Appendix 6.3 Visual Assessment of Visible Aviation Lighting

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Appendix 6.3 Visual Assessment of Visible Aviation Lighting

Introduction

This Technical Appendix has been prepared to accompany Chapter 6: LVIA in Volume 1 of the Nisthill Wind Farm (hereafter the Proposed Development) EIA Report. The Civil Aviation Authority (CAA) requires that 'en-route obstacles' at or above 150 m above ground level are lit with visible lighting to assist their detection by aircraft. As such, there is potential that the Proposed Development may need to display visible red lights at night. The effect of the Proposed Development at night would result from visible medium intensity red coloured light fittings located on the hubs, which would be set at 2,000 candelas (cd) in poor visibility and 200 cd in good visibility. There would also be 32 cd red coloured light fittings located on the towers of all proposed turbines. It should be noted that all turbines would also include infra-red lighting on the turbine hubs which would not be visible to the human eye. The focus of this Appendix is on the visual assessment of the visible aviation lighting requirements of the Proposed Development. For the assessment of lighting effects, the visual sensitivity and magnitude criteria described in Appendix 6.1 has been applied.

This visual assessment of turbine lighting is supported by a baseline light pollution map (**Figure 6.18a**), a hub lighting ZTV map (**Figure 6.18b**), a lighting intensity ZTV (**Figure 6.18c**) and night-time photomontage visualisations from three viewpoints (See visualisation **Figures 6.20, 6.21** and **6.25**).

Regulations and Guidance

ICAO / Civil Aviation Authority (CAA) Regulations

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

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

- Daylight: Above 500 cd/m^2
- Twilight: 50-500 cd/m^2
- Night: Below 50 cd/m^2

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

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

Minimum requirements:

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

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

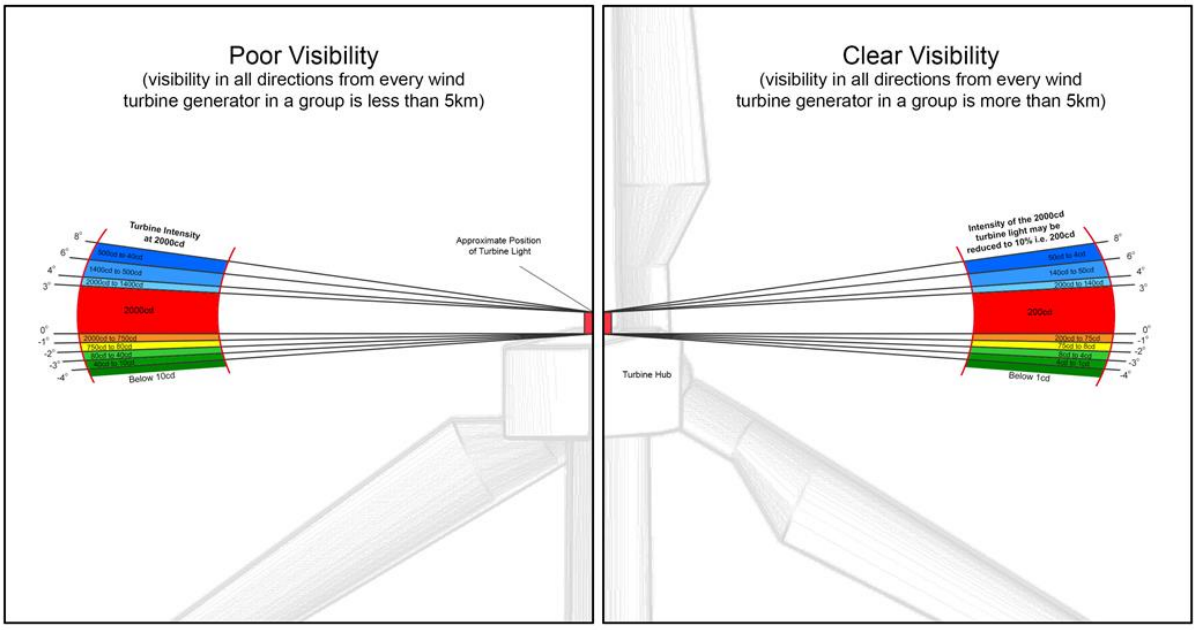
Within the UK, the ICAO/ EASA requirements for lighting wind turbines are implemented through CAA publication 'CAP 764: Policy and Guidelines on Wind Turbines', and 'CAP393: Air Navigation Order 2016'. The CAA have confirmed that UK policy broadly aligns with the International standards, including insofar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

The proposed turbines, at 180 m to blade tip, would require lighting under Article 222 of the Air Navigation Order (ANO, 2016). This requires a single, medium intensity, 'steady' red aviation light (emitting 2,000 cd) to be fitted at hub level to each turbine. In addition, the CAA requires 3 low intensity lights to be fitted at the intermediate level on the turbine tower (CAA, 2017), to provide 360 degree visibility around the tower. The intermediate 'tower' lights will be 32 cd.

