Technical Appendix 7.5: Aviation Lighting Assessment

Contents

1.0 Introduction

This Technical Appendix sets out an evaluation of the effects of the lights of the Proposed Development on the visual amenity of the local area during times when the turbines are lit. The assessment is supported by:

- a Zone of Theoretical Visibility (ZTV) showing the areas from which the lights will be theoretically visible (Figure 7.8); and
- night-time visualisations from five viewpoints (as shown on Figure 7.8):
  - VP1 A701 Source of the Tweed Layby (Figure 7.13);
  - VP3 A701 layby south of Glenbreck (Figure 7.15);
  - VP8 Tweedsmuir Bridge (Figure 7.20);
  - VP9 Fruid Dam (Figure 7.21); and
  - VP11 Talla Linn (Figure 7.23).

The assessment draws upon the Aviation Lighting and Mitigation Report provided in Technical Appendix 16.1 prepared by Wind Power Aviation Consultants Ltd (WPAC).

1.1 Regulations and Guidance

As the proposed turbines would be over 150 m to blade tip, they are above the threshold for Civil Aviation Authority (CAA) Regulations for lighting (CAA, 2016). The CAA requirements include:

- medium intensity steady red (2000 candela) lights on the nacelles;
- a second 2000 candela light on the nacelles to act as alternates in the event of a failure of the main light (note that both lights should not be lit at the same time);
- the lights on these turbines to be capable of being dimmed to 10% of peak intensity when the lowest visibility (as measured at suitable points around the wind farm by visibility measuring devices) exceeds 5 km; and
- intermediate level 32 candela lights to be fitted on the turbine towers.

Infrared lighting as required by the Ministry of Defence (MOD) is not visible to the naked eye and is therefore not considered further.

Chapter 16 and Technical Appendix 16.1 advise that a reduced lighting scheme has been agreed to by the CAA, such that only three of the proposed turbines (Turbine 1, Turbine 3, and Turbine 6) would be lit with medium intensity steady red (2000 candela) lights on the hubs (plus back-up light), that can be dimmed to 10% when visibility exceeds 5 km. No tower lights are proposed. The other four turbines (Turbine 2, Turbine 4, Turbine 5, and Turbine 7) would not be lit with visible aviation lighting.

Guidance on Assessment of Lighting Effects

The Guidelines for Landscape and Visual Impact Assessment (3rd edition, GLVIA3) recognise that sometimes there is a need for assessment of lighting effects for development (not solely wind farms) and includes the following guidance: "*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*."

NatureScot guidance on the preparation of visualisations for wind farms relating to dark photomontages states: "*It is difficult to illustrate turbine lighting well in visualisations, although some recent examples which use photographs taken in low light conditions (just before or after sunrise / sunset) have been more useful.*" And "*Where an illustration of lighting is required, a basic visualisation showing the existing view alongside an approximation of how the wind farm might look at night with aviation lighting may be useful*" (SNH, 2017).

Regarding the selection of viewpoints for illustration of night-time lighting, NatureScot state that illustration "*is only likely to be required in particular situations where the wind farm is likely to be regularly viewed at night (e.g. from a settlement, transport route) or where there is a particular sensitivity to*

lighting (e.g. in or near a Dark Sky Park or Wild Land Area). Not all viewpoints will need to be illustrated in this way."

Advising on the preparation of images: "*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. It is only necessary to illustrate visible lighting, not infrared or other alternative lighting requirements. We have found that [photography taken at] 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. It is important that the photographs represent the levels of darkness as seen by the naked eye at the time and the camera exposure does not make the image appear artificially brighter than it is in reality. It can also be helpful to note the intensity of other lights in the area to enable comparison (e.g. television transmitters) as this can aid the assessment process."*

NatureScot, at a seminar on aviation lighting in November 2019, advised a proportionate and pragmatic approach to lighting assessments. NatureScot's view is that lengthy and detailed debate about the exact brightness of lights is not very helpful and that it is better to discuss relative brightness and to focus on where they will be visible, and how they will change the baseline night view. However, it is considered that the perceived brightness of the lights that will be observed from each viewpoint is important to understand, including an understanding of atmospheric dispersal, attenuation by distance, angle of view relative to the focus of the light, and darkness adaptation, in order to be able to make a meaningful assessment of visual effects.

1.2 Examples of Lighting

The intensity of light emitted is measured in candela (cd), but the apparent brightness of light received from low intensity lights by the human eye is measured in microlux (microlumens per m^2). These units can be difficult to use without translation into examples that may be familiar to viewers. Some examples include[1]:

- Planet Venus: 140 microlux;
- Orion constellation, upper left and lower right stars: 1.5-2 microlux;
- Orion constellation, 'belt' stars: 0.3 microlux;
- faintest light visible to a 'typical' person: 0.01 microlux; and
- car rear brake lights, although they vary, are in the order of 70-80 candela, and at 1 km may appear as 100 microlux.

