Technical Appendix 5.3: Aviation Lighting Night-Time Impact Assessment Part 1

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Technical Appendix 5.3: Aviation Lighting Night-Time Impact Assessment

Introduction

1.1 In the interests of aviation safety, structures of 150m or more in height, including wind turbines, require steady red visible medium intensity aviation lighting, as set out in Article 222 of the Air Navigation Order (ANO) 2016. As the Proposed Development will comprise wind turbines up to 200 m to blade tip height, there is a requirement for visible aviation lighting, which may be perceptible to landscape and visual receptors from locations across the study area. The introduction of visible aviation lighting in rural locations, where there are fewer sources of artificial lighting, and where darkness or dark skies may be an integral and valued aspect of the landscape, could lead to potentially significant landscape and visual effects at night.

1.2 This appendix is not a technical appraisal of lighting. The Applicant commissioned a specialist aviation consultant (Aviatica) to develop an aviation lighting scheme for the Proposed Development that complies with the relevant guidance (CAA, 2025). The aviation lighting scheme was submitted to the Civil Aviation Authority (CAA) on 11th June 2026 and was subsequently approved on 30th June 2026 – see **Technical Appendix 4.3: Aviation Assessment**. scheme is therefore . The assessment of the landscape and visual effects of visible aviation lighting in this appendix is therefore based on the proposed lighting scheme.

1.3 This technical appendix sets out the background to the requirements for visible aviation lighting, followed by an assessment of landscape and visual effects arising for representative receptors across the study area. Receptors considered in the assessment are identified in the Landscape and Visual Impact Assessment (LVIA) contained in **Chapter 5: Landscape and Visual Amenity**. The assessment of effects of aviation lighting on residential visual amenity is considered separately in **Technical Appendix 5.2: Residential Visual Amenity Assessment.** This appendix should be read with reference to **Chapter 5** and the accompanying visualisations (**Figures 5.2.1 to 5.2.18**) presented in **Volume 3b: Landscape and Visual Impact Assessment Visualisations (Part 1)**, along with **Technical Appendix 5.1: LVIA and Visualisation Methodology**. **Figures A5.3.1 to A5.3.3** accompany this appendix.

1.4 In August 2021, the Scottish Government established the Aviation Lighting Guidance Working Group (Scottish Government, 2021) to develop guidance to ensure that landscape and visual impacts of visible aviation lighting systems are assessed consistently. The final guidance was published collaboratively by the Scottish Government and NatureScot in November 2024 and sets out a three step process to be taken to the assessment of landscape and visual effects associated with visible aviation lighting (NatureScot, 2024). The three steps are defined as follows:

- Step 1 – Defining the lighting proposal.
- Step 2 – Understanding the baseline; and
- Step 3 – Assessing the effects.

1.5 The approach taken and scope of this assessment are considered to be consistent with the guidance.

Regulatory Background

1.6 The regulatory background to the requirements for visible aviation lighting on wind turbines is outlined below.

Aviation Lighting Requirements

1.7 Article 222(1) of the ANO 2016 sets out the statutory requirement for the lighting of 'en-route obstacles', which applies to structures of 150 m or more above ground level. The Article states: "*The person in charge of an en-route obstacle must ensure that it is fitted with medium intensity steady red lights positioned as close as possible to the top of the obstacle and at intermediate levels spaced so far as practicable equally between the top lights and ground level with an interval of not more than 52 metres*." (UK Government, 2016).

1.8 This article is incorporated into the CAA's Civil Aviation Policy (CAP) 764 7th Edition Policy Statement on the lighting of onshore wind turbines, which states: "*One medium intensity (2000 candela) red light must be placed on the nacelle of the turbine; a second 2000 candela red light serving as an alternate should be provided in case of failure of the operating light".* In practice, this means the installation of two lights on the top surface of the turbine nacelle.

1.9 Additionally, and in accordance with Article 222(1) of the ANO, the CAA requires that "*At least three (to provide 360 degree coverage) low-intensity Type B lights (32 candela) lights must be provided at an intermediate level of half the nacelle height ± 10 m*."

1.10 CAP 764 includes provision for the medium intensity 2000 candela (cd)[1] lights to be controlled by visibility sensors in order to reduce the intensity of the light in clear weather conditions. It states, "*If visibility in all directions from every wind turbine generator in a group is more than 5 km, the light intensity for any visible light required by Article 222 of the ANO (2016) as amended to be fitted to any generator in the windfarm and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type*".

Lighting Specification

1.11 The International Civil Aviation Organisation (ICAO) Code – Annex 14, Table 6-3 (ICAO, 2018) sets out the specification requirements for medium-intensity obstacle lights. These requirements vary at different vertical angles of elevation, relative to the lighting horizontal plane, which in this case will be the nacelle height of the wind turbines. The intensity of the light emitted from an aviation obstruction light is designed to vary with the observed angle. It aims to be at its brightest when observed from a similar level or just above (i.e. projecting horizontally), but less bright as the observer falls below or above the light. Different manufacturers produce lights with slightly varying characteristics, though broadly similar in complying with the minimum requirements, and maximum recommendations, of these international standards.

Perception of Light

1.12 The main effect of aviation lighting comes from visibility of the aviation lights. This type of lighting will not cause sky glow, but can contrast with natural darkness, and can draw attention. In clear conditions they are generally seen as sharply defined points of red light, especially when seen against a dark sky or dark landform or when seen in landscapes with little or no existing sources of artificial light present.