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

A diagrammatic interpretation of the minimum requirements of ICAO/CAP393 based on information provided by a specific bulb manufacturer ('LuxSolar Medium Intensity Obstruction Light') is shown in Plate 6.3.1 below and in **Figure 6.18c**. It illustrates the potential light intensity from a medium-intensity hub mounted aviation light, based on the ICAO minimum standard of 2000 cd minimum average intensity required over +3° beam spread from the horizontal. It also provides illustration of the likely light intensity in poor visibility <5 km (2,000 cd) and clear visibility >5 km (200 cd).

Plate 6.3.1 - Diagrammatic interpretation of minimum requirements of ICAO/CAP393 (LuxSolar Medium Intensity Obstruction Light)

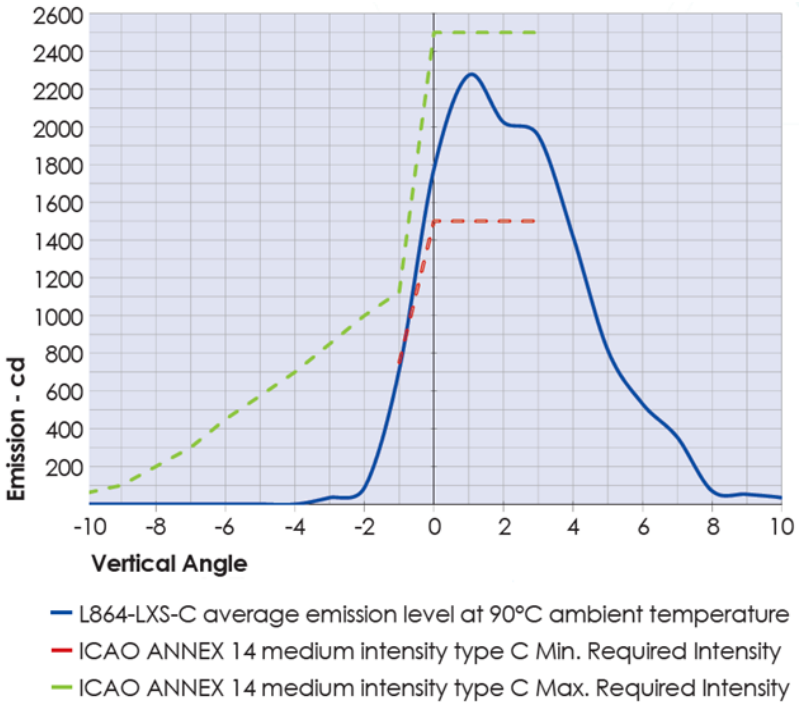


Note the turbine in the diagram is only split vertically to illustrate the difference between the light intensity in poor visibility (2,000 cd) and clear visibility (200 cd). The turbine light is designed to emit the same light intensity horizontally in 360°.

The graph in Plate 6.3.2 below illustrates the ICAO (Annex 14) minimum required (red line) and maximum recommended (green line) light intensity emission that may be experienced at various vertical angles, with the horizontal plane of the lights represented by 0 degrees vertical angle. The average emission level of the LuxSolar Medium Intensity Obstruction Light (blue line) is also shown, providing an illustration of the light emissions for one particular model of light. Whilst the precise model of light to be used for the Proposed Development is not known at this time, the graph clearly demonstrates that the intensity of the aviation lights requires to be most intense between 0 to +3° from horizontal and that the intensity of emitted light required by IACO is lower below the horizontal. The use of a particular model of aviation light which offers a reduced light intensity below the horizontal and above +3° would provide a reduction in the intensity of the lights for

receptors viewing them from areas below the horizontal. This is described further in the Detailed Assessment section of this Appendix.

Plate 6.3.2 – Lighting Intensity Graph



A Zone of Theoretical Visibility (ZTV) map of lighting intensity based on the LuxSolar Medium Intensity Obstruction Light is shown in **Figure 6.18c** and assessed further in the Reduced Effects section of this Appendix. Although the model of light to be used for the Proposed Development is not known at this time, the ZTV provides an illustration of the potential intensity if current aviation warning light technology is deployed.

