LVIA Appendix 6.2

Visual Assessment of Turbine Lighting

SCOTTISHPOWER RENEWABLES

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6.1 Introduction

1. Civil Aviation Authority (CAA) guidance requires that 'en-route obstacles' at or above 150 m above ground level are lit with visible lighting to assist their detection by aircraft. As such, there is potential that parts of the proposed Development may be visible at night. The effect of the proposed Development at night would result from visible medium intensity (2000 candela) red coloured light fittings located on the nacelles, and on the turbine towers, of all proposed turbines. It should be noted that all turbines would also include infra-red lighting on the turbine hubs which would not be visible to the human eye. The focus of this technical appendix (TA6.2) is on the visual assessment of the visible lighting requirements of the proposed Development.

2. This visual assessment of turbine lighting is supported by ZTV map figures (**Figures 6.2-1 to 6.2-**3), a baseline light pollution map (**Figure 6.2-4**), a Lighting Intensity ZTV (**Figure 6.2-5**) and night-time photomontage visualisations from four viewpoints (**Figures 6.2-6 to 6.2-**9).

6.2 Regulations and Guidance

6.2.1 ICAO / Civil Aviation Authority (CAA) Regulations

3. ICAO (a UN body) sets international Standards; Recommendations and 'Notes' for aviation lighting in its publication 'Annex 14 to the Convention on International Civil Aviation' - Volume I Aerodrome Design and Operations (ICAO, Eighth Edition, July 2018).

4. ICAO Table 6.1 (page 6-4) identifies the international definitions of daylight; twilight and night based on measured background illuminance as follows.

- **Daylight:** Above 500 cd/m2
- **Twilight:** 50-500 cd/m2
- **Night:** Below 50 cd/m2

5. For 2,000 candela medium intensity steady or fixed red lights, ICAO indicates a requirement for no lighting to be switched on until 'Night' has been reached, as measured at 50cd/m2 or darker.

6. ICAO Table 6.3 (page 6-5) identifies minimum requirements and recommendations for 2,000cd aviation lights on wind turbines at 150m and above. In summary these are:

7. Minimum requirements:

- **0 to +3 ° from horizontal:** 2,000cd minimum average intensity (or 1,500cd minimum intensity)
- **-1 degree from horizontal:** 750cd minimum intensity

8. The European Aviation Safety Agency (EASA) implements ICAO in European airspace. In pursuit of international standards for use around the globe, a project team has been established to provide clearer direction to lighting manufacturers, as there is scope for interpretation of ICAO in different ways by manufacturers.

9. Within the UK, the ICAO/ EASA requirements for lighting wind turbines are implemented through CAA publication 'CAP 764: Policy and Guidelines on Wind Turbines', and 'CAP393: Air Navigation Order 2016'. CAA have confirmed that UK policy broadly aligns with the International standards, including insofar as the point at which lights must be switched on at 'Night' rather than 'Twilight'.

10. The proposed turbines, at 200m to blade tip, would require lighting under Article 222 of the Air Navigation Order (ANO, 2016). This requires medium intensity 'steady' red aviation lights (emitting 2,000 candela) to be fitted at nacelle level. In addition, the CAA requires low intensity lights to be fitted at the intermediate level on the turbine tower (CAA, 2017). The intermediate 'tower' lights will be 32 candela.

11. Air Navigation Order 2016 (CAP393) Article 223 (8) states that *"If visibility in all directions from every wind turbine generator in a group is more than 5km the light intensity for any light required by this article to be fitted to any generator in the group and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type."* This allows the minimum intensities identified above to be dimmed to 10% of their values if meteorological conditions permit (i.e. the 2,000cd minimum intensity may be dimmed to 10%, or 200cd, if visibility is greater than 5km, i.e. in moderate to excellent or 'clear' visibility).

12. The graph in **Plate TA 6.2.1** below illustrates the ICAO (Annex 14) minimum required (red line) and maximum recommended (green line) light intensity emission that may be experienced at various vertical angles, with the horizontal plane of the lights represented by 0 degrees vertical angle.

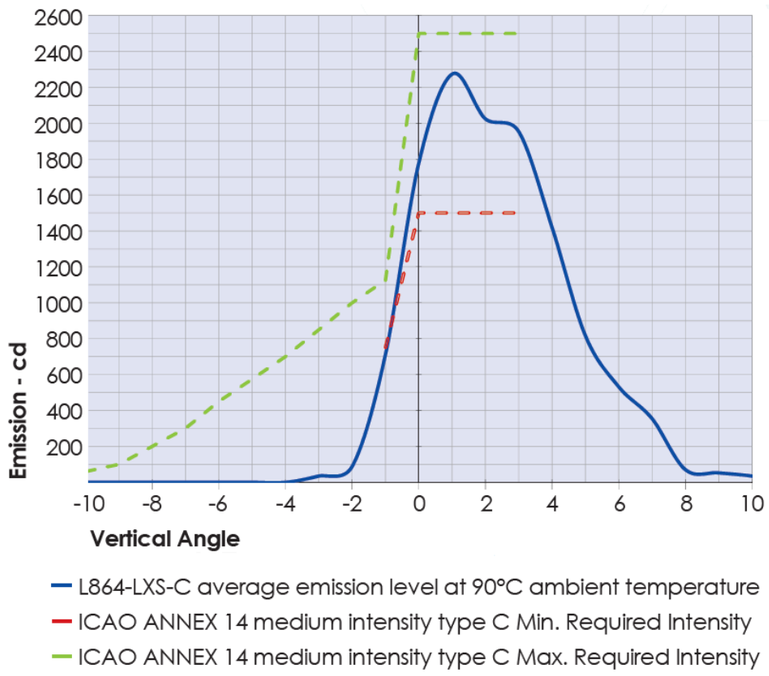

Plate TA6.2.1: Lighting Intensity Graph[1]

13. The average emission level of the LuxSolar Medium Intensity Obstruction Light is also shown (blue line), providing

[1] LuxSolar Medium Intensity Obstruction Light CAP 168 MIOL-C: Data Sheet, January 2018.

an illustration of the light emissions for one particular model of light. Whilst the precise model of light to be used for the proposed Development is not known at this time, the graph clearly demonstrates that the intensity of the aviation lights requires to be most intense between 0 to +3° from horizontal and that the intensity of emitted light required by IACO is lower below the horizontal. The use of a particular model of aviation light which offers a reduced light intensity below the horizontal and above +3° would provide mitigation of the intensity of the lights for receptors viewing them from areas below the horizontal.

14. Following the graph in **plate TA: 6.2.1,** the intensity of light emissions reduces as the vertical elevation angle changes. These calculations do not take account of the potential for some of the emitted light spilling onto the passing blades which would be visible at all negative angles, albeit as a less intense and diffuse reflected glow. At -10 negative elevation angle the reduction in intensity would result in a 2000 cd light being barely perceptible.