NatureScot advises that quantitative analysis is 'less useful' for the assessment of effects on the night-time experience of the lights than qualitative comparisons with existing lights that people may be familiar with. However, it is clear from the science of lighting and as set out in Technical Appendix 16.1, that understanding the calculated light intensities and brightness of lights (quantitative) is important to be able to carry out an assessment, even in a relative (qualitative) way. It is important to note that specifications for existing lights in the landscape are not available, such that comparisons cannot be quantitative.

The apparent brightness of the light (received by the human eye) depends not only on how much light is emitted (intensity), but also on intervening atmospheric conditions (rain, fog, dust, haze, etc) that cause atmospheric dispersal of light; the lit environment of the viewer (standing in a well-lit area or a dark place); and the distance from the light source. The apparent brightness reduces with distance (attenuation) in clear weather as well as when there are poorer viewing conditions. Brightness reduces with the square of the distance (x=1/distance2), such that a light observed from a distance of 10 km will have an apparent brightness only 1 % of that of the same light observed from a distance of 1 km. This assessment therefore assumes that over approximately 20 km, the lights are likely to go unnoticed.

When lights are designed to give a horizontal beam with reduced upward and downward spill of light, the brightness of the light is decreased for viewers close to the turbines viewing them from below.

An important factor for perception of light is the different ways that cameras and human eyes perceive light. Cameras are governed by lenses and settings, human eyes adapt to different light environments (for example it can seem very dark when lights are first switched off, until one's eyes become accustomed to the dark). Dark adaptation of the human eye is related to the 'rods' and 'cones', light-detecting cells in the back of the eye that have different roles in low light levels, with rods taking over from cones when it is dark. Cones detect colour and are used in the light (being less sensitive in low light levels), while rods are not as good with colour but can pick up faint lights (they switch off in bright light). Dark adaptation is when the rods can fully activate and can make out faint lights in a dark environment, but as soon as a light is switched on, even briefly, cones take over again and it takes time for the rods to

[1] See also Technical Appendix 16.1.

reactivate. Lights clearly visible to dark-adapted eyes may be imperceptible when other lights are first switched off (before dark adaptation can occur), or when in a bright place such as under street lights or from within a dark vehicle when much of the attention is on the pool of light from the headlights. In these environments, dark adaptation cannot occur in full as the rods in our eyes cannot fully take over. It is noted that most people will be close to lights after dark, either in lit houses/properties, or in vehicles with headlights on. This makes the perception of other lights more difficult.

In contrast, cameras do not have any adaptation, but light capture depends on exposure and camera settings (modern cameras may have auto-adjust or 'night mode', but this is not adaptation in the same way as the human eye). This means that images can be very different to what we experience. An issue for photographic capture and rendition of lights is that existing lights shown in photographs can appear larger and more blurred than those seen by the naked eye in the field. 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 is difficult to avoid when taking photographs of lights (particularly moving lights such as vehicle headlights). To best model the lights as if they were existing, this effect has been added to the hub lights in the viewpoint illustrations.

It is not possible to accurately model the exact brightness of the lights, given variations in not only light specifications and camera settings, but also weather and atmospheric conditions at the time of photography, as well as the resolution and colour calibration of a computer screen, ambient light when viewing images on screen, and finally printer resolution and paper quality. However, the lights illustrated on the figures have been 'calibrated' as best possible using comparison with images of other lights in the views, and other examples of existing potentially equivalent lighting[2] observed in the Scottish Borders, and other lights on wind farms in other parts of Scotland.

The duration of effects of the lights depends on when the lights are switched on and off. Sunset occurs when the sun disappears below the horizon, sunrise is the time at which the sun first appears on the horizon in the morning. The exact times of sunset and sunrise vary throughout the year. Although it is not visible, the sun still illuminates the sky with diffused light for a period of time after sunset and before sunrise, known as twilight. There are different stages of twilight:

- Evening civil twilight begins once the sun has disappeared below the horizon and lasts about half an hour after sunset, morning civil twilight includes also the half hour before sunrise. Civil twilight is still bright, such that the aviation lights are unlikely to be very visible against the bright sky. Aviation lights will be switched on during evening civil twilight and switched off during morning civil twilight.
- Nautical twilight lasts for approximately half an hour after civil twilight in the evening, or before civil twilight in the morning (landforms are still visible while the stars start to appear and so it is a valuable time for navigators at sea). During this phase the aviation lights will be on and will become more visible as the daylight diminishes.
- Astronomical twilight is when landforms are not visible but the sun still illuminates the sky a little. Full night is when the sun no longer illuminates the sky.

It is noted that it does not necessarily get completely dark, with lingering light on short summer nights, moonlight, or the glow from settlement lights, and light reflected off clouds. In these conditions, the turbines may be partially visible over short distances at different times of night, and the apparent brightness of the lights may be affected by other lights, e.g. when seen against the late sun-lit clouds in views towards the west or seen from well-lit areas. Conversely, there will be evenings and mornings that are darker due to weather conditions such as thick cloud cover.

[2] Comparison with other existing lights should be done cautiously, as brightness and characteristics of other lights is not known.