Guidelines for Landscape and Visual Impact Assessment (GLVIA3)

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

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

Institute of Lighting Professional Guidance

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

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

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

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

CPRE also identifies these same broad terms as the three types of light pollution:

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

NatureScot Guidance

Visual Representation Guidance

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

The night time photography has therefore been captured in low light conditions, when other artificial lighting (such as street lights and lights on buildings) is on, to show how the wind farm lighting would look compared to the existing baseline at night.

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

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

Evolving NatureScot Approaches to Turbine Lighting

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

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

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

In terms of visual effects, NatureScot's view (as expressed at a seminar in November 2019) is that lengthy debate about the exact brightness of lights (including in visualisations) is potentially not helpful and that it is better to focus on where they will be visible, how many lights will be visible and the level of change from the baseline situation. While this approach is recognised in the Visual Assessment in this Appendix, the distinction between effects of aviation lighting at 2000cd and the reduced 200cd form the basis of the assessment. NatureScot has also taken a pragmatic view with night-time visualisations, requesting that decision makers, consultees and communities require visualisations from a small number of relevant viewpoints to understand these effects. NatureScot also recognises the challenges of capturing night time photography and accept that some post photographic manipulation of images to provide a good representation is acceptable.

Assessment Parameters

Overview

A description of the proposed turbine lighting is found within Chapter 3 and Chapter 14 in Volume 1 of the EIA Report. Based on this information, the following assumptions have been made with regards to visible lighting of the Proposed Development for the LVIA:

- the CAA requires that all obstacles at or above 150 m above ground level are fitted with visible medium intensity lighting (2,000cd) located on the turbine hub;
- the CAA requires that a secondary light is fitted to the hub for use only when the primary light fails and would not be lit concurrently;
- there is an additional requirement for three 32cd lights to be provided at an intermediate level of half the hub height. These would need to be fitted around the towers to allow for 360degrees horizontal visibility; and
- The 2,000 cd medium intensity lights may be dimmed to 10 %, or 200 cd, if visibility is greater than 5 km, i.e., in moderate to excellent or 'clear' visibility.

Worst Case Aviation Lighting Scheme

In relation to the Proposed Development, the worst-case scenario for night time effects includes the following parameters:

- all four turbines would have red, medium intensity visible lights mounted on the hub at 102.5 m;
- 2,000 cd and 200 cd intensity hub lights have been assessed representing two differing worst case situations. 2,000 cd represents the maximum intensity possible. 200 cd represents the maximum intensity that would be used when visibility extending from the wind farm exceeds 5 km;
- all turbines would also have low-intensity lights (32 cd) to be provided on the turbine towers at an intermediate level of half the hub height at 51.25 m; and
- the steady red lighting fixed to the top of the hubs and to the turbine towers may appear to flicker on and off with the blade movement. This would occur when the turbine blades pass between the lights and the observers.

On the basis of the CAA requirements, it is evident that the effect of the visible lights of the Proposed Development will be dependent on a range of factors, including the intensity of lights used, and the clarity of atmospheric visibility. In compliance with EIA regulations, the likely significant effects of a 'worst-case' scenario for turbine lighting are assessed and illustrated in this visual assessment. A worst-case approach is applied which considers the effects of 2,000 cd and 200 cd scenarios during periods of clear visibility. It should be noted however, that as the required medium intensity lights are only likely to be operated at their maximum 2,000 cd during periods of poor visibility, that 2,000 cd intensity actually represents an unrealistic worst-case position, as it is unlikely to ever be experienced at that maximum illumination level.

Whilst the assessment focuses on the worst-case scenario described above, the intensity of the lighting could be further reduced by the positive or negative angles of the viewpoint relative to the horizontal nature of the lighting beam. This is considered in the section on Reduced Effects.

Representative Night-Time Viewpoints

A hub height ZTV was used to identify where there could be direct line of sight from the surrounding area to the proposed turbine lights mounted on the turbine hubs (**Figure 6.18b**). This ZTV does not take account of any intervening screening that may arise although it must be noted that tree cover across the West Mainland of Orkney is especially sparse and rural settlement is typically dispersed.

Night-time visualisations have been produced for the three representative viewpoints. These were selected from the LVIA viewpoints and agreed with NatureScot and Orkney Islands Council (OIC), as follows:

- Viewpoint 2: A966 Hundland Road junction;
- Viewpoint 3: Vinquin Hill; and
- Viewpoint 7: Birsay Community Hall.