6.2.2 Guidelines for Landscape and Visual Impact Assessment (GLVIA3)

15. GLVIA3 (page 103) provides the following guidance on the assessment of lighting effects: *"For some types of development the visual effects of lighting may be an issue. In these cases it may be important to carry out night-time 'darkness' surveys of the existing conditions in order to assess the potential effects of lighting and these effects need to be taken into account in generating the 3D model of the scheme. Quantitative assessment of illumination levels, and incorporation into models relevant to visual effects assessment, will require input from lighting engineers, but the visual effects assessment will also need to include qualitative assessments of the effects of the predicted light levels on night-time visibility."*

16. GLVIA3 (page 60) also provides the following guidance with regards to mitigation of obtrusive light: *'lighting for safety or security purposes may be unavoidable and may give rise to significant adverse effects; in such cases, consideration should be given to different ways of minimising light pollution and reference should be made to appropriate guidance, such as that provided by the Institution of Lighting Professionals (ILP, 2011)'.*

6.2.3 Institute of Lighting Professional Guidance

17. Guidance produced by the Institute of Lighting Professionals (ILP) (2011) (GN01:2011)[2] is useful in setting out some key lighting terminology that relates to potential visual effects.

> **'Obtrusive Light**, whether it keeps you awake through a bedroom window or impedes your view of the night sky, is a form of pollution, which may also be a nuisance in law and which can be substantially reduced without detriment to the lighting task. **Skyglow** - the brightening of the night sky; **Glare** - the uncomfortable brightness of a light source when viewed against a darker background; and **Light Intrusion** - the spilling of light beyond the boundary of the property or area being lit, are all forms of obtrusive light which may cause nuisance to others.

18. The following key guidance within the ILP GN01:2011 is noted as follows:

- '*The most sensitive/critical zones for minimising sky glow are those between 90° and 100° (note that this equates to 0-10° above the horizontal).*
- *Keep glare to a minimum by ensuring that the main beam angle of all lights directed towards any potential observer is not more than 70°.*
- *In rural areas the use of full horizontal cut off luminaires installed at 0° uplift will, in addition to reducing sky glow, also help to minimise visual intrusion within the open landscape.*
- *Upward Light Ratio (ULR) of the Installation is the maximum permitted percentage of luminaire flux that goes directly into the sky. A ULR of 0 (zero) Candela (cd) is suggested for Dark Sky Parks.'*

19. CPRE[3] also identifies these same broad terms as the three types of light pollution:

> ***'skyglow** – the pink or orange glow we see for miles around towns and cities, spreading deep into the countryside, caused by a scattering of artificial light by airborne dust and water droplets.*
> ***glare** – the uncomfortable brightness of a light source.*
> ***light intrusion** – light spilling beyond the boundary of the property on which a light is located, sometimes shining through windows and curtains'.*

6.2.4 SNH Guidance

6.2.4.1 Visual Representation Guidance

20. In terms of how lighting is captured in visualisations, the main change in the latest version of the SNH guidance "Visual Representation of Wind Farms" (Version 2.2, February 2017) is in paragraphs 174-177, which states: *"The visualisation should use photographs taken in low light conditions, preferably when other artificial lighting (such as street lights and lights on buildings) are on, to show how the wind farm lighting will look compared to the existing baseline at night"… "We have found that approximately 30 minutes after sunset provides a reasonable balance between visibility of the landform and the apparent brightness of artificial lights, as both should be visible in the image."*

21. The night time photography has therefore been captured in low light conditions, when other artificial lighting (such as street lights and lights on buildings) is on, to show how the windfarm lighting would look compared to the existing baseline at night. For the assessment of lighting effects, the visual sensitivity and magnitude criteria described in **TA: 6.1 (LVIA Methodology)** has been applied.

22. Existing lights shown in the photographs appear larger and more blurred than those seen to the naked eye in the field when the photographs were captured. The term used in photography to describe this effect is 'Bokeh' which has been defined as 'the way the lens renders out-of-focus points of light'. This has proved difficult to avoid when taking photographs of light at varied distances across a view. The blurred nature of the lights is also exacerbated by their movement, particularly on vehicle headlights. Where the lights of the proposed Development have been added to the night time views this effect has been emulated.

23. The turbine blades, when they intermittently pass in front of the aviation lights, would cause randomised flickering when the lights are switched 'on'. The turbines used in the night time visualisations have been positioned so that their blades face away from the viewpoint so that all the lights are visible and on within the visualisations, representing a worst-case impression. The flickering effect caused by the blades interacting with the lights would be most usually apparent from a south westerly direction due to the prevailing south westerly wind.

24. The lighting represented in the viewpoint visualisations has been calibrated using examples of existing, equivalent, turbine lighting observed in the field in other parts of Scotland, during similar periods of dusk / darkness as captured in the photography for the agreed viewpoints. A photographic example of existing turbine lights is included in this TA as reference (**See Plate 6.2.3),** noting that these examples may not reflect the technology present in the light that has been used to configure the intensity ZTVs in this assessment.

6.2.4.2 Evolving SNH Approaches to Turbine Lighting

25. Recent SNH workshops indicate that a proportionate and pragmatic approach is required, both in terms of the need to assess likely significant effects under the EIA regulations, complying with current civil aviation standards and providing mitigation on a project and site-specific basis.

26. Mitigation options to eliminate or reduce the need for, and effects of, visible lighting are evolving quickly and developers are exploring these with consultees and the CAA in relation to specific sites. SNH has offered a perspective on the efficacy of different mitigation options, noting that the most effective appears to be radar activated, albeit accepting the considerable cost implications inherent in this potential option.

27. Ministers and planning authorities are using planning conditions to manage effects. It is recognised that the EIAR should not necessarily specify one mitigation option, as these are evolving rapidly, and developers need flexibility to utilise the most appropriate mitigation once they are ready to start discharging conditions. Conditions provide some flexibility for developers to identify the most appropriate mitigation option(s) post consent and prior to construction, and to agree these with the relevant decision maker.

[2] Institute of Lighting Professionals (ILP) - Guidance Notes for the Reduction of Obtrusive Light GN01:2011
[3] CPRE – 'What is Light Pollution' found at webpage - https://www.nightblight.cpre.org.uk/what-is-light-pollution

28. In terms of visual effects, SNH's view (as expressed at a seminar in November 2019) is that lengthy debate about the exact brightness of lights (including in visualisations) is potentially not helpful and that it is better to focus on where they will be visible, how many lights will be visible and the level of change from the baseline situation. This is recognised in the visual assessment in this **TA:6.2**. SNH has also taken a pragmatic view with night-time visualisations, requesting that decision makers, consultees and communities require visualisations from a small number of relevant viewpoints to understand these effects. SNH also recognises the challenges of capturing nigh-time photography and accept that some post photographic manipulation of images to provide a good representation is acceptable.