1.13 The human perception of light intensity over distance follows an inverse square relationship, meaning that as the distance increases, the light must spread out over a larger surface and the surface brightness decreases. Although the actuality of the lights remains constant, the apparent light intensity (brightness) and size of a light source as perceived by people will vary dependent on distance, angle of view and atmospheric conditions. As distances increase, the light source will appear smaller. As atmospheric conditions become less clear (a reduction in clarity with increased humidity, rain, drizzle, snow or the presence of haze, mist, fog or a low cloud base etc.) the brightness will appear reduced. Clarity varies at different levels within the sky, and across different places. Decline in brightness over distance is not uniform.

1.14 The brightness at which lights are perceived also depends on the background against which they are seen. They may seem brighter because of the stronger contrast when there is no moonlight for example, or when they are seen against a dark landmass rather than against a sky where there is some residual twilight.

[1] Candela (cd) is the measurement of luminous intensity (i.e. light emitted in a particular direction by a light source) Note: a candle emits light with a luminous intensity of roughly one cd.

Perception of red lights by humans in periods of low light and darkness is also variable from person to person, and therefore what the eye sees in practice at night is very inconsistent.

1.15 Perception of light by receptors is also subject to the type of activity being undertaken. In rural areas, many activities at night are likely to involve some form of personal light for safety, such as a headtorch, which inhibits the optical process of 'dark adaptation'. Dark adaptation is associated with chemical changes in the eye. This is a relatively slow process and can typically take up to 30 minutes of exposure to darkness for human vision to adapt. Any, even short exposure to bright light (such as street lighting within a settlement or car headlights), resets the dark adaptation process. As such, a fully dark-adapted state is more likely for the generally fewer receptors who purposefully seek out dark skies and the absence of artificial lighting, for activities such as stargazing (NatureScot, 2024).

1.16 Due in part to this variability in the way that the human eye can perceive light during periods of low light and darkness, it is considered that no aviation lighting visualisation will ever be able to consistently replicate what individuals may experience in the field, and should therefore only be used as a tool to aid understanding of potential effects, and not as a replacement for observations made in the field.

Potential Mitigation

1.17 A number of potential mitigation options are currently available or are being developed by the wind energy sector in collaboration with the CAA and other stakeholders. Mitigation options which may have the potential to influence the resultant landscape and visual effects which may occur from the introduction of visible aviation lighting are outlined below.

Reducing the Number of Lights

1.18 As an alternative to lighting all turbines, the lighting of cardinal or peripheral turbines (i.e. those located at the outer extremities of a wind farm development) is an established mitigation option for wind farms and is allowed for under the provisions of ANO Article 222 (7) which states, "*This article does not apply to any en-route obstacle for which the CAA has granted a permission to the person in charge permitting that person not to fit and display lights in accordance with this article".* In addition, the requirement for low intensity lights at mid-mast level (as required by Article 222(1) of the ANO), can often be removed with CAA agreement.

1.19 In the case of the Proposed Development, Aviatica has developed a reduced lighting scheme, with four of the five turbines (T1, T3, T4 and T5) having two medium intensity 2000 candela lights (one operating and one for back up) but no low intensity lights at mid-tower level. As noted above, the reduced lighting scheme was approved by the CAA on 30th June 2026 – see **Technical Appendix 4.3**.

Intensity Reduction (Automatic Dimming)

1.20 As noted above CAP 764 includes provision for the medium-intensity 2000cd lights to be controlled by visibility sensors that may reduce the intensity of the light to not less than 10% of the minimum peak intensity (e.g. 200cd) in times of clear meteorological conditions (if the horizontal meteorological visibility in all directions from every wind turbine in the group is more than 5 km).

1.21 This is achieved with the installation of sensors on wind turbines within different parts of a wind farm. These sensors measure prevailing atmospheric conditions and visibility range. Where atmospheric conditions limit visibility (based on measurements local to the site of the sensor) to distances of less than 5 km in any direction (e.g. through the presence of low cloud cover, rain, mist, haze or fog) the lights are illuminated at the necessary 2000cd. This form of mitigation is permitted by the CAA (and does not therefore require project-specific approval from the CAA), and forms part of the Proposed Development.

Vertical Directional Intensity

1.22 Vertical directional intensity mitigation (sometimes called 'narrow vertical beam spread' or 'angle intensity mitigation') comprises the use of particular aviation lights that have greater control of the light intensity emitted at certain angles above and below the horizontal plane. It can be a very effective form of mitigation, especially in reducing potential effects for receptors located at lower elevations relative to the

aviation lights but can be less effective for elevated or more distant receptors at similar vertical elevations towards which a greater luminous intensity may be emitted.

1.23 Aviation lighting is required to operate at the minimum intensities defined in ICAO, across a relatively narrow (3°) vertical beam spread, projecting horizontally from the nacelle light, between -1° to +2°, as explained in ICAO Table 6-3. Individual lights have slightly varying characteristics, though broadly similar in complying with international standards with sharply declining intensity when viewed from a lower level.

1.24 The emitted luminous intensity of a light mounted on the turbine nacelle therefore reduces at vertical angles below (and above) the horizontal plane. This results in a reduction in visible lighting at elevations of less than -1° vertical angle. That is to say, the light will appear less bright to an observer looking up at the nacelle from below, than it will to an observer at the same elevation as the nacelle. The intensity at angles below -1° may also vary dependent on the specific obstacle lighting manufacturer's specification.