2.0 Methodology and Approach

2.1 Assessment Methodology

The methodology and approach to the assessment of significance of lighting effects are based on the methodology of the LVIA, which is based on GLVIA3 (LI and IEMA, 2023) as set out in Technical Appendix 7.1. Key aspects relevant to the visual assessment of aviation lighting include:

- identification of baseline lighting at night, including existing lights of local properties and existing wind farms or other structures visible, as well as areas of darkness;
- information about likely brightness of lighting seen from viewpoints (based on information in Technical Appendix 16.1[3]);
- description of lighting relative to the existing lights; and
- assessment of effect on the night-time view as a result of the introduced lights.

In considering sensitivity of receptors and magnitude of change to arrive at a judgement of significance of effects, the following is noted.

- Guidance on sensitivity is generally in relation to day time views. Night-time sensitivity is very different. At night, viewpoints of high value and susceptibility may be of low sensitivity because people do not go there to see the dark. Locations within Dark Skies Parks are an exception to this as people go to experience the dark and observe the stars, but for most places, sensitivity is low as people move through or between lit spaces (turning lights on or using headlights as necessary) and usually view darker landscapes from better lit locations. However, consideration of night-time sensitivity also needs to include how many people will be at that location to see the night-time view (many on main commuter roads in winter, to none on mountain tops) and who will see the view (residents who may go out of their homes to see the night sky, or road users who will be focussed on the road ahead lit by headlights).
- The change to night views includes consideration of baseline lighting in the view and the proposed lights, including intensity and position in the view in relation to existing lights, as well as colour, nature (steady or flashing) and duration.

Changes to night-time viewing experiences are considered briefly for all viewpoints, with those where the lights are considered to be more noticeable discussed in more detail.

The likely brightness of the lights seen from each viewpoint is a function of emitted light and angle of view (reduced downward light spill from a horizontal beam design), as well as distance attenuation and atmospheric conditions. The assessment below considers potential brightness of the lights in clear conditions. Technical Appendix 16.1 sets out tables of predicted maximum brightness for each light from each viewpoint, based on clear-air conditions with no attenuation by scatter/absorption by air-borne dust, droplets or aerosols.

Fieldwork

Field visits undertaken for the LVIA between September 2022 and April 2024 included observations made after dark. Fieldwork and photography specific to the night-time lighting assessment was undertaken in September 2023 to April 2024.

ZTV Modelling

ZTV mapping has been carried out to identify the theoretical visibility of the hub lights. It is noted that the ZTV uses a bare ground model and does not account for local screening by woodlands or buildings. The ZTV on Figure 7.3 is calculated to show visibility of all hubs to 45 km. Figure 7.8 shows the visibility of the aviation lights, calculated to 20 km and the hub height for the lit turbines only, and is coloured to illustrate the downward angle of view (from the light to the viewer) and therefore indicates the brightness emitted at that angle. It does not include attenuation by distance, nor does it take account of variations in atmospheric conditions.

Production of Visualisations

Photography for night-time photomontages to illustrate potential effects of aviation lighting was carried out in the evening. A set of photographs was taken prior to sunset to ensure that the camera was correctly set up, and to allow cross reference between lights caught on dark photographs and buildings caught on day time photographs. A series of photograph sets were taken over a period of about an hour

[3] It is noted that TA16.1 used the slightly different locations for the viewpoints, that were proposed prior to photography being completed. The grid references are therefore slightly different from the viewpoints in TA7.3, but this does not alter the findings of brightness in TA16.1 or findings of effect in this assessment.

and a half from sunset into nautical twilight. This enabled the photographer to take multiple sets as the sky darkened, with varied camera settings. Downloaded sets were then reviewed to select a set that best matched NatureScot advice on having the sky relatively dark and other lights in the landscape on, but the form of the landscape still visible.

Photomontages prepared for night-time views using photography taken during twilight were produced using the same method as for daylight photomontages (methodology as set out in Technical Appendix 7.1), with turbines rendered in black as silhouettes. Images of aviation lights are provided for indicative illustration only and have been modelled on the basis of approximately 2000 cd for viewpoints within 5 km, and 200 cd for more distant locations, with attenuation for distance and using information from Technical Appendix 16.1.

3.0 Scope of the Assessment

The assessment of effects of aviation lighting at night considers the visibility of lighting at viewpoints, with the provision of dusk montages for five viewpoints:

- VP1 A701 Source of the Tweed Layby (Figure 7.13);
- VP3 A701 layby south of Glenbreck (Figure 7.15);
- VP8 Tweedsmuir Bridge (Figure 7.20);
- VP9 Fruid Dam (Figure 7.21); and
- VP11 Talla Linn (Figure 7.23).

It is noted that NatureScot and Scottish Borders Council requested additional viewpoints including VP5 Tweedsmuir Village Hall, VP13 Hart Fell, and VP17 Lowther Hill to be included in the aviation lighting assessment. These locations are considered below, but no dusk visualisations are provided.

Settlements are places where people are most likely to be at night but are also where there is abundant lighting. From well-lit areas, faint lights are more difficult to see due to lack of dark adaptation. With lights nearby, although the lights of the Proposed Development may be visible from settlements, there will be no likelihood of significant effects. Settlements are therefore not considered further.