6.3 Assessment Parameters

29. A description of the proposed turbine lighting is found within **Chapter 4 Development Description and Chapter 14, Section 14.2 Aviation,** based on this, the following assumptions have been made with regards to visible lighting of the proposed Development for the LVIA:

- the CAA requires that all obstacles at or above 150 m above ground level are fitted with visible lighting and in the case of wind turbines these should be located on the nacelle;
- the CAA requires that a secondary light is fitted for use only when the primary light fails and would not be lit concurrently; and
- there is an additional requirement for lights to be provided at an intermediate level of half the nacelle height. These would need to be fitted around the towers to allow for 360-degree horizontal visibility.

30. In relation to the proposed Development the worst-case scenario for night time effects includes the following parameters:

- all turbines would have red, medium intensity visible lights mounted on the nacelle (125 m);
- 2000cd and 200cd intensity lights have been assessed representing 2 differing worst case situations. 2000cd represents the maximum intensity possible. 200cd represents the maximum intensity that would be used when visibility extending from the windfarm exceeds 5 km;
- all turbines would also have low-intensity lights (32 candela) to be provided on the turbine towers at an intermediate level of half the nacelle height (62.5 m); and
- the steady red lighting fixed to the top of the nacelles and to the turbine towers may appear to flicker on and off with the blade movement. This would occur when the turbine blades pass between the lights and the observers.

31. On the basis of the CAA requirements, it is evident that the effect of the visible lights of the proposed Development will be dependent on a range of factors, including the intensity of lights used, the clarity of atmospheric visibility and the degree of negative/ positive vertical angle of view from the light to the receptor. In compliance with EIA regulations, the likely significant effects of a 'worst-case' scenario for turbine lighting are assessed and illustrated in this visual assessment. A worst-case approach is applied which considers the effects of 2,000cd lights and 200cd lights during periods of clear visibility. It should be noted however, that as the required medium intensity lights are only intended to be used likely to be operated at their maximum 2,000cd during periods of poor visibility, that 2,000cd lighting intensity actually represents an unrealistic worst case position, as it is unlikely to ever be experienced at that maximum illumination level. Similarly, 200cd is unlikely to be experienced by observers at locations lower or higher (in the case of some hilltops) than the turbine nacelle heights due to the reduction in light intensity at negative/ positive elevation angles from the light.

32. Whilst it is noted that the actual light perceived at assessment viewpoints (and within the Study Area) is likely to be less intense than the maximum intensity of the light (2,000cd in visibility <5km and 200cd in visibility >5km), this TA6.2 assesses the maximum possible intensity of light observed at each of the viewpoints considered and represents this maximum intensity in corresponding visualisations.

33. Although aviation lighting manufacturers must meet the minimum requirements, their products may vary in relation to recommended limits set out in ICAO standards, which makes it difficult producing accurate visualisations as the lighting characteristics of different light fittings, of the same intensity, may vary outside the minimum requirements stipulated by ICAO. The night-time photomontages shown in these figures have been produced to show both 2,000cd and reduced intensity 200cd lighting intensity, to inform the assessment of worst-case effects assessed. If the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5km, the CAA allows that the intensity for the light may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type, or 200cd in this case. Aviation warning lights will allow for reduction in lighting intensity to 200cd when visibility from every wind turbine is more than 5km. The night-time photomontage representations assume full lighting intensity of the 2,000 candela (cd) warning lights, as a worst-case and are therefore likely to over-represent the likely visibility of aviation warning lighting experienced in reality as visibility is likely to be poorer when they operate at that level.

6.4 Assessment of Effects

6.4.1 Types of Effect

34. The visual assessment of turbine lighting is intended to determine the likely effects that the proposed Development will have on the visual resource i.e. it is an assessment of the effects of aviation lighting on views experienced by people at night.

35. The assessment of turbine lighting in this TA does not consider effects of aviation lighting on landscape character (i.e. landscape effects). For 2,000 candela medium intensity steady or fixed red lights, ICAO indicates a requirement for no lighting to be switched on until 'Night' has been reached, as measured at 50cd/m2 or darker. This is helpful as it does not require 2,000 candela medium intensity to be on during 'twilight', when landscape character may be discerned. It is considered that the proposed aviation lighting will not affect the perception of landscape character, which is not readily perceived at night in darkness, particularly in rural areas. While aviation lighting will be visible and result in visual effects, as assessed in this TA, the effects of aviation lighting on the perception of landscape character are scoped out of this assessment.

6.4.2 Baseline Lighting

36. The existing baseline lighting levels have been mapped for the surrounding landscape (see **Figure TA: 6.2-4**) based on Open Source data of Light Pollution across the UK[4]. This Open Source data has been used to help understand and illustrate the existing baseline lighting levels of the Study Area.

37. Each pixel in the mapping shows the level of radiance (night lights) shining up into the night sky, which have been categorised into 9 colour bands to distinguish between different light levels, from low level light pollution colour band 1 (darkest) to high level light pollution 9 (brightest). Along with the vast majority of the surrounding plateau landscape, the proposed Development is located in an area within the lowest level of light pollution (darkest). The map also clearly identifies the main concentrations of night-time lights, creating light pollution that spills up into the sky. Most notably, this is in, and around the main settlements, particularly the Girvan/Prestwick area and Newton Stewart, but also other smaller settlements on the coast such as Turnberry and Ballantrae. Smaller villages are also shown as having concentrations of night-time lights, including Barr and Colmonell. In addition, the map also identifies transport infrastructure such as parts of the A714 as having lower levels of light, particularly where they pass through settled areas.

6.4.3 Galloway Forest Dark Sky Park

38. The Galloway Forest Park was awarded status as a Dark Sky Park (DSP) in 2009 and was subsequently extended to land to the north and east in 2012 to include an area outside the GFP. The DSP is composed of two zones, namely a Core and Buffer Zone. The conditions for DSP status require stringent lighting guidance for the Core Zone. The Buffer Zone is required around the Core Zone to protect the status of the Core but does not in itself need to reach to the same dark sky class in order for the DSP to keep its status. DGC supports the DSP in LDP2 policy

[4] Light Pollution data source – Earth Observation Group,NOAA National Geophysical Data Center. Data processed by LUC on behalf of CPRE

ED11. The Galloway Forest Dark Sky Park is located approximately 16.4 km to the east of the nearest proposed Development turbine with the Dark Sky Park Buffer Zone boundary lying approximately 11.7 km to the east of the nearest proposed Development turbine.