1.25 As such, this embedded mitigation within the design of the lights has the potential to substantially reduce the extent and perceived intensity of lights visible when viewed from different elevations (effectively the angle of view), when seen from either below (lower elevations) or above (higher elevations) the height of the turbine hub. A lighting intensity Zone of Theoretical Visibility (ZTV) can be helpful to illustrate the potential mitigation from an assumed aviation light, and to demonstrate how light emissions may reduce relative to vertical angle from the horizontal plane. Refer to **Figure A5.3.2 and A5.3.3**.

1.26 There is no need to seek project-specific approval from the CAA for this as it constitutes embedded design mitigation and meets the requirements of CAP 764.

Radar or Transponder Activated Lighting

1.27 ICAO Annex 14 also details guidance on 'Visual Aids for Denoting Obstacles'. With specific reference to mitigation of effects on visual amenity, Note 2 outlines that *"An autonomous aircraft detection system may be installed on or near an obstacle (or group of obstacles such as wind farms), designed to operate the lighting only when the system detects an aircraft approaching the obstacle, in order to reduce light exposure to local residents."*

1.28 A number of manufacturers have developed radar activated aviation lighting systems (aviation obstruction lighting detection system), whereby the lights would only be switched on when aircraft approach within a specified airspace zone, and this technology is currently permitted by aviation authorities in EU countries, including Germany (Federal Aviation Office) and the Netherlands (Netherlands Aerospace Centre), as well as the United States (Federal Aviation Authority).

1.29 This technology is not currently approved by the CAA and as such is not considered further as a potential mitigation option in this assessment.

Proposed Aviation Lighting Scheme and Embedded Mitigation

1.30 Due to the height of the proposed turbines (200 m to blade tip) visible aviation safety lighting is required. The proposed aviation lighting scheme which forms the basis of this assessment has been agreed with the CAA (see **Technical Appendix 4.3 Annex 1)** and is summarised below:

- Two medium intensity red lights on the nacelles of T1, T3, T4 and T5 (four turbines in total). The secondary light on each turbine is fitted for use in the event of failure of the primary light and will not be lit concurrently.
- Infra-red lights (not visible to the naked eye) to Ministry of Defence (MoD) specification on the nacelles of all five turbines; and
- No intermediate level red lights (32cd), located on turbine towers, are proposed as part of this lighting scheme.

1.31 The Applicant is committed to the implementation of intensity reduction (automatic dimming) mitigation, as described above, of the medium-intensity aviation lights to be installed on the Proposed Development turbines. This will therefore allow for the 2000cd lights to be dimmed to not less than 10% of the minimum

peak intensity (i.e. 200cd) when horizontal meteorological visibility exceeds 5 km in all directions. This situation is considered to represent the most reasonable maximum effect (i.e. worst case) scenario, and the predominant state in which the lights will be experienced by people across the study area. When weather conditions are poor (visibility is less than 5 km distance), the lights will be more difficult to perceive, despite being lit at their full intensity.

1.32 Lights will operate between evening civil twilight (approximately 30 minutes after sunset) and morning civil twilight (approximately 30 minutes before sunrise).

Lighting Specification

1.33 The Applicant is also committed to the implementation of vertical directional intensity mitigation comprising the use of aviation lights that are designed to operate close to the minimum required intensities (as discussed above). At the present time neither the proposed manufacturer or precise model and specification of aviation light to be used on the Proposed Development is known. Although the precise details of performance, and thus the mitigation delivered, will vary according to the exact manufacturer and light used, the principles of vertical directional intensity mitigation will apply (i.e. decline in intensity with increased or decreased angle from the horizontal plane), and these are referred to in the assessment where relevant.

1.34 Table 1 below sets out the specific maximum and minimum luminous intensity values emitted at different vertical angles of elevation, as derived from a candidate aviation safety light which complies with the ICAO requirements (Contarnex for the CEL-WT-MIC). Values of lights provided by other manufacturers may be different but would be comparable to comply with the ICAO requirements.

1.35 To deliver vertical directional intensity mitigation, the light uses the latest finely tuned LEDs which are designed to minimise the spillage and over-brightness, and the vertical beam spread is minimised, with the brightest beam between -1˚ and +2˚. It is important to note that aviation lights exceed the minimum requirement in the centre of the beam spread (at 0° to 1˚), as it is difficult to meet the average intensity requirement (2000cd) across the full range of the minimum beam spread (between -1˚ and +2˚). As such, the maximum cd values between -1° and +2° listed in **Table 1.1** below slightly exceed 2000cd and 200cd respectively.

1.36 The specified aviation warning light has informed the production of the lighting intensity ZTVs (**Figure A5.3.2 and A5.3.3**). This illustrates the often much reduced luminous intensity emitted at specific vertical elevation angles, towards particular viewpoints.