Whilst aviation lighting manufacturers must meet the minimum requirements, their products may vary in relation to recommended limits set out in ICAO standards, which makes it difficult to produce accurate visualisations as the lighting characteristics of different light fittings, of the same intensity, may vary outside the minimum requirements stipulated by ICAO.

Therefore, this Assessment assumes a possible worst case and the night-time photomontages have been produced to show both 2,000 cd and 200 cd reduced intensity lighting, to inform the assessment of effects assessed. However, it should be noted that the night-time photography has been captured in periods of good visibility, which is greater than 5 km. As a result, the night-time photomontage representations of the 2,000 cd lights are, therefore, an unrealistic over-representation of the likely visibility of the visible aviation lighting. This is because visibility on the site (and likely at the viewpoint itself) is very likely to be much poorer when they operate at that intensity.

Furthermore, the actual intensity of the visible aviation lighting could be reduced owing to the reduced intensity experienced from the viewpoints owing to their location above or, more typically, below the horizontal angle of the beam as shown in **Figure 6.18c**. These reductions are not illustrated in the night-time photomontages shown in **Figures 6.20, 6.21** and **6.25**.

Assessment of Effects

Types of Effect

The Visual Assessment of turbine lighting is intended to determine the likely effects that the Proposed Development will have on the visual resource, that is to say it is an assessment of the effects of visible aviation lighting on views experienced by people at night.

The assessment of turbine lighting in this Appendix does not consider effects of aviation lighting on landscape character. For visible medium intensity steady or fixed red aviation warning lights, ICAO indicates a requirement for no lighting to be switched on until 'night' has been reached, as measured at 50 cd/m^2 or darker. This is helpful as it does not require them to be on during 'twilight', when landscape character may be clearly discerned. It is considered that visible aviation lighting will therefore not affect the perception of landscape character, which is not readily perceived at night in darkness, particularly in rural areas. The

assessment of visible lighting is solely a visual effect. While aviation lighting will be visible and result in visual effects, as assessed in this Appendix, the effects of aviation lighting on the perception of landscape character are scoped out of this assessment. This decision to scope out landscape effects reflects the Scottish Ministers' recent finding in the Decision Letter and Conditions for the Crystal Rig IV Wind Farm Phase IV Public Inquiry (24th March 2021).

Baseline Lighting

The existing baseline lighting levels have been mapped for the surrounding landscape (see **Figure 6.18a**) based on Open Source data of Light Pollution across the UK. This Open Source data has been used to help understand and illustrate the existing baseline lighting levels of the Study Area.

Each pixel in the mapping shows the level of radiance (night lights) shining up into the night sky, which have been categorised into nine colour bands to distinguish between different light levels, from low level light pollution colour band one, shown as grey, to high level light pollution nine, shown as brown. West Mainland is shown to be mostly grey, indicating low levels of light pollution. Although there is settlement across most of West Mainland, it is sufficiently dispersed to avoid concentrations of light from arising. The exceptions occur where slightly higher levels of light pollution occur in association with the settlements of Dounby, Birsay and Tingwall within the first 10 km radius, and high levels occur in association with Stromness and Kirkwall in the 20 to 25 km radius. The Proposed Development is located in an area within the lowest level of light pollution and although rural properties with domestic lights and roads with vehicle lights occur in the surrounding landscape, these are not of sufficient intensity to contribute to notable levels of light pollution.

Cumulative Assessment of Visible Turbine Lights

As there are no visible turbine lights currently operating in the Study Area for the Proposed Development, and other planned developments within the Study Area are not required to display visible aviation lighting, there is no requirement for a cumulative assessment of visible turbine lights, although there is the possibility that future onshore wind farms on the Orkney Islands may also require visible turbine lights.

Detailed Assessment

Approach

The detailed assessment of the visual effects of the hub aviation lighting is based on three selected representative viewpoints as recommended in NatureScot's 'Visual Representation of Wind Farms – Guidance Version 2.2' (2017) and as presented in this section. To ensure a rounded assessment, consideration has also been given to the extent to which the hub aviation lighting would be visible from all 19 of the representative viewpoints, in order to understand the potential for wider significant effects and establish an area within which visual receptors have the potential to be significantly affected.