39. The park attracts people wishing to appreciate the night time sky with an absence of night time light pollution. Forestry Land Scotland (FLS) promotes 10 viewing locations in the DSP buffer zone which offer stopping points to view the night sky. The sensitivity of the 10 viewing locations to the potential effects of the turbine lights is higher than other areas of the DSP, as visitors will come to these sites with the express intention of viewing the night sky and this experience could be affected by other sources of light. Of the 10 Viewpoints promoted by FLS for the DSP, Bruce's Stone in Glen Trool, has distant views of the existing Kilgallioch Windfarm and also has potential views of the proposed Development. Bruce's Stone is included as an assessment viewpoint and a night time assessment location. Whilst the Hub ZTV (highest point on turbines proposed to be lit) shows theoretical visibility at Glentrool Visitor Centre - DSP viewpoint 3 and Caldons woodlands - DSP viewpoint 5, substantial intervening forestry prevents unobstructed views to the west that would allow a view of the proposed Development turbine lights.

40. While these 10 viewing locations are identified as being suitable viewing sites, people could feasibly be viewing the night sky from any part of the Dark Skies Park. Parts of the Core Zone of the DSP around the Merrick uplands, which offer visibility of the proposed Development are remote upland area and they are not generally somewhere that people are likely to go at night to view the night sky (in general, people would tend to use the viewing locations). Further to these specifically identified Dark Sky Park viewpoints, areas of potential visibility within the Dark Sky Park (and buffer area) that lie with Glentrool Forest have been closely scrutinised during field work and it is considered that all of the other areas of potential visibility that occur within reach of a public highway do not have any actual visibility of proposed Development turbines due to the large amount of forestry within Glentrool Forest that intervenes.

6.4.4 Representative Night-Time Viewpoints

41. A hub height ZTV was used to identify where there could be direct line of sight from the surrounding area to the proposed turbine lights mounted on the hub (**Figures TA: 6.2-1 & 6.2-2**). This ZTV does not take account of any intervening screening that may arise as a result of forestry or woodland cover. A further ZTV has also been produced showing the theoretical visibility of the tower lights (**Figure TA: 6.2-3).** The night time visual assessment has been carried out from four viewpoint locations. These were selected from the LVIA viewpoints and agreed with statutory consultees. Night time photomontage visualisations (**Figures TA: 6.2-6 to 6.2-9**) have been produced to inform this assessment. The four night time visual assessment viewpoints are:

- Viewpoint 4: SUW (west of Derry);
- Viewpoint 6: Minor Road Bennylow (Culvennan Fell);
- Viewpoint 14: Bruce's Stone, Glen Trool; and
- Viewpoint 15: A77 by Cairnpat.

6.4.5 Summary of Detailed Night Time Assessment

42. Detailed visual assessment of night time viewpoints is presented in Section 6.4 of this report and summarised as follows:

- For receptors at Viewpoint 4 – SUW (West of Derry), the magnitude of change for a 2000cd or a 200cd light would be increased in comparison to visual effects experienced during the day. Both the 2000cd light and 200cd light scenarios are predicted to result in a High magnitude of change resulting in a Significant night time effect.
- For receptors at Viewpoint 6 – Minor Road Bennylow (Culvennan Fell), the magnitude of change for a 2000cd or a 200cd light would be increased in comparison to visual effects experienced during the day. A slightly higher magnitude of change was predicted for the 2000cd light compared to the 200cd light although neither scenario is predicted to result in a significant night time effect;
- For receptors at Viewpoint 14 – Bruce's Stone in the DSP, the magnitude of change for a 2000cd or a 200cd light would be increased in comparison to visual effects experienced during the day. A slightly higher magnitude of change was predicted for the 2000cd light compared to the 200cd light. The 200cd light is not predicted to result in a significant effect. The 2000cd light is predicted to result in a significant effect however, it should be noted that this outcome would only occur during periods of poor visibility (<5km visibility at the proposed Development turbines) at a distance of nearly 20km. Taking these factors into account the 2000cd light is highly unlikely to ever be experienced at the maximum intensity that results in this significant effect. This finding exemplifies the unrealistic worst-case position and precautionary approach taken in this assessment (as described in section 6.3.4. of this TA); and
- For receptors at Viewpoint 15 – A77 by Cairnpat the magnitude of change for a 2000cd or a 200cd light would be increased in comparison to visual effects experienced during the day. A slightly higher magnitude of change was predicted for the 2000cd light compared to the 200cd light although neither scenario is predicted to result in a significant night time effect.

6.4.6 Cumulative Assessment of Visible Turbine Lights

43. Whilst there are no turbine lights currently operating in the Study Area for the proposed Development, it is recognised that other planned developments within the Study Area have proposals for visible aviation lighting and that these lights could be seen in conjunction with the proposed lighting for the proposed Development. When considering the representative viewpoints to assess the visual effects of lighting for the proposed Development, the Arecleoch Extension and Clauchrie application turbine lights would be seen from Viewpoint 6 (Minor Road Bennylow, Culvennan Fell). From this location, the Arecleoch Extension turbines are largely screened by the intervening landform of Craig Airie Fell and only two of the turbine hub lights would be potentially visible as lights close to the horizon to the east of the proposed Development lighting. The Clauchrie windfarm turbines lights would appear above the northern skyline in this view. These additional proposals for turbine lighting would be viewed at distance from this location (Arecleoch Extension 18 km and Clauchrie 23 km) and as a result would be far less visible from this location than the lights of the proposed Development. There is a cumulative interaction in the sense that all of these lights could potentially be viewed from this location simultaneously increasing the amount of the horizon potentially populated by turbine lighting. On balance, when considering the addition of the proposed Development lighting to a baseline that includes Arecleoch Extension and Clauchrie lights the magnitude of change is considered to be broadly similar to the assessment of the visual effect of the proposed Development turbine lights due to the diminished intensity of the cumulative application scenario lights that would appear in the future baseline. As a result no further increase in effect would occur as a result of this potential cumulative situation.

6.5 Potential Further Mitigation

44. Based on the graph in **plate TA 6.2.**1, the vertical elevation angles for the viewpoints and resultant perceived intensity of light are calculated in the following **Table TA 6.2.1**. This table confirms that all 4 viewpoints are positioned below 0 degree vertical angle from the horizontal plane of the light fittings. **Figure TA: 6.2-5** illustrates where negative elevation angles (ranging from 0 to 3 degrees vertical angle above the horizontal plane and 0 to -10 degrees vertical angle below the horizontal plane) would occur within the predicted full extent ZTV for the proposed lit turbines of the proposed Development.