Routes can pass through dark areas between settlements, and although drivers' and passengers' attention is most likely to be on the road ahead corresponding with the area lit by the vehicle headlights, other lights in the landscape are also noticeable. Routes can be considered using representative viewpoints and knowledge of roadside screening by vegetation and buildings.

During the times when the lights will be on, the perception of the character of the landscape is reduced to nothing in darkness, such that whilst the lighting may be seen in views when the outlines of landforms and horizons will still be visible, the likelihood of significant effects on the perception of landscape character decreases rapidly with the onset of darkness. As such, an assessment of effects of aviation lighting on landscape character has been scoped out.

4.0 Baseline Lighting

The site itself is unlit, except for a light on the temporary meteorological mast on the site.This light is 32 candela flashing red. The closest properties to the site, including Oliver, Newbigging and properties of Tweedsmuir, have lights on and within buildings. Other farms and residential properties scattered across the study area have lights. There are no settlements within 10 km of the site that have streetlights; Broughton is the closest street-lit settlement, approximately 12 km to the north. Settlements within the study area tend to be set within valleys and are not generally large enough to create a notable glow in the sky ('skyglow'). Roads are a source of moving lights with vehicle headlights and rear lights seen frequently along roads, in particular on the A701, the M74 and the A702.

There are no existing wind farms with lit turbines within the study area.

Although comparison can be made with the 32 candela light on the temporary mast currently on site, no ready comparison can be made between the lights that would be installed at the Proposed Development and the lights on other features in the wider study area because their technical specifications are not known. The perceived brightness of a light at any given distance depends fundamentally on this specification. Additionally, the specifications of lights of the type required for wind farms are developing in response to the issues which may arise for visual amenity and may be different by the time construction is carried out.

5.0 Assessment of Visual Effects of Aviation Lighting

As stated above, three turbines (Turbine 1, Turbine 3, and Turbine 6) would be lit with a 2000/200 cd steady red light on the top of the hub (a second light on each hub would be installed as backup but would not be lit when the primary light is functional). The lights would come on during evening civil twilight and be turned off during morning civil twilight.

Mitigation includes the reduction of intensity of the lights during conditions of clearer visibility, such that the lights would only operate at full intensity of 2000 cd when visibility is less than 5 km. At other times they would be at 10%, i.e. 200 cd. Technical Appendix 16.1 sets out that Met Office meteorological data for the local area suggests that the hub lights would be at 2000 cd for 2% of the time and at 200 cd for 98% of the time, when the cloud-base is above hub height.

Candidate lights are designed to give a horizontal beam with reduced upward and downward spill of light, such that the brightness of the light is decreased for viewers close to the turbines viewing them from below. At angles steeper than -4° the lights should not be visible, although it is assumed that there would be a little light leakage, and from nearby locations the reflection of light on the passing blades would be visible. Angles discussed below and shown on Figure 7.8 are angles emitted from the bulb.

The lights on the proposed turbines will be brighter than the light currently on the temporary meteorological mast, which emits at 32 cd. They will be steady red lights, rather than flashing as the temporary meteorological mast light, but in some wind directions will have turbine blades passing between the light and the viewer such that they may appear to be intermittent. The lights will be placed on the top of the hubs, there will be some screening afforded by the shape of the hub itself for viewers below. For closer viewers in some conditions, some reflection of the light off the blades may occur when the blades are beyond the light relative to the viewer.

5.1 Analysis of ZTV

The aviation lighting ZTV on Figure 7.8 was modelled for the three turbines that are proposed to be lit: Turbine 1, Turbine 3 and Turbine 6. The ZTV is calculated to show the minimum vertical viewing angle for the lights visible at each point, i.e. the angle closest to the horizontal for the brightest light - which is not necessarily the closest turbine or the same turbine at each point. Whilst the ZTV does not indicate which turbine would be the brightest, it indicates the least amount of downward reduction in intensity. The ZTV illustrates that there would be greater (steeper) downward angles of view[4] when closer to the proposed turbines, and lesser (shallower) downward angles when seen from higher ground including the valley sides and hill tops. It should be noted that the ZTV on Figure 7.8 does not illustrate the brightness of light that may be received in any one place, which needs to take account of distance attenuation, weather conditions and the technical specifications for a candidate light unit. Calculations for apparent brightness have been provided for the viewpoint locations considered in Technical Appendix 16.1.

5.2 Assessment of Visibility of Lights from Viewpoints

Table 1 below sets out the likely visibility and brightness of turbine lights from the viewpoints. Data is taken from Technical Appendix 16.1[5]. Light emitted from the source is measured in candela, micro-lux is the unit to measure light received by the eye. It should be noted that off-road or hilltop locations are unlikely to have viewers at night.