Representative Viewpoints

Viewpoint 2: A966 Hundland Road junction

Nearest Visible Turbine Light: 1.4 km

Night-Time Baseline Condition and Sensitivity

This viewpoint represents the views of residents and road users at night, with road-users on the A966 a minimum of approximately 1.4 km from the closest turbine and residents in this local area a minimum of approximately 1.0 to 1.6 km.

During daylight, the view from this viewpoint extends across the low and undulating coastal hills to the north beyond which the North Atlantic can be glimpsed, while to the south the view is contained by the rising landform of the coastal hills such that it does not extend beyond the close range. During night time, individual landscape elements that create different landscape patterns in the view are difficult to discern. The baseline night photography is captured at a time where the shape of the low hills to the north and ridgeline to the

south can only be distinguished against the lighter shade of the sky. The ridgeline is low and rounded and the houses located along it, can be identified as distinct built features.

The clustering of properties around this viewpoint and its location on the A966 coastal road would suggest that there would be some baseline lighting visible from the properties and / or passing vehicles. The photograph, however, shows practically no baseline lighting, possibly because residents have their window coverings closed or some of the properties were not occupied at the time, and because traffic flows on the A966 are typically light, especially at night. Whilst occasional vehicle lights and domestic lights can be seen from this location at close to middle range, they are a small part of the overall baseline lighting level which is considered to be relatively dark.

The value and visual susceptibility of receptors at night differs when compared to the assessment carried out for daytime conditions. During the night the landscape has a diminished scenic quality and receptors would not have the same appreciation of the landscape which is dark and muted compared with the landscape scenery evident during the day. However, the proximity of the residents in relation to the Proposed Development is such that the susceptibility to change in this instance remains at a similar level. The susceptibility of residents is heightened by the long periods of time over which the hub aviation lighting would potentially be experienced from their properties. In contrast, road-users would experience the lighting over only short periods of time and with their concentration on the road at night, this would reduce their susceptibility. Taking these factors into account, the night-time sensitivity of residents is considered to be **high** and of road-users is considered to be **medium**.

Night-Time Effect Worst Case Aviation Lighting Scheme

2,000 cd Light Intensity

In the worst-case scenario, all of the four hub lights would be visible from this viewpoint. The photomontage in **Figure 6.20i** shows that the Proposed Development would be seen to introduce lights to a part of the view where there are very few other lights visible, although domestic lighting associated with properties along the ridgeline and headlights of passing vehicles on the A966 do form part of the baseline lighting. The lights would affect the darkness experienced along the northern coast of West Mainland and the proximity of the Proposed Development combined with the overall dark baseline lighting levels would tend to increase the visual impression that the turbine lights would have on receptors at this location, despite the fact that they would be contained within the south-eastern sector of the wider open night time views. It is, therefore, considered that these lights would form a substantial addition to the existing baseline and the magnitude of change would be **medium-high** for residents and **medium** for road-users**.** The effect on residents represented by this viewpoint and in the surrounding area would be **major** and **significant**, while the effect on road-users would be **moderate** and **significant.**

200 cd Light Intensity

The description of lights visible for 2,000 cd also applies to the 200 cd reduced intensity scenario. The photomontage in **Figure 6.20j** shows that while the reduced intensity of the lighting would reduce the overall effect, the close proximity of the Proposed Development would mean in this instance, there would not be a notably reduced magnitude of change in respect of residents. It is considered that the 200 cd lights would also form a substantial addition to the existing baseline and the magnitude of change is assessed as **medium** resulting in a **major / moderate** and **significant** effect for residents. In respect of road-users the magnitude of change would drop to **medium-low** giving rise to a **moderate / minor** and **not significant** effect.

Viewpoint 3: Vinquin Hill

Nearest Visible Turbine Light: 1.5 km

Night-Time Baseline Condition and Sensitivity

This viewpoint represents the views of residents at night, with rural properties set across the west-facing slopes of Vinquin Hill at a minimum of 1.2 to 1.8 km from the closest turbine.

The principal orientation of properties on the west-facing side of Vinquin Hill is westwards towards Hundland Hill which occupies the opposite shore of the Loch of Swannay. Views during the daytime are across a foreground of the farmed loch shore, open water of the loch and farmed hillside of Hundland Hill beyond.

Daytime views also include the dispersed settlement across Vinquin Hill but also across the surrounding rural landscape. In views during the night time, however, individual landscape elements that create different landscape patterns in the view are difficult to discern. The baseline night photography is captured at a time when the landform is seen as dark shapes in contrast with the slightly lighter context of the sky and the loch, with an evening glow evident across the western sky. The detail of the landform is not readily visible. Baseline lighting in this view is limited to the domestic lighting from a few rural properties, while the overall level of lighting is low and the darkness is seen as the defining feature.