Table 1.1 – Turbine Lighting Intensity

Vertical Angle of Lighting from Nacelle	Maximum luminous intensity (cd)	Minimum luminous intensity (cd)	10% Maximum luminous intensity (cd)	10% Minimum luminous intensity (cd)
Above 5°	146.74	33.98	14.67	3.40
4° to 5°	247.02	134.45	24.70	13.45
3° to 4°	481.39	236.85	48.14	23.69
2° to 3°	1159.9	481.34	115.99	48.13
1° to 2°	2118.8	1169.6	211.88	116.96
0° to 1°	2205.5	1968.4	220.55	196.84
-1° to 0°	2035.9	986.85	203.59	98.69
-2° to -1°	995.52	382.92	99.55	38.29
-3° to -2°	393.66	197.24	39.37	19.72

Vertical Angle of Lighting from Nacelle	Maximum luminous intensity (cd)	Minimum luminous intensity (cd)	10% Maximum luminous intensity (cd)	10% Minimum luminous intensity (cd)
-4° to -3°	199.15	130.89	19.92	13.09
-5° to -4°	130.79	91.7	13.08	9.17
below 5°	94.03	38.37	9.40	3.84

Approach to Assessment of Lighting Effects

1.37 The assessment of effects arising from lighting follows the same methodology detailed in **Technical Appendix 5.1**. It is important to note that the assessment is not a technical lighting assessment based on a quantitative measurement of light levels; it relies on professional judgement of what the naked human eye can reasonably perceive in the context of the baseline situation with regard to existing sources of artificial lighting.

1.38 The Guidelines for Landscape and Visual Impact Assessment, 3rd Edition (GLVIA3) (Landscape Institute, 2013), notes that quantitative assessments of lighting impacts will be carried out by lighting engineers, but that "*the visual effects assessment will also need to include qualitative assessments of the effects of the predicted light levels on night-time visibility*." (paragraph 6.12, page 103).

1.39 The assessment is based on effects arising in relation to the steady red light fixed to the top of the agreed four turbine hubs, as illustrated in the supporting visualisations. Though the maximum 2000cd intensity values are referenced in Table 1 and Table 2 and **Figures A5.3.2 and A5.3.3**, in accordance with NatureScot guidance, this assessment considers the perceived effects of the aviation lights at 200cd only, to reflect the predominant emitted intensity of 200cd during clear weather conditions (NatureScot, 2024).

1.40 Reflected glow across the immediate surfaces of the turbine blades and hub may be evident under certain conditions and is represented in the visualisations. Infra-red lights are required for military and emergency service aircraft flying at night. These lights are not designed to be visible to the naked eye and are not considered further in this assessment.

1.41 When determining the magnitude of change associated with the Proposed Development, the methodology in **Technical Appendix 5.1** considers the duration of the change. For operational effects of lighting, this is deemed to be long term (but ultimately reversible). For night-time effects, the frequency of the effect should also be considered. Aviation lighting will only be apparent during hours of darkness, which changes with the seasons. In the summer months the duration of visibility of aviation lighting will reduce. It will also be activated much later at night when fewer people may be around to experience the lighting. In the winter, the converse will be the case. The period when visibility is greater than 5 km is likely to be longer in summer, due to generally better weather conditions.

1.42 Although the intensity of the emitted light remains constant, the perceived light intensity ('brightness') experienced by visual receptors (people) will also vary dependent on distance and atmospheric conditions. As distances increase, the light source will appear smaller and perceived light intensity will decrease.

Baseline

1.43 Due to the reduction in perceived intensity of aviation lighting with increasing distance, significant landscape and visual effects are considered unlikely to occur beyond 20 km. As such, and in accordance with NatureScot guidance (2024), the study area for the aviation lighting night-time assessment is focused within approximately 20 km of the Proposed Development.

1.44 Owing to the relatively populated nature of the 45 km study area, which includes large population centres such as Glasgow and Kilmarnock, artificial lighting associated with settlement, and the road network is a relatively consistent feature in night-time views. The core of the study area within 20 km of the Proposed

Development includes the moorlands between Glasgow and Kilmarnock. From more remote parts of the moors to the east of the Site, darker skies can be experienced. More rural and suburban areas to the north, west and south of the Site tend to be subject to the influence of artificial lighting from settlement and traffic on the road network. This includes the M77, which passes from north-east to south-west through the centre of the study area, and brings lighting associated with moving traffic at night. The operational Middleton Wind Farm (six turbines at 105m to tip height), within 5 km to the north of the Site is also notable for having visible aviation lighting, which is due to its proximity to Glasgow Airport.

Cumulative Developments

1.45 While there are a number of operational wind farms located within 20 km of the Site (see **Figure 5.1.7b in Volume 3a** of the EIA Report) none, with the exception of Middleton Wind Farm, have aviation lighting fitted due to their respective tip heights being below 150 m. Consented and proposed wind farms subject to aviation lighting requirements are likely to introduce visible aviation lighting into baseline night-time views within 20 km of the Site, including:

- Mill Rig (under construction - 6 turbines at 250m to tip height); and
- Mossmulloch (application submitted - 5 turbines at 200m to tip).

1.46 Both of these schemes are over 15 km from the Proposed Development, so the scope for significant cumulative night time interactions is limited. Where there is potential for intervisibility, this is discussed.

Zone of Theoretical Visibility Mapping

1.47 The aviation lighting ZTV – Nacelle Lighting shown on **Figure A5.3.1** highlights the areas across the study area from which visible aviation lighting installed on the turbine hubs of T1, T3, T4 and T5 may theoretically be seen. This ZTV does not take account of potential screening provided by vegetation or buildings. To illustrate the potential variability in emitted intensity relative to vertical viewing angle, the Visible Aviation Light Intensity ZTV, shown on **Figure A5.3.2**, is coloured according to the vertical angles set out in **Table 1.1**. **Figure A5.3.3** shows the same information within a 20 km radius of the Proposed Development, to provide more detail. The lighting intensity ZTV does not show the reduction in perceived light intensity over distance, given it would be highly variable depending upon atmospheric conditions. As such, the lighting intensity ZTV shows a worst-case scenario of perceived lighting intensity, based on clear air conditions.