Table 6.2.1: Viewpoint Lighting Intensity Calculations

Viewpoint	Distance to nearest turbine (m)	Vertical Angle from Horizontal plane of light location to viewpoint location	Approximate intensity for each viewpoint allowing for vertical angle	
			2000cd light	200cd light
Viewpoint 4: SUW (west of Derry)	2877	**-2.67º**	40cd	4cd
Viewpoint 6: Minor Road Bennylow (Culvennan Fell)	7471	**-1.03 º**	500cd	50cd
Viewpoint 14: Bruce's Stone, Glen Trool	19484	**-0.48 º**	1250cd	125cd
Viewpoint 15: A77 by Cairnpat	22544	**-0.53 º**	1250cd	125cd

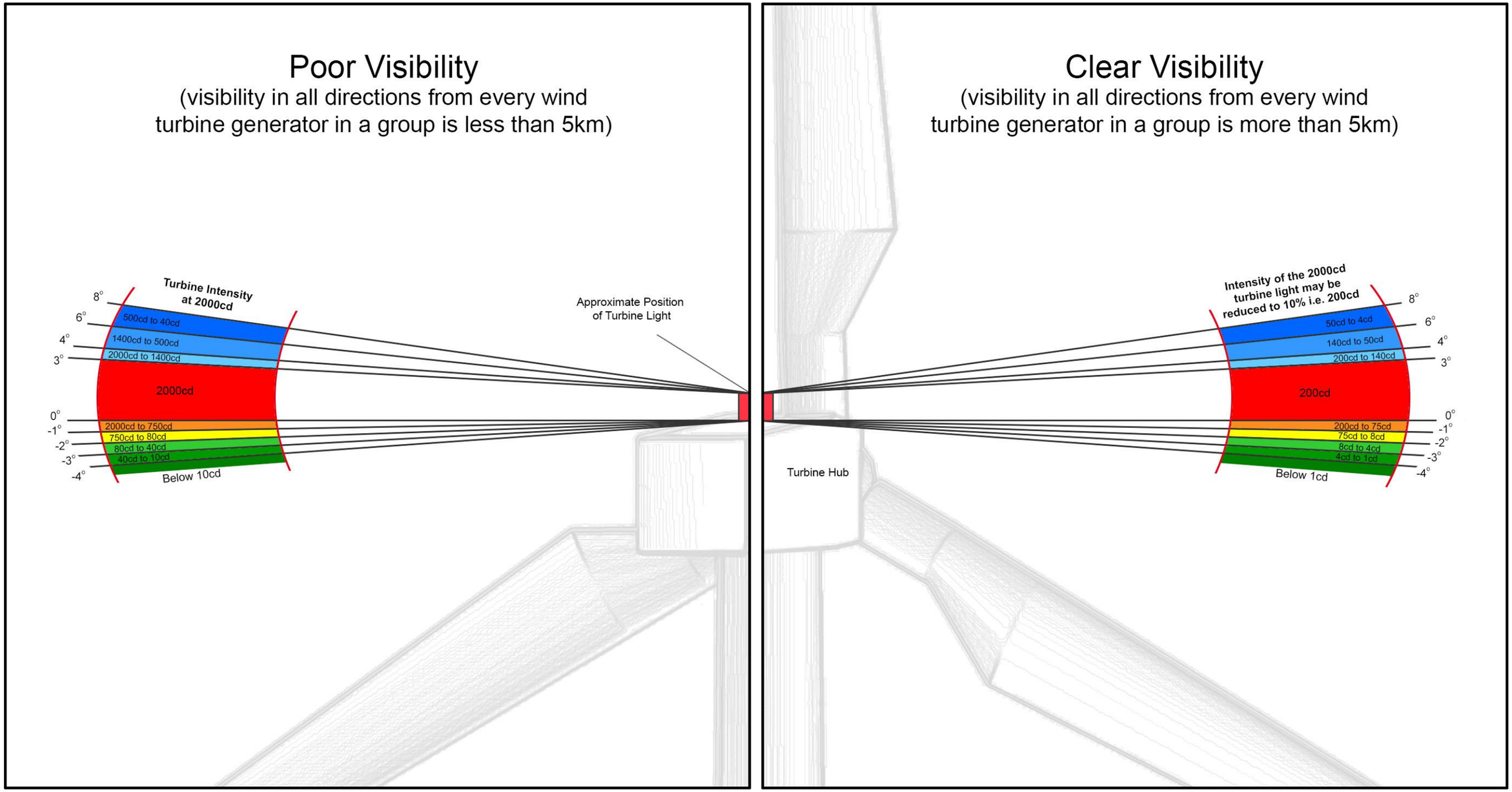

Plate TA 6.2.2 Diagrammatic interpretation of minimum requirements of ICAO/CAP393 (LuxSolar Medium Intensity Obstruction Light)

Note the turbine in the diagram is only split vertically to illustrate the difference between the light intensity in poor visibility (2000cd) and clear visibility (200cd). The turbine light is designed to emit the same light intensity horizontally in 360 °.

45. Based on the graph in **plate TA 6.2.**1, a diagrammatic interpretation of the minimum requirements of ICAO/CAP393 along with the manufacturers measured intensity calculations is shown in **Plate TA 6.2.2**. It illustrates the potential light intensity from a medium-intensity nacelle mounted aviation light, based on the ICAO minimum standard of 2000cd minimum average intensity required over +3° beam spread from the horizontal. It also provides illustration of the likely light intensity in poor visibility <5km (2,000cd) and clear visibility >5km (200cd)

46. With specific relation to the proposed Development, **Figure TA: 6.2-5** - Lighting Intensity ZTV, illustrates where the vertical angles shown in the graph on **plate TA: 6.2.1** occur on the landform of the Study Area along with the corresponding intensity reductions for each of the 2000cd and 200cd situations. It is clear from **Figure TA: 6.2-5** that the full intensity of the lights would only theoretically be experienced from a small proportion of the Study Area when on similar or more elevated terrain[5].

47. **Figure TA: 6.2-5** illustrates that the vast majority of the area between 5km and 20km would experience the turbine lighting at a vertical angle of between 0 and -2 degrees, which would result in an approximate range of lighting intensity of between 2000-80cd when visibility <5km and 200-8cd when visibility >5km. The majority of the area within 5km of the proposed Development would experience the turbine lighting at a vertical angle of between -1 and -3 degrees, which would result in an approximate range of lighting intensity of between 750-40cd when visibility <5km and 75-4cd when visibility >5km. The maximum intensity of the turbine hub light (2000cd in visibility <5km and 200cd in visibility >5km) is largely shown on elevated areas to the east on the upper slopes of the Galloway Hills and on the slopes and to the north on Benerairdand closely surrounding hills. Closer to the Site, this maximum intensity is also found on hills within the context of the operational Kilgallioch windfarm including Craig Airie Fell, Benbrake Hill and Far Cairn.

