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. Unfortunately this is not as simple a process as one might imagine. This issue has been running for at least 20 years so far, however progress is now being made. In the same response to a recent planning inquiry paper the CAA responded stating: *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. 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 part of a much wider airspace modernisation programme currently under way.

28. 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 13 they are unobtrusive small aerials, approximately 1.2 metres long that are very reliable and relatively inexpensive to install and operate.

Figure 13 ADSB/SSR Passive Aerial

29. Bearing the above in mind, it would be prudent to ensure that any 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 fitment hurdles have been overcome.

30. 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 Unst, with very little if any night low level civilian traffic, the number of times the lights will activate is likely to be so small as to be statistically insignificant. The 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.

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

Conclusion

31. This report has assessed the requirements for both visible, CAA approved aviation lighting and MOD approved Infra-Red lighting for the Energy Isles Wind Farm. The resulting layout is set out in Figure 5 and makes use of both CAA/ANO Red lights and MOD IR lights. The proposed layouts have been approved by the MOD and CAA.

32. The report also reports the brilliance of lights that will be visible taking into account the elevation angle between the turbine obstruction light and the viewpoints and the distance between each turbine and each viewpoint. The report shows that for at least 94% 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.

33. The report then identifies additional mitigation options that should the regulatory process allow, would enable the visible medium intensity and visible low 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 will enable the future lighting effects to be mitigated to the extent of becoming almost non-existent.

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 such as business parks and blocks of flats 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.

[redacted]

Cdr John Taylor RN (Ret)
Managing Director
Wind Power Aviation Consultants Ltd
www.wpac.co.uk

Appendix A CAA Lighting Layout Approval Letter

Safety and Airspace Regulation Group
Future Safety

Civil Aviation Authority

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

13 August 2021
Ref Windfarms/Energy Isles

Dear Mike,

Proposed Energy Isles Wind Farm Obstacle Lighting Scheme, located on Yell, Shetland Islands

Reference: Energy Isles Lighting Brief (AL2) dated 12 August 2021

1. Thank you for the report at reference which details the obstacle lighting scheme for the Energy Isles wind turbine proposed development.

2. The proposed development has 18 turbines, with turbine heights in excess of 150m high ground to tip. This brings them into scope of the Air Navigation Order Article 222 requirements for obstacle lighting at night.

3. Based on the information and proposal contained within the report and your, the CAA confirms that in accordance with the Air Navigation Order (ANO) Article 222 section 6, we agree a variation to the lighting requirements specified in the ANO Article for the proposed Energy Isles wind farm as per the following:

- medium intensity steady red (2000 candela) lights on the nacelles of Turbines 11, 12, 14, 16, 19, 20, 21, 24, 25, 26 and 28;
- a second 2000 candela light on the nacelles of the turbines stated above to act as alternates in the event of failure of the main light;
- the visible lights on these turbines will be capable of being dimmed to 10% of peak intensity when the visibility as measured at the wind farm exceeds 5km;
- infra-red lights to MoD specification installed on the nacelles of Turbines 11, 12, 14, 15, 16, 19, 20, 21, 24, 25, 26 and 28;
- At least three (to provide 360 degree coverage) 32 candela lights provided at an intermediate level of half the nacelle height ± 10 m each on Turbines 12, 16, 20, 26 and 28.

4. The above variation differs from the lighting brief in two elements:
(i) Takes account of your covering e-mail in which you propose not lighting turbine 15 but turbine 21 instead (which we concur provides a better overall perimeter visible red lighting coverage)
(ii) Addresses a minor typographical error between the list of turbines with IR lighting on page 4 (which does not include turbine 21) and figure 3 (which does) in the brief.

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

Yours sincerely,

[redacted]

Andy Wells
Manager Rulemaking and Safety Publications

Civil Aviation Authority

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