1.48 The ZTV (see **Figure A5.3.2 and A5.3.3**) indicates widespread theoretical visibility in all directions within approximately 5 km of the Proposed Development. There are some larger areas of coniferous forest which would limit actual visibility, notably to the east of the Site between the Proposed Development and the operational Whitelee Wind Farm. From more open areas of moorland around the Site, and farmland to the west and south **Figure A5.3.2** highlights that the proposed aviation lighting tends to be seen from below the horizontal, given the undulating nature of the landscape. This results in the proposed aviation lights generally being seen below 1055cd (106cd when dimmed to 10%) and from lower intensities with proximity to the Site. There are some areas of higher ground within 5 km, to the far east (within Whitelee Wind Farm) and small areas to the north-west (including higher ground around Dodd Hill), where the lights may be seen at higher intensities. From these areas, and when visible, the lights on the operational Middleton Wind Farm will also likely be visible, along with other light sources.

1.49 Within 5 km to 10 km visibility will be more widespread to the south-west. Through here the landscape tends to fall in elevation towards the coast to the south-west, with the proposed aviation lighting (when visible) seen below the horizontal (generally being seen below 1055cd and 106cd when dimmed to 10%). This pattern continues to the south-west between 10 km to 20 km, with visibility becoming slightly more intermittent. Settlement, woodland and hedgerows are also more likely to provide local screening in views to the north-east from this area (the Ayrshire Basin). There are areas of higher ground further west and south, within 20km, and where aviation lights may be seen at higher intensities. When visible, the lights will be seen at greater distances and in a varied landscape context with a range of light sources between.

1.50 To the north-east, within 5 km to 20 km, the pattern of visibility will be more limited, as the land starts to fall in elevation towards the Clyde Valley and the landform provides screening. From this area the landscape is more developed, with settlements and major roads. Views towards the Proposed Development will be more limited in reality and existing nearby sources of artificial light are more likely to draw the eye.

Visualisations

1.51 To inform the assessment of aviation lighting effects, night-time photomontage visualisations accompany this report. Viewpoints were selected to illustrate views experienced by residents, recreational and transport receptors. Two viewpoints were selected and agreed with EAC as follows:

- Viewpoint 1: A77 near Drumboy (**Figure 5.2.1**) to represent views experienced by residential receptors nearest to the Site and within 2 km;
- Viewpoint 7: Dunlop Road (A735) Stewarton (**Figures 5.2.7**) to represent views experienced by residential and recreational receptors, to the north of the settlement of Stewarton.

1.52 Due to the embedded design mitigation of automatic dimming, and in accordance with NatureScot guidance (2024), nacelle lights were modelled at the reduced 200 cd intensity setting, as a realistic worst case scenario. Visualisations are presented in accordance with the industry standard guidance prescribed by NatureScot, and the Landscape Institute. The methodology for the preparation of night-time photomontage visualisations is detailed within **Technical Appendix 5.1**.

Photography

1.53 NatureScot guidance for capturing night-time baseline photography states that "*It is important to capture a reasonable balance between visibility of the underlying landform and the apparent brightness of any artificial lights, as both should be visible in the image*", noting that 30 minutes after sunset (around the end of civil twilight), as an appropriate window *"when the shape of landform can still be discerned, and the night sky will still not be at its darkest, but importantly there will likely be a distinction between the sky and the land, or bodies of water"* (NatureScot, 2024).

1.54 The period of time when landform is visible along with existing light sources, and the perception of certain aspects of landscape character in fading light or darkness is possible is relatively narrow, and will vary considerably with the seasons, as well as weather and viewing conditions on any given day. The actual night-time view for most of the hours when the turbines are lit, will usually be darker, and the proposed lighting and other artificial light sources will be seen against a dark sky or dark landform. In such conditions, certain aspects of landscape character such as variations in landcover are harder to perceive. However, certain aspects of landscape character, such as the profile of an important skyline, or sense of remoteness, can still be appreciated at night.

1.55 Baseline dusk photography was undertaken in accordance with NatureScot guidance. Photography was captured at dusk in clear conditions and sought to capture the presence of existing baseline sources of artificial lighting (e.g. lighting associated with settlement, street lighting, motor vehicles and other sources) present in the landscape as closely as is experienced by the human eye as feasible. Multiple ranges of photography were taken several minutes apart in increasing darkness, with the most appropriate range of baseline photography for each viewpoint selected following careful consideration.

Photomontages

1.56 The dusk photomontage visualisations provided in **Figures 5.2.1 g/ h and 5.2.7 g/ h** show the baseline view and aviation lighting set to 200cd. Because of inherent limitations in representing lighting on a static photomontage, and the variable effects of atmospheric conditions, the visualisations do not seek to represent changes in emitted brightness as a result of viewing angle or perceived brightness (expressed in microlumens) as a result of distance. The dusk photomontages therefore represent a 'worst case' scenario based on emitted intensity (expressed in cd), which would be reduced in actuality due to viewing angle and viewing distance. As noted above, the maximum intensity 2000cd setting is not represented in the

visualisations or considered in the assessment due to the embedded design mitigation of automatic dimming of the aviation lights under clear conditions (i.e. when the photography was captured).