Table 1 – Brightest lights seen from Viewpoints (from Technical Appendix 16.1)

Viewpoint Location	Notes on Screening and turbine with Brightest Light[6]	Micro-lux in Poor Visibility (less than 5km, 2000 cd at source)	Micro-lux in Good Visibility (200 cd at source)	Example Lights Comparable with the Brightest Light (based on Technical Appendix 16.1)
VP1: A701 Source of the Tweed Layby	One lit hub visible. Turbine 3 at 9.7 km	10.5	1.1	In poor visibility: unlikely to be visible at this distance. In good visibility: Similar to a star in the constellation Orion, or a car break light at 10km.
VP2: A701 Tweedhopefoot	No lights visible			

[4] Angles are reported as negative angles in the direction of light emission, rather than view angles looking up at the lights.
[5] It is noted that TA16.1 used the slightly different locations for the viewpoints, that were proposed prior to photography being completed. The grid references are therefore slightly different from the viewpoints in TA7.3, but this does not alter the findings of brightness in TA16.1 or findings of effect in this assessment
[6] The turbine with the brightest light is not necessarily the closest.

Viewpoint Location	Notes on Screening and turbine with Brightest Light[6]	Micro-lux in Poor Visibility (less than 5km, 2000 cd at source)	Micro-lux in Good Visibility (200 cd at source)	Example Lights Comparable with the Brightest Light (based on Technical Appendix 16.1)
VP3: A701 Layby south of Glenbreck	Three lit hubs visible. Turbine 1 at 4.4 km	13	1.3	In poor visibility: Less bright than a car brake light at 3 km. In good visibility: Similar to a star in the constellation Orion, or a car brake light at 10km.
VP4: A701 layby near Hawkshaw	Three lit hubs visible. Turbine 3 at 4.4 km	23.1	2.3	In poor visibility: Less bright than a car brake light at 2 km. In good visibility: Similar to a star in the constellation Orion.
VP5 Tweedsmuir Village Hall	Two lit hubs visible Turbine 6 at 1.7 km	25	2.5	In poor visibility: Less bright than a car brake light at 2 km. In good visibility: Similar to a star in the constellation Orion.
VP6: A701 Stanhope	Two lit hubs visible Turbine 6 at 6.5 km	5.7	0.6	In poor visibility: a car brake light at 5 km or a sodium street light at 5 km. In good visibility: Similar to a fainter star in the constellation Orion.
VP7: Hopehead, Kingledoors Burn	Two lit hubs visible Turbine 6 at 1.2 km	59.3	5.9	In poor visibility: less bright than a car brake light at 1 km, similar to a modern LED cycle light at approximately 0.7 km. In good visibility: similar to a car brake light at 5 km.
VP8 Tweedsmuir Bridge	Three lit hubs visible Turbine 6 at 1.4 km	38.9	3.9	In poor visibility: a little brighter than a car brake light at 2 km, similar to a modern LED cycle light at 1 km. In good visibility: similar to a car brake light at 5 km.
VP9: Fruid Dam	Two lit hubs visible Turbine 1 at 3.4 km	17.8	1.8	In poor visibility: Less bright than a car brake light at 2 km. In good visibility: Similar to a star in the constellation Orion.
VP10: Talla Dam	One lit hub visible Turbine 6 at 3.0 km	14.7	1.5	In poor visibility: Less bright than a car brake light at 2 km. In good visibility: Similar to a star in the constellation Orion, or a car break light at 10km
VP11: Talla Linn	Two lit hubs visible Turbine 1 at 7.3 km	20.6	2.1	In poor visibility: a little less bright than a car brake light at 2 km. In good visibility: Similar to a bright star in the constellation Orion.
VP12: Broad Law	Three lit hubs visible Turbine 3 at 7.6 km	30.6	3.1	In poor visibility: a little brighter than a car brake light at 2 km. In good visibility: Less bright than a car brake light at 5 km.
VP13: Hartfell	Three lit hubs visible Turbine 1 at 10.6 km	20.3	2.0	In poor visibility: unlikely to be visible at this distance. In good visibility: Similar to a star in the constellation Orion.
VP14: Chalk Rig Edge	Two lit hubs visible Turbine 1 at 10.3 km	19.6	2.0	In poor visibility: unlikely to be visible at this distance. In good visibility: Similar to a star in the constellation Orion.
VP15: Trahenna Hill	Three lit hubs visible Turbine 3 at 13.5 km	11.9	1.2	In good visibility: Similar to a star in the constellation Orion, or a car brake light at 10 km. It is noted that this is a remote viewpoint with people unlikely to be there after dark.
VP16: Culter Fell	No lights visible			
VP17: Lowther Hill	Three lit hubs theoretically visible but at over 20 km distance			Unlikely to be visible at over 20 km.
VP18: Tinto	No lights visible			
VP19: Byrehope Mount	Three lit hubs theoretically visible but at over 20 km distance			Unlikely to be visible at over 20 km.
VP20: Pykestone Hill	Three lit hubs visible	21.0	2.1	In poor visibility: unlikely to be visible at this distance.

Viewpoint Location	Notes on Screening and turbine with Brightest Light[6]	Micro-lux in Poor Visibility (less than 5km, 2000 cd at source)	Micro-lux in Good Visibility (200 cd at source)	Example Lights Comparable with the Brightest Light (based on Technical Appendix 16.1)
	Turbine 6 at 10.9 km			In good visibility: Similar to a star in the constellation Orion.

Table 2 below considers the likely effects of the lights from the five selected viewpoints, with reference to the data set out above, in Technical Appendix 16.1, and Figure 7.8, with dusk montages provided as referenced.