    Whilst as noted in section 6.3.1, this Technical Appendix adopts a precautionary worst-case approach in this visual assessment, these approximate intensity calculations illustrate that whilst there is potential visibility of turbine lights at locations shown on the Turbine Hub Light ZTVs (**Figures TA6.2-1 and TA6.2-2**) the intensity of these lights would vary as illustrated on **Figure TA6.2-5** using the approximate lighting intensity levels of the LuxSolar Medium Intensity Obstruction Light referred to in this TA.

48. In addition to the control measures that may be applied to dim the lighting, as described above, it is proposed to explore the possibility of using 'smart' aviation lighting (aviation obstruction lighting detection system) whereby the lights would only be switched on when aircraft approach them (see **Chapter 14, Section 14.2 Aviation**).

49. The CAA is in the process of consulting on a new policy statement on En-Route Aviation Detection Systems for Wind Turbine Obstruction Lighting Operation. SPR has had an opportunity to review the CAA's proposal as part of an industry working group considering this guidance. It is expected that this guidance will be finalised and released during 2019.As this technology is not yet fully approved at the time of writing, the assessment has not considered this mitigation in its conclusions. The draft guidance would allow the aviation lights only to be illuminated when an aircraft is detected by a radar entering a volume bounded by 4 km (horizontal distance) from the perimeter group of turbines and 300m above the highest turbine tip of the Site. Our calculations estimate that the upper boundary of this volume would be around 2500 ft above ground level[6]. The aviation lighting would not be activated when commercial airlines pass over the Site as such aircraft ordinarily operate in Controlled Airspace (CAS), the base of which CAS over the Site being 5,000 ft and above. Given the lights are only required for general aviators flying at night in the vicinity of the Site at altitudes of up to 2500 ft, it is anticipated that the lights will be rarely on in this quiet airspace.

50. The widest transit across the proposed Development is circa 2.15 km (approx. west to east between Turbine 02 and Turbine 01), then the horizontal coverage volume would be 10.15 km (4+2.15+4). At 125-250 knots (250 kt is the maximum speed permitted below 10,000ft) the lights would be on for between approximately 1.5 and 3 minutes, provided the radar can track the aircraft across the windfarm. If radar activated lighting is required, this would require a separate planning application, radar licencing and relevant CAA approvals. Optimally, any such radar deployment could benefit multiple windfarms in the South Ayrshire or Dumfries and Galloway regions.

51. If this technology could be installed, the level of exposure of visual receptors in the area to turbine lights would be greatly reduced, in line with the amount of time during which passing air traffic would activate the aviation lights. As this technology is not yet approved, the assessment has not considered this mitigation in its conclusions.

6.6 Conclusion

52. The visual effects of turbine lighting were considered from 4 agreed viewpoints. At night the turbines would not in themselves be visible during times of darkness. Nevertheless, the assessment of night time effects for the proposed Development has predicted significant effects where effects were assessed as not significant during the day for viewpoint 14 at Bruce's Stone in the DSP (2000cd lighting intensity only). This is largely due to the appearance of lighting on an upland horizon which is currently far less affected by the effects of any other existing lighting and the particular view towards the proposed Development is a narrow focussed view along Glen Trool which draws the eye towards the location of the proposed Development. The visual effect of lighting at viewpoint 14 is not found to be significant when visibility is greater than 5km from the proposed Development and the turbine lights are operating at 200cd. Significant effects found at viewpoint 4 are largely as a result of the close proximity to the proposed Development (both 2000cd and 200cd lighting intensity).

53. The duration of the effect of the lights on receptors is likely to be over a relatively short period, more commonly experienced during evening and morning hours of darkness, around dusk and sunrise. The ICAO standard requires the lights to be switched on 30 minutes after sunset, removing the likelihood of visible lighting during twilight. The visual effects of the proposed Development at night would also be limited by the activity of receptors at night. Receptors that experience views at night are generally limited to residents of settlements, rural properties and motorists using the road network although receptors within the Dark Sky Park would also be affected. Views from within properties are likely to be restricted by the use of window coverings, particularly in winter. Views from remote rural / coastal locations, beaches, mountains and footpaths etc. are visited infrequently at night therefore numbers of receptors affected will be low. The assessment of night time effects is also based on clear night time viewing conditions. At dusk and sunrise it may be possible to identify the formation of the turbines with the lighting switched on, but only in conditions of good and excellent visibility. At sunrise it may also be possible, in views from the west, to see the turbines with lights switched on whilst backlit by the rising sun.

[5] Based on the emissions of the LuxSolar Medium Intensity Obstruction Light, referenced in this report.

[6] In terms of the maximum height of the coverage volume, this is calculated as follows (300m above the highest part of the turbine or group of turbines). The highest height above sea level within the proposed Development is turbine 7 located at 199 m AOD (rounded up to the nearest 10m contour). With 180 m turbines and 300 m above the highest part of the turbine, the maximum height of the radar coverage required would be 679 m or 2227 ft, rounded up to 2500 ft.