Effects on Landscape Character at Night

1.57 Many key characteristics of landscape, such as landcover, can only be fully appreciated during the day. There will be a relatively short window of time, during dawn and dusk, when landform and landcover will be visible along with existing and new light sources. As such, effects associated with visible aviation lighting are considered to be primarily visual and will be influenced by the type of activity being undertaken at night and the process of dark adaptation. However, it is acknowledged that dark skies can form a valued aspect of landscape character, which can also contribute to certain perceptual characteristics of the landscape. As NatureScot guidance notes: "*Some characteristics are weakened by darkness and are ultimately no longer present, as they are less visible, such as evidence of cultural settlement, variations in landcover and habitats, or an appreciation of key vistas. Other perceptual characteristics can however be strengthened, such as the apparent absence of development, or the profile of an important skyline… a frequently valued characteristic of many parts of the UK, and particularly Scottish countryside, is its dark skies and a general absence of visible lighting*" (NatureScot, 2024).

1.58 Theoretical visibility of the aviation lighting of the Proposed Development within 20 km is shown on **Figure A5.3.3a and b**. Focusing on Landscape Character Types (LCT), where significant effects on landscape character resulting from the aviation lighting are more likely to arise, theoretical visibility is indicated from the host LCT '79 - Plateau Moorland with Windfarms - Ayrshire' and the adjacent LCT '214 - Plateau Moorland with Windfarms - Glasgow & Clyde Valley', both of which are similar in character. This is widespread within 5 km and extending to the south-east. However, actual visibility will be greatly reduced by coniferous forest, which is characteristic of the LCT.

1.59 Depending on the vantage point, and where open views towards the Proposed Development are available, the proposed aviation lighting will generally be seen in the context of artificial light sources to the west of this LCT, including roads and rural settlement. Traffic on the M77, which passes through this LCT, will also be apparent from areas. Lights on the operational Middleton Wind Farm will also often form a component of the view, to the north-west. Given the undulating nature of the landscape, the proposed aviation lights will also generally be seen from just below the horizontal. The key characteristics of this LCT do not specifically recognise any dark sky qualities. Nevertheless, and in this context, significant effects on landscape character is likely to extend into the hours of darkness. But these effects are not judged to affect a greater geographical extent than identified in the daytime assessment from these LCT (contained within a localised area of approximately 5 km to the north of these LCT and from areas which have not been altered by existing wind farm development).

1.60 There is also theoretical visibility of the proposed aviation lighting from the LCT '66 - Agricultural Lowlands - Ayrshire' to the south-west, including areas within 5 km. Actual visibility will be reduced by hedgerows, woodland and areas of settlement, which are features characteristic of this LCT. Where open views towards the Proposed Development are available, the proposed aviation lighting will generally be seen beyond artificial light sources in this LCT, including roads and rural settlement. As this landscape is generally of a lower elevation than the site, the proposed aviation lights will also be seen from below the horizontal. The key characteristics of this LCT do not specifically recognise any dark sky qualities. Nevertheless, and in this context, significant effects on landscape character is likely to extend into the hours of darkness. But these effects are not judged to affect a greater geographical extent than identified in the daytime assessment from this LCT (contained within 5 km to the north-east of this LCT).

1.61 From other LCT within 10 km, theoretical visibility tends to be more intermittent. As such, effects on landscape character associated with the proposed aviation lighting is unlikely to be significant. All landscape designations are of a distance where night time effects are unlikely to be significant too.

Effects on Visual Amenity

1.62 Table 1.2 below details the predicted visibility of the proposed turbine lighting, as it will be seen from each LVIA viewpoint (informed by **Figures 5.2.1 to 5.2.18**). The table highlights the predicted emitted

intensity range of nacelle mounted aviation lighting in cd informed by the values presented on **Figure A5.3.2** which takes into account variability of lighting intensity based on viewing angle (cd). Values are given for maximum emitted intensity of lighting and at 10% intensity, the latter of which would be more typical in clear weather conditions and provides the basis for the assessment.

1.63 The table also indicates the potential influence of coniferous forestry in further screening the theoretical visibility of turbine lighting from each viewpoint location, informed by the baseline photography and observations from fieldwork.

Table 1.2 Summary of Turbine Lighting Visibility

Table 1.2 Key:

O - Nacelle lighting potentially visible

n/a - No nacelle lighting visible

X - Nacelle lighting screened by forestry/ other features

Viewpoint	Direction and distance (km) to nearest lit turbine	T1	T3	T4	T5	Intensity range (cd) at maximum (and 10% intensity)[2]
VP1 - A77 near Drumboy	East 1.1 km	O	O	O	O	199 to 131cd (20 to 13cd)
VP2 - Glassock Bridge - A77/A719	South 2.9 km	O	O	O	O	394 to 197cd (39 to 20cd)
VP3 - Harelaw Road	North-west 3.4 km	O	O	O	x	996 to 384cd (100 to 38cd)
VP4 - Kingsford B769	West 3.7 km	O	O	O	O	394 to 197cd (39 to 20cd)
VP5 - Queenseat B764	East 4.2 km	O	O	O	O	2036 to 987cd (204 to 99cd)

[2] Rounded to nearest whole number.