Table 2 – Visibility of Aviation Lights from Selected Viewpoints

Viewpoint Location	Brightness information from Technical Appendix 16.1	Receptors, Night-time Sensitivity and Baseline Lighting	Assessment of Effects of Visibility of Aviation Lighting
VP1: A701 Source of the Tweed Layby Figure 7.13	– One lit hub visible – Turbine 3 at 9.7 km – 10.5 microlux at full intensity but unlikely to be visible in poor visiblity at this distance – 1.1 microlux in clear visibility	Road users on the A701. Value is typically low as people are not in that location in order to see the night-time view; susceptibility is low as people are usually focussing on the road ahead or on the area lit by headlights. Low night-time sensitivity. At night, the landscape is dark, with only lights of vehicles along the road. There are no properties close to the viewpoint that are visible.	At night, turbines would be seen as dark structures ahead along the valley. Lighting on Turbine 3 would be seen as a single red light along the otherwise dark valley. The light would not be bright, as there would be distance attenuation and some reduction due to downward angle (-1°). The light would be similar to a star in the constellation Orion, or a car break light at 10 km. The light would not be as bright as lights on vehicles that north-bound road users may be following. Viewers in vehicles do not have dark adaptation and would be seeing lights on other vehicles on the road. The aviation lights would not give rise to significant effects.
VP3: A701 Layby south of Glenbreck Figure 7.15	– Three lit hubs visible – Brightest on Turbine 1 at 4.4 km – 13 microlux at full intensity – 1.3 microlux in clear visibility	Road users on the A701. Value is typically low as people are not in that location in order to see the night-time view; susceptibility is low as people are usually focussing on the road ahead or on the area lit by headlights. Low night-time sensitivity. At night, the landscape is dark, with lights associated with the properties of Glenbreck and vehicles along the road.	At night, turbines would be seen as dark structures or silhouettes ahead along the road. Lighting on the turbines would be seen as three red lights above the otherwise dark landscape. The lights would not be bright, as there would be reduction due to downward angle (-3°), and some distance attenuation. The lights would be less bright than a car brake light at 3 km in poor visibility, and similar to a star in the constellation Orion, or a car brake light at 10km in clearer conditions. The lights would be less bright than those on vehicles seen further along the road (the furthest section of road in view is approximately 1.5 km away) and less bright than those on vehicles that north-bound road users may be following. Viewers in vehicles do not have dark adaptation and would be seeing lights on other vehicles on the road. The aviation lights would not give rise to significant effects.
VP8 Tweedsmuir Bridge Figure 7.20	– Three lit hubs visible – Brightest on Turbine 6 at 1.4 km – 38.9 microlux at full intensity – 3.9 microlux in clear visibility	Road users and local residents. Value is typically low as people are not in that location in order to see the night-time view; susceptibility is medium as although people are usually focussing on lit spaces, they may include people outside their residences after dark. Medium night-time sensitivity. At night, the landscape is dark, with lights associated with the properties of Tweedsmuir, including properties and vehicles along the A701.	At night, turbines would be seen as silhouettes on the horizon above the western slopes of the valley. Lighting on the turbines would be seen as three red lights above the otherwise dark landscape. The lights would be similar to a car brake light at 2 km, with reduction due to downward angle (-7° to -12°), although little distance attenuation. In good visibility they would be similar to a car brake light at 5km. The lights would be similar in brightness to those on vehicles on the A701 in dull conditions when the lights are operated to full intensity. In clear conditions when the lights are operated at 10 % intensity, they would be less bright than those on vehicles in view and are likely to be less bright than some property lights. Viewers in vehicles and most people at properties do not have dark adaptation and would be seeing the lights in the context of other lights around them. The exception may be people spending time outside who may achieve partial darkness adaptation. Overall, it is judged that the aviation lights would not give rise to significant effects.