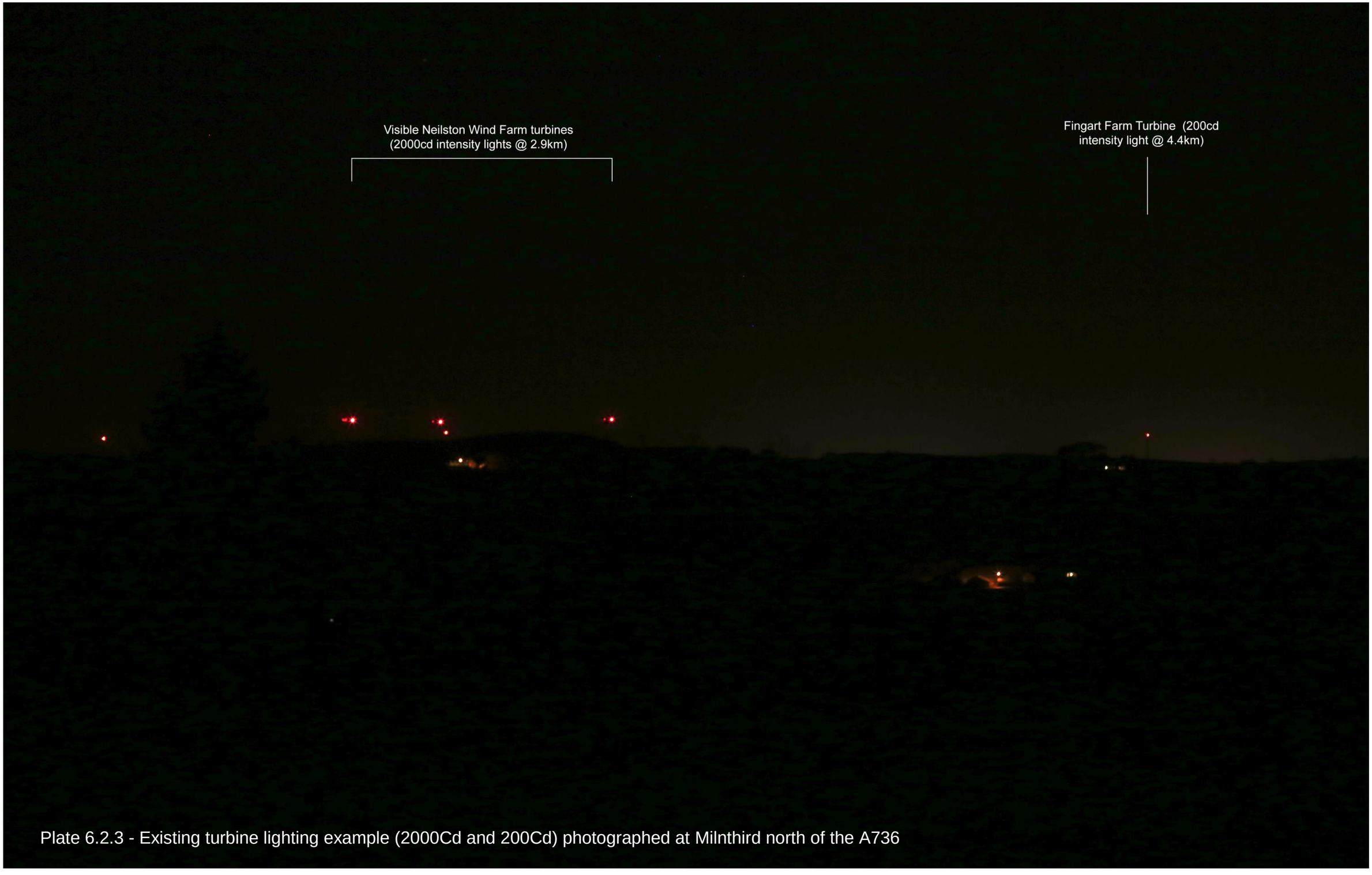

Plate 6.2.3 - Existing turbine lighting example (2000Cd and 200Cd) photographed at Milnthird north of the A736

6.7 Detailed Night Time Visual Effects

Receptor	Night Time Effects			Potential Further Mitigation
	Night Time Baseline Condition and Sensitivity	**Night Time Effect (2000cd lights)**	**Night Time Effect (200cd lights)**	Reduced Lighting Intensity based on the measured intensity of the 'LuxSolar Medium Intensity Obstruction Light' at different vertical angles, as explained in section 6.3.4 of this TA.
Viewpoint 4: SUW (west of Derry) Nearest Visible Turbine Light: 2,877 m	This viewpoint represents views from the SUW at night when in reasonably close proximity to the proposed Development lights (2.8 km). Views to the south and west during the day are across a foreground landscape of moorland with a backdrop of forestry and existing windfarms. At night, however, individual landscape elements that create different landscape patterns in the view are difficult to discern. There is no existing lighting context in the view to the south and west and the overall impression of the night time view at this location is of a very dark upland landscape. In the evening the contrast between land and sky on the west skyline can be seen beyond dusk as the setting sun maintains a low glow against the skyline to the west for a sustained period. The effect of this is more prolonged in summer months. The value and visual susceptibility of walkers on the SUW differs at night when compared to the assessment carried out for day time conditions. During the night the landscape has a diminished scenic quality and walking receptors would not have the same appreciation of the landscape which is dark and muted compared with the landscape scenery evident during the day. Taking these factors into account, the night time Sensitivity of this location is considered to be Medium.	All of the 11 proposed Development hub lights would be visible from this location and 8 of the proposed tower lights would also be visible. The proposed Development lights would be seen as an introduction of lights to a part of the upland horizon where none are currently seen, with no existing lighting present in any other direction of view. The location of the viewpoint relative to the prevailing south westerly wind would mean that the lights on the hubs would at most times be seen in front of the rotors and would not be intermittently obscured by intervening blades. On this basis they would not appear to flicker as the turbine blades pass the hub and tower lights. The proximity of the proposed Development combined with the dark upland backdrop would increase the relative intensity of the turbine lights and it is considered these lights would form a substantial addition to the existing baseline. The magnitude of change is assessed as High resulting in a **Significant** effect.	The description of lights visible for 2000cd also applies to 200cd lights. The effect differs slightly but given the close proximity of the proposed Development, the reduction in intensity to 200cd lights in this instance would not result in a reduced magnitude of change. It is considered that the 200cd lights would also form a substantial addition to the existing baseline and the magnitude of change is assessed High resulting in a **Significant** effect.	In periods of poor visibility (<5km) a 2000cd light would be required which at this viewpoint would be perceived as 40cd. In periods of clear visibility (>5km) the 2000cd light may be dimmed to 200cd, resulting in an intensity at the viewpoint of 4cd. (See Table 6.2-1).
Viewpoint 6: Minor Road Bennylow (Culvennan Fell) Nearest Visible Turbine Light: 7,471 m	This viewpoint represents road users at night who would have elevated views towards the proposed Development lights when travelling north bound during the hours of darkness. There is some existing lighting in the mid-distant landscape at the isolated properties of West Culvennan, Dirnow and Drumabrennan. Occasional vehicle lights are seen either crossing the view along the minor road to New Luce or on the section of road immediately to the north of the viewpoint. Whilst these lights can be seen from this location, they are a small part of the overall baseline lighting level which is considered to be very dark. During the day, the landscape in the view has a simple land use pattern and the evidently man modified commercial forestry and existing turbines reduce susceptibility. However, at night these elements would not be discernible and the susceptibility to wind turbine lighting is unmoderated by the presence of other wind turbines. Taking these factors into account, the night time Sensitivity of this location is considered to be Medium.	All of the 11 proposed Development hub lights would be visible from this location. 6 of the proposed tower lights would also potentially be visible but at 7.4 km, these low intensity lights would not be as noticeable within the context of the medium intensity nacelle lights. The proposed Development lights would be seen as an introduction of lights to a part of the upland horizon to the north where there is very little existing lighting. The location of the viewpoint relative to the prevailing south westerly wind would mean that the lights on the hubs would mostly be intermittently obscured by intervening blades so that they would appear to flicker as the turbine blades pass the hub and tower lights. The proposed Development lighting would appear as a noticeable addition when combined with the dark upland backdrop resulting in a Medium magnitude of change. The combination of sensitivity and magnitude in this instance would result in a **Not Significant** effect.	The description of lights visible for 2000cd also applies to 200cd lights. The effect differs, however, due to a reduction in intensity. It is considered therefore that the 200cd lights whilst still apparent would not form a readily noticeable addition to the existing baseline. The magnitude of change is assessed as Medium-Low resulting in a **Not Significant** effect.	In periods of poor visibility (<5km) a 2000cd light would be required which at this viewpoint would be perceived as 500cd. In periods of clear visibility (>5km) the 2000cd light may be dimmed to 200cd, resulting in an intensity at the viewpoint of 50cd. (See Table 6.2-1).
Viewpoint 14: Bruce's Stone, Glen Trool Nearest Visible Turbine Light: 19,484 m	The effect of the proposed Development during the day was scoped out of the detailed viewpoint assessment due to distance from the proposed Development and the existing cumulative development which is seen in the same part of the distant view west. Bruce's Stone is within the Galloway Forest Park and is one of the Dark Sky Park viewing locations. As a result the viewpoint at night is considered to have a higher value than other nearby locations in Glen Trool as it is a location in which visitors are directed to in order to view the night sky and is easily accessible from the nearby car park. There is no visible lighting in the baseline view and car lights are not evident due to screening from the trees found along the road leading up to the car park area. The high hills that surround the glen act as shielding to part of the sky to the north and south and to some degree also to the east. The amount of sky available to	All of the 11 proposed Development hub lights and proposed tower lights would be visible from this location. At 19.4 km the low intensity tower lights would be barely discernible. The location of the viewpoint relative to the prevailing south westerly wind would mean that the lights on the hubs would at most times be seen in front of the rotors and would not be intermittently obscured by intervening blades. On this basis they would not appear to flicker as the turbine blades pass the hub and tower lights. The proposed Development lights would be seen as an introduction of lights to a location where there is currently no visible lighting. The distant night time view of the plateau landscape to the west is a focus from this location due to the high sided glen and evening sunsets which frames and channels the viewers' attention	The description of lights visible for 2000cd also applies to 200cd lights. The effect differs, however, due to a reduction in intensity. It is considered therefore that the 200cd lights whilst still perceptible would not form as noticeable an addition to the existing baseline as the 2000cd lights. The magnitude	In periods of poor visibility (<5km) a 2000cd light would be required which at this viewpoint would be perceived as 1250cd. In periods of clear visibility (>5km) the 2000cd light may be dimmed to 200cd, resulting in an intensity at the viewpoint of 125cd. (See Table 6.2-1).