Viewpoint	Direction and distance (km) to nearest lit turbine	T1	T3	T4	T5	Intensity range (cd) at maximum (and 10% intensity)[2]
VP6 - Neilston Pad	North 5.7 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP7 - Dunlop Road (A735), Stewarton	South-west 6.4 km	x	x	O	O	996 to 384cd (100 to 38cd)
VP8 - Berryhill Moscow A719	South 7.4 km	O	O	O	O	996 to 384cd (100 to 38cd)
VP9 - Buiston A735	South-west 8.8 km	n/a	n/a	n/a	n/a	n/a
VP10 - Foreside	North 8.5 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP11 - Standing Stones, north of Irvine	South-west 15.5 km	O	O	O	O	996 to 384cd (100 to 38cd)

Viewpoint	Direction and distance (km) to nearest lit turbine	T1	T3	T4	T5	Intensity range (cd) at maximum (and 10% intensity)[2]
VP12 - B7038 Ditton south of Kilmarnock	South-west 15.7 km	O	O	O	O	996 to 384cd (100 to 38cd)
VP13 - Loudon Hill A71	South-east 16.4 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP14 - Kilbirnie Connelston A760	North-west 18.8 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP15 - Mauchline A76	South 19.6 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP16 - Glasgow Necropolis	North-east 20.4 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP17 - Clyde Muirshiel Regional Park Visitor Centre	North-west 21.5 km	O	O	O	O	2036 to 987cd (204 to 99cd)
VP18 - Wright's Well, Campsie Fells	North-east	O	O	O	O	2036 to 987cd

Viewpoint	Direction and distance (km) to nearest lit turbine	T1	T3	T4	T5	Intensity range (cd) at maximum (and 10% intensity)[2]
	33.6 km					(204 to 99cd)

Representative Assessment Viewpoints

1.64 Whilst the potential visibility of aviation lighting is summarised for each of the assessment viewpoints (as set out in **Table 1.2**), the following detailed assessment focuses on the two representative night-time viewpoints for which night-time photomontages were produced.

Table 1.3 - Viewpoint 1: A77 near Drumboy

Grid Reference	249341, 648952	**Figure Number**	5.2.1h
LCT	79 - Plateau Moorland with Windfarms - Ayrshire	**Designated Landscape or Wild Land Area**	None
Direction of view	West	**Approximate distance to Nearest Lit Turbine (km)**	1.1 km
Number of Hub Lights Visible	4	**Light Intensity: Accounting for Automatic Dimming and Vertical Directional Intensity Embedded Design Mitigation**	20 to 13 cd range
Location, Description of Existing View and Potential Receptors			
This viewpoint is located on the A77, to the east of the M77 and to the east of the Site. The viewpoint is representative of views from the properties at Drumboy, which face in a western direction towards the Site. The view is also representative of oblique views for road users and cyclists on the A77/ local cycle route as they pass the Site. From this location, open, wide angle, close proximity views looking over the motorway (with associated lights on moving vehicles) towards the coniferous forest on Glenouther Moor are available. The tops of the forest form the near and dark horizon with areas of open moorland visible beyond the motorway to the south of the Site.			
Night-Time Sensitivity			
Night-time views from this location are most likely to be experienced by residents and road users. Residential receptors are of high susceptibility. Road users/cyclists on this local route are of medium susceptibility. The view is not within a designed landscape or of recognised importance, therefore the value of the view is considered to be low. **Nevertheless, the sensitivity of the view is judged to be high given that it represents direct, primary views from residential properties.**			
Assessment of Visual Effects			
Figure 5.2.1h illustrates the view of the Proposed Development at night with the turbines lit at 200 cd intensity (representative of automatic dimming). The hubs of all four lit turbines will be visible, seen silhouetted against the night sky. Depending on the wind direction, red light on the moving blades as they pass the nacelle lights may also be perceptible. The nacelle lights will introduce further artificial lighting into the view, along with lights from moving traffic on the motorway. The visibility and perceived intensity of lighting will vary at different times dependent on viewing conditions, whilst the duration over which the visible lighting is evident will vary seasonally, in relation to the hours of relative darkness. The aviation lighting intensity ZTV (refer to **Figure A5.3.3**) indicates that the maximum luminous intensity of light emitted due to the viewing angle from this location will be substantially reduced. The maximum cd value emitted in the direction and angle of view towards this viewpoint will be in the 20 to 13 cd range.			

Due to the presence of existing light sources in the view; the small number of additional lights; and the reduced intensity due to the viewing angle, the scale of change associated with the visible aviation lighting is judged to be medium. Taking account of the high sensitivity will result in a **Moderate (significant)** visual effect. Views of this type will be experienced from a short section of the road (under 2 km in length as the road passes to the east of the Site) and are therefore considered to be small/ localised in geographical extent.
Potential for Cumulative Effects
Views of under construction, consented and proposed wind farms with aviation lighting are very limited.