Viewpoint Location	Brightness information from Technical Appendix 16.1	Receptors, Night-time Sensitivity and Baseline Lighting	Assessment of Effects of Visibility of Aviation Lighting
VP9 Fruid Dam Figure 7.21	– Two lit hubs visible – Brightest on Turbine 1 at 3.4 km – 17.8 microlux at full intensity – 1.8 microlux in clear visibility	Occasional road users on the minor road or workers leaving the dam after dark. Value is typically low as people are not in that location in order to see the night-time view; susceptibility is low as people are usually focussing on the road ahead or on the area lit by headlights. Low night-time sensitivity. At night, the landscape is dark, without regular lights of vehicles along the road. There are no properties close to the viewpoint that are visible.	At night, turbines would be seen as dark structures or silhouettes along the valley away from the dam. Lighting on the two hubs would be seen against the sky beyond, as small red lights along the otherwise dark valley. The lights would not be bright, as there would be some distance attenuation and some reduction due to downward angle (-3°). In conditions where the lights are operated at full intensity, the lights would be less bright than a car brake light at 2 km (see Technical Appendix 16.1). In most conditions, where the lights are operated at 10 % intensity, they would be similar to a bright star in the constellation Orion. Viewers in vehicles do not have dark adaptation. However, this is generally a dark landscape, and people who have walked along the reservoir (core path) may have some dark adaptation. Overall, however, the aviation lights would not give rise to significant effects.
VP11: Talla Linn Figure 7.23	– Two lit hubs visible – Brightest on Turbine 1 at 7.3 km – 20.6 microlux at full intensity – 2.1 microlux in clear visibility	Road users on the minor road. Value is typically low as people are not in that location in order to see the night-time view; susceptibility is low as people are usually focussing on the road ahead or on the area lit by headlights. Low night-time sensitivity. At night, the landscape is dark, with only lights of vehicles passing along the minor road. Lights at the property at Talla Linnfoots may be visible from near this viewpoint.	At night, turbines would be seen as dark structures or silhouettes ahead along the valley. Lighting on the two hubs would be seen against the backdrop of land, as small red lights along the otherwise dark valley. The lights would not be bright, as there would be distance attenuation and slight reduction due to downward angle (-1°). In conditions where the lights are operated at full intensity, the lights are less likely to be visible at this distance, but theoretically could be a little less bright than a car brake light at 2 km (see Technical Appendix 16.1). In most conditions, where the lights are operated at 10 % intensity, they would be similar to a bright star in the constellation Orion. Viewers in vehicles do not have dark adaptation and may be seeing lights on other vehicles on the road. However, this is generally a dark landscape. Given the distance to the site, the aviation lights would not give rise to significant effects.

5.3 Assessment of Visibility of Lights from Routes

Roads

Given the information in Technical Appendix 16.1 and for the viewpoints in the tables above, whilst the lights would be visible, there are unlikely to be significant effects on routes around the study area. Observations relative to routes are set out below. It is noted that road users tend to have low night-time sensitivity, and do not have fully dark-adapted vision because of lights associated with vehicles. People are likely to be focussed on the road ahead or on features within the pool of light created by headlights. Lights are most likely to be noticeable when ahead but lightly oblique to the main headlight direction and are most likely to be noticeable by passengers rather than drivers.

The A701 along the Tweed valley: This route passes through a dark landscape, with only the occasional lights associated with properties.

The ZTV on Figure 7.8 indicates that there would be theoretical visibility of the turbine lights from much of the route between the watershed above the Devil's Beef Tub to Tweedsmuir, and from Kingledores to Stanhope. The assessment of daytime effects (Technical Appendix 7.3) identifies that there are sections within forest planting that have less open views and the Proposed Development would be screened. Several viewpoints are used to represent the sequence along this route:

- VP1: A701 Source of the Tweed Layby: from where no lights are likely to be visible in poor conditions, but one light would be seen with similar brightness to a car brake light at 10 km in good conditions;
- VP2: A701 Tweedhopefoot: no lights visible;

- VP3: A701 Layby south of Glenbreck: Three lights less bright than a car brake light at 2 km in poorer visibility, but less bright than at VP1 in clear visibility;
- VP4: A701 layby near Hawkshaw: three lit hubs slightly brighter than at VP3.
- VP5: Tweedsmuir Village Hall: two lights similar to VP4; and
- VP6: A701 Stanhope: two lights less bright than VP3, similar to a car brake light at 5 km;

In poor conditions, when the light is operated at full intensity, the lights would appear no brighter than car brake lights at approximately 2 km away – and therefore no brighter than other vehicle lights that might be on the road. In clear conditions when the lights are operated at 10 %, the lights would be no brighter than a car brake light at 5 km – likely to be noticeably less bright than other vehicle lights.

With downward reduction in brightness reducing brightness from closer sections of the route, and distance attenuation affecting brightness for more distant sections, the lights would appear brightest at around Hawkshaw. Overall, it is judged that with the mitigation by downward reduction in brightness, there would be no significant effects on this route in relation to the aviation lighting.

Minor road from Tweedsmuir to Talla Linn: This route passes through a dark landscape, with lights only at properties near the reservoir and at Talla Linnfoots. The ZTV (Figure 7.8) indicates almost continuous visibility of lights from the top of Talla Linn to Tweedsmuir, except along the eastern half of the reservoir. From Talla Linn (VP11), the elevation of the location means that downward angle is only - 1 °, but distance attenuation means that the lights would be a little less bright than a car brake light at 2 km, should they be visible (the viewpoint is over 5 km from the Proposed Development), or similar to a bright star in the constellation Orion in clear conditions. From Talla Linn, the road drops down to the reservoir (steeper downward angle from the lights) but gets closer. At the reservoir (VP10), the lights would be less bright than at the top of Talla Linn. Below the reservoir forest screening would reduce views, till the road opens out again at Tweedsmuir. At Tweedsmuir Bridge (VP8) the three lights would be seen over the valley and in the context of lights of the properties of Tweedsmuir. They would be a little brighter than a car brake light at 2 km - brighter than at Talla Linn because although there is a steeper downward angle, there is less distance attenuation. Whilst the lights would be visible from this route, they would not give rise to significant effects on the experience of the route.