Receptor	Night Time Effects			Potential Further Mitigation
	Night Time Baseline Condition and Sensitivity	Night Time Effect (2000cd lights)	Night Time Effect (200cd lights)	Reduced Lighting Intensity based on the measured intensity of the 'LuxSolar Medium Intensity Obstruction Light' at different vertical angles, as explained in section 6.3.4 of this TA.
	viewers at this location is therefore not as extensive as it would be from a more elevated position. The view to the west (and towards the proposed Development Site) is framed by these same hills. In the evening the contrast between land and sky on the west skyline can be seen beyond dusk as the setting sun maintains a low glow against the skyline to the west for a sustained period. The effect of this is more prolonged in summer months. The framed view and lingering sunsets create a focus for views at dusk from this location. Equally the dawn sunshine breaking across the hills seen at the head of the Glen to the east creates an attractive sunrise across Loch Trool. Taking these factors into account, the night time Sensitivity of this location is considered to be High.	in this direction. The distance from the proposed Development would reduce the intensity of the turbine lighting experienced at this location, however, it is considered these lights would still form a noticeable addition to the existing baseline view of sensitive receptors within the Dark Sky Park who would be at this location to view the night sky and whose views are focussed along Glen Trool. The magnitude of change is therefore considered to be Medium - Low resulting in a **Significant** effect.	of change is assessed as Low resulting in a **Not Significant** effect.	
Viewpoint 15: A77 by Cairnpat Nearest Visible Turbine Light: 22,544 m	This viewpoint is located on an elevated section of the A77 that crosses the Rhinns Peninsula and that has views to the east towards the upland plateau moorland and forestry landscapes in which the majority of existing turbines in the Study Area are located. During the day these turbines are a visible element in the distant view. The national speed limit applies and whilst this section of the road is winding, road speeds were noted to still be between 50-60 mph. The section of road close to the viewpoint is directly facing the location of the proposed Development increasing road users susceptibility. A few isolated properties are located nearby although views from these properties are focussed on a southerly aspect towards the Machars and the distant coastline. At night the landscape in the view is more difficult to discern and appears dark and muted, as a result the intervening horizons and successive layers of differently textured landscapes (between foreground and background landscape) is not apparent. There are existing lights of isolated properties and vehicle movement close to the viewpoint. Existing lights are also seen in the Machars but are far less apparent due to distance. There are no permanent lights visible on the upland landscape where the proposed Development would be located although car lights were noticed on the skyline in the same part of the panorama as Artfield Fell when carrying out the night time survey at this viewpoint. Taking all of this into account, the night time Sensitivity of this location is considered to be Medium.	All of the 11 proposed Development hub lights would be visible from this location. 4 of the proposed tower lights would also potentially be visible but at 22.5 km, these low intensity lights would be barely discernible. The proposed Development lights would be seen as an introduction of lights to a part of the upland horizon to the north east where there is no permanent existing lighting and only the occasional vehicle movement close to the horizon. The proposed Development lighting would appear as distant features of the night skyline to the north east, backclothed by the distant Galloway Hills. The location of the viewpoint relative to the prevailing south westerly wind would mean that the lights on the hubs would mostly be intermittently obscured by intervening blades so that they would appear to flicker as the turbine blades pass the hub and tower lights. It is considered that the proposed lights would form a new feature in the night time view which within the context of the distant and dark upland backdrop would appear as a series of relatively low intensity lights on the distant skyline. The magnitude of change is considered to be Medium – Low resulting in a **Not Significant** effect.	The description of lights visible for 2000cd also applies to 200cd lights. The effect differs, however, due to a reduction in intensity. It is considered therefore that the 200cd lights whilst still perceptible would not form as noticeable an addition to the existing baseline as the 2000cd lights. The magnitude of change is assessed as Low resulting in a **Not Significant** effect.	In periods of poor visibility (<5km) a 2000cd light would be required which at this viewpoint would be perceived as 1250cd. In periods of clear visibility (>5km) the 2000cd light may be dimmed to 200cd, resulting in an intensity at the viewpoint of 125cd. (See Table 6.2-1).

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