Table 4 - Viewpoint 7: Dunlop Road (A735) Stewarton

Grid Reference	241645, 646478	**Figure Number**	5.2.7h
LCT	66 - Agricultural Lowlands - Ayrshire	**Designated Landscape or Wild Land Area**	None
Direction of View	North-east	**Approximate distance to Nearest Lit Turbine (km)**	6.4 km
Number of Hub Lights Visible	2	**Light Intensity: Accounting for Automatic Dimming and Vertical Directional Intensity Embedded Design Mitigation**	100 to 38 cd range
Location, Description of Existing View and Potential Receptors			
This viewpoint is located on a small area of open, recreational ground to the west of Dunlop Road on the northern outskirts of Stewarton. The view is representative of residential views from certain properties on rising ground to the north of Stewarton. Visibility from the centre of this settlement (the Main Street) and the majority of properties within the settlement is limited. From this location open, wide angle views looking over a field towards properties on rising ground to the north-east of Stewarton are available. Subdued interior lighting and outdoor lighting add a number of artificial light sources to the view. Glimpses of more distant farmland, woodland and moorland contribute to the dark horizon too. Lights on vehicles moving along the A735, in the foreground of the view, add further occasional artificial light sources.			
Night-Time Sensitivity			
Residential receptors are of high susceptibility. The view is not within a designated landscape and is considered to be of lower value. Accordingly, the sensitivity of the view is high.			
Assessment of Visual Effects			
Figure 5.2.7h illustrates the view of the Proposed Development at night with the turbines lit at 200 cd intensity (representative of automatic dimming). The hubs of two lit turbines (T4 and T5) will be visible, seen silhouetted against the night sky. Lighting on the hubs of T1 and T3 will be screened by buildings and vegetation on the horizon, from this location. Depending on the wind direction, red light on the moving blades as they pass the nacelle lights may also be perceptible. The nacelle lights will introduce further artificial lighting into the view, along with lights from buildings in Stewarton and traffic on the A735.			

The visibility and perceived intensity of lighting will vary at different times dependent on viewing conditions, whilst the duration over which the visible lighting is evident will vary seasonally, in relation to the hours of relative darkness. The aviation lighting intensity ZTV (refer to **Figure A5.3.3**) indicates that the maximum luminous intensity of light emitted due to the viewing angle from this location will be substantially reduced. The maximum cd value emitted in the direction and angle of view towards this viewpoint will be in the 100 to 38 cd range. Due to the presence of existing light sources in the view; the small number of additional lights; and the reduced intensity due to the viewing angle, the scale of change associated with the visible aviation lighting is judged to be small. Taking account of the high sensitivity will result in a **Minor (not significant)** visual effect. Views of this nature will be experienced from a limited number of properties to the north of Stewarton and as such, the geographical extent of effects is considered to be small/ localised. This view is not representative of views from the centre of/ wider settlement.
Potential for Cumulative Effects
Views of under construction, consented and proposed wind farms with aviation lighting are very limited and/ or very distant.

Summary of Lighting Effects

1.65 Aviation warning lights are proposed on turbines T1, T3, T4 and T5 (four turbines in total). Medium intensity 2000cd lighting will only be activated in weather conditions where visibility is less than 5 km, with automatic dimming during clear conditions (visibility beyond 5 km in all directions from the proposed turbines) reducing the required emitted light intensity to 200cd. As such, the reduced 200cd setting has formed the basis of this assessment.

Landscape Effects

1.66 No significant night time landscape effects are predicted. In terms of night time effects on landscape character, theoretical visibility of the aviation lighting of the Proposed Development within 45 km is shown on **Figure A5.3.2** (with LCT shown on **Figure A5.3.3**). Theoretical visibility is indicated from the host LCT '79 - Plateau Moorland with Windfarms - Ayrshire' and the adjacent LCT '214 - Plateau Moorland with Windfarms - Glasgow & Clyde Valley', both of which are similar in character. This visibility will be widespread within 5 km and further to the south-east. However, actual visibility will be greatly reduced by coniferous forest, which is characteristic of the LCT. The key characteristics of this LCT do not specifically recognise any dark sky qualities. Nevertheless, significant effects on landscape character are judged to extend into the hours of darkness. But these effects are not judged to affect a greater geographical extent than identified in the daytime assessment from these LCT (contained within 5 km to the north of these LCT).

1.67 There is also theoretical visibility of the proposed aviation lighting from the LCT '66 - Agricultural Lowlands - Ayrshire' to the south-west, including areas within 5 km. Actual visibility will be reduced by hedgerows, woodland and areas of settlement, which are features characteristic of this LCT. Where open views towards the Proposed Development are available, the proposed aviation lighting will generally be seen beyond artificial light sources in this LCT, including roads and rural settlement. Significant effects on landscape character are likely to extend into the hours of darkness. But these effects are not judged to affect a greater geographical extent than identified in the daytime assessment from this LCT (contained within 5 km to the north-east of this LCT).

Visual Effects

1.68 Significant visual effects are predicted for Viewpoint 1: A77 near Drumboy. This is due to the introduction of aviation lighting seen in relatively close proximity (but noting that artificial lights on moving traffic on the M77, in the foreground, form a component of the view). No significant visual night time effects are considered likely from Viewpoint 7: Dunlop Road (A735) Stewarton given the increased viewing distance

(6.4 km); partial screening provided by buildings and intervening vegetation; presence of a large number of existing light sources in the view and limited area with visibility, from the settlement.

1.69 Outside of the two representative night time assessment viewpoints, significant visual effects are also anticipated from higher sensitivity viewpoints within approximately 5 km (where receptors are likely to be present during the hours of darkness), including VP3 - Harelaw Road and VP4 - Kingsford B769. A detailed night time assessment has not been undertaken from these viewpoints in accordance with NatureScot (2024) guidance only a small selection of night time views need to have night time photomontages prepared and the scope of the night time assessment has been agreed with EAC. Given the proximity and nature of views; higher likelihood of being frequented at night; and findings of the daytime (and night time) assessments, there is the potential for significant effects from these two viewpoints (VP3 and 4).

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