Minor road from Tweedsmuir to the Fruid Reservoir: this is an unlit route that passes only a few properties. The ZTV (Figure 7.8) indicates continuous visibility of lights from the reservoir to Tweedsmuir, although there is notable woodland screening. From the Fruid Dam (VP9), two lights would be seen less bright than a car brake light at 2 km in poor visibility (with lights operated at full intensity), and similar to a star in the constellation Orion in clear visibility (with lights operated at 10 %). From lower sections of the route south of Menzion, while views are not obscured by vegetation (young trees are growing by the roadsides), the lights may appear brighter, similar to at VP4 on the A701 near Hawkshaw, appearing less bright than a car brake light at 2 km, or similar to a star in the constellation Orion. Closer to Menzion and Tweedsmuir, woodland screening means that light would be obscured by trees. Whilst the lights would be visible, they would not give rise to significant effects on the experience of the route.

Recreational Routes

Core Paths and rights of way within 10 km will have few walkers at dusk. Paths tend not to be frequented after dark, although some people may be out late walking dogs on sections of paths nearer settlements or properties. It is also possible that occasionally people are out overnight camping, finishing longer walks or are out to see dark skies. These people may achieve more dark adaptation than people in vehicles or lit spaces, although focus for most is likely to be on lit areas using torches, especially when walking on rough ground.

The lights of the Proposed Development would be visible but of lower intensity for valley sections due to strong downward angles for routes close to the Proposed Development site. Given the low numbers of likely viewers, and attenuation by angle, significant effects are considered to be unlikely.

For route sections further from roads and settlements, numbers of viewers will be very low. For the route sections that pass over hill ridges, such as over Glenwhappen Hill, Broad Law, Culter Fell, or Chapelgill Hill, the lights will be seen at shallower downward angles and would appear brighter than at lower elevations. However, significant effects on these routes are considered unlikely given the very low likely number of people out at night.

5.4 Lighting in the Cumulative Scenarios

There are currently no existing or under construction wind farms in the study area that are lit with aviation lighting. Whilst the Proposed Development would therefore be the first lit wind farm in the area, it means that there are no cumulative effects of lighting in the existing scenario as assessed above.

Consented and application stage wind farms across the study area are identified in Technical Appendix 7.4 and shown on Figure 7.9.

- There are no consented wind farms with turbines of over 150 m to blade tip, such that there would be no cumulative effects of turbine lighting in the consented scenario.
- Most of the wind farms at application stage are proposed for over 150 m to blade tip and would be required to have aviation safety lighting.
  - As noted in Technical Appendix 7.4, the closest is Grayside, which would be located north of the Clyde group, approximately 7 km to the west of the Proposed Development. There would be no low-level locations with views to both the Proposed Development and Grayside from which people might see the lights from the same location. High level locations would have combined visibility of lights, but viewers are less likely to be present. It is judged that there would be no likelihood of significant cumulative effects of lighting of these developments.
  - Bodinglee, Daer and Rivox would be located over 15 km from the Proposed Development with several hills and settled valleys in between. It is judged that there would be no noticeable relationship between the lights of those developments and the Proposed Development.

5.5 Summary

As set out in Technical Appendix 16.1, three turbines of the Proposed Development would be lit: Turbine 1, Turbine 3 and Turbine 6. These turbines would each have a medium intensity 2000 cd steady red light on the top of the hub (a second light on each hub would be installed as a backup but would not be lit when the primary light is functional). No mid-tower lights would be used. The lights would come on during evening civil twilight and be turned off during morning civil twilight. Mitigation permitted under CAA guidance includes the reduction of the intensity of the lights during conditions of clearer visibility, such that the lights would only operate at full intensity of 2000 cd when visibility is less than 5 km; at other times they would be at 10 %, i.e. 200 cd. Meteorological data for the local area suggests that the 2000 cd lights would be at 2000 cd for 2 % of the time and at 200 cd for 98 % of the time when the cloud-base is above hub height. The lights used would be designed to emit a horizontal beam of light with reduced upward and downward spill of light, such that the brightness of the light emitted is decreased for viewers close to the turbines viewing the lights from below.

The assessment of the effects of the lighting on views after dark considered viewpoints and routes and assessed the appearance of the proposed lighting relative to exemplar lights and existing lights in the views and the change to the night-time viewing experience. Off-road locations are likely to have very few viewers.

Seen from the public road network, the lights would be at their brightest from the A701 south of Tweedsmuir. At viewpoint VP4 near Hawkshaw, given the proximity to the site (little attenuation by distance) but a reduction of intensity due to a downward angle (- 3 °), the lights would be seen appearing less bright than a car brake light at 2 km when the lights are operated at 2000 cd. This is judged not to incur significant visual effects during dark hours. In good visibility conditions, the lights would be reduced to 200 cd and would be noticeably less bright, appearing similar to a star in the constellation Orion.

Paths tend not to be frequented after dark, although some people may be out late walking dogs on sections of paths nearer settlements or properties. It is also possible that occasionally people are out overnight. These people may achieve more dark adaptation than people in vehicles or lit spaces, although focus for most is likely to be on lit areas using torches, especially when walking on rough ground.

Whilst the lights would be visible as low to very low intensity red lights from viewpoints and from routes around the study area, no significant effects are identified as arising from aviation lighting during dark hours.

6.0 References

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