The value and visual susceptibility of receptors at night differs when compared to the assessment carried out for daytime conditions. During the night, the landscape has a diminished scenic quality and receptors would not have the same appreciation of the landscape which is dark and muted compared with the landscape scenery evident during the day. However, the proximity of the residents in relation to the Proposed Development is such that the susceptibility to change in this instance remains at a similar level. The susceptibility of residents is heightened by the long periods of time over which the hub aviation lighting would potentially be experienced from their properties. Taking these factors into account, the night-time sensitivity of residents is considered to be **medium-high**.

Night Time Effect Worst Case Aviation Lighting Scheme

2,000 cd Light Intensity

In the worst-case scenario, all four of the hub lights would be visible from this viewpoint. The hub aviation lighting would appear as a relatively close range feature in the night sky, readily visible to the west and seen set above the enclosing skyline of Hundland Hill. The Proposed Development would be seen to introduce lights to a part of the view where there are very few other lights visible. The visualisation in **Figure 6.21k** shows that the hub aviation lights would affect the darkness experienced across the west-facing slopes of Vinquin Hill. The proximity of the Proposed Development combined with the overall dark baseline lighting levels would tend to increase the visual impression that the 2,000 cd turbine lights would have on receptors at this location, despite the fact that they would be contained within the eastern sector of the wider, open, night time views. It is, therefore, considered that these lights would form a substantial addition to the existing baseline and the magnitude of change would be **medium-high.** The effect on residents at this viewpoint and in the surrounding area would be **major / moderate** and **significant.**

200 cd Light Intensity

The description of lights visible for 2,000 cd also applies to the 200 cd reduced intensity scenario. The visualisation in **Figure 6.21l** shows that although the intensity of the lights would be substantially reduced, they would still form the defining feature in the view owing to their proximity and the contrast they present in respect of the lack of lighting and predominance of the darkness in the night time view. It is considered that the 200 cd lights would also form a substantial addition to the existing baseline and the magnitude of change is assessed as **medium** resulting in a **moderate** and **significant** effect.

Viewpoint 7: A967 Birsay Community Hall

Nearest Visible Turbine Light: 4.5 km

Night-Time Baseline Condition and Sensitivity

This viewpoint represents the views of residents and road users at night, with road-users on the A986 and residents in this local area, at a minimum of approximately 4 km to 4.5 km from the closest turbine.

During daylight, the view from this viewpoint extends across the Loch of Boardhouse to Kirbuster Hill, with the moorland hills seen extending to the south. The steep slopes of Ravie Hill enclose the view to the south and shallower slopes of the coastal hills enclose the view to the north. The predominant land use is agricultural and there is a dispersal of farmsteads and other rural properties across this landscape. During night time, individual landscape elements that create different landscape patterns in the view are difficult to discern. The baseline night photography is captured at a time where the shape of the low hills to the north and east, and ridgeline to the south can only be distinguished against the lighter shade of the sky. While the detail of the landscape is not discernible, the farmsteads and rural properties can be identified owing to the typically light coloured materials.

The location of the community hall, caravan and campsite and rural properties close to this viewpoint and its location on the A986 would suggest that there would be some baseline lighting visible from the properties and /or passing vehicles. The photograph, however, shows practically no baseline lighting, possibly because residents have their window coverings closed or some of the properties are currently not occupied, and because traffic flows on the A966 are typically light, and more so at night. Whilst occasional vehicle lights and domestic lights can be seen from this location, they are a small part of the overall baseline lighting level which is considered to be relatively dark.

The value and visual susceptibility of receptors at night differs when compared to the assessment carried out for daytime conditions. During the night the landscape has a diminished scenic quality and receptors would not have the same appreciation of the landscape which is dark and muted compared with the landscape scenery evident during the day. However, the proximity of the residents in relation to the Proposed Development is such that the susceptibility to change in this instance remains at a similar level. The susceptibility of residents is heightened by the long periods of time over which the hub aviation lighting would potentially be experienced from their properties. In contrast, road-users would experience the lighting over only short periods of time and with their concentration on the road at night, this would reduce their susceptibility. Taking these factors into account, the night-time sensitivity of residents is considered to be **medium-high** and of road-users is considered to be **medium**.

Night-Time Effect Worst Case Aviation Lighting Scheme

2,000 cd Light Intensity

In the worst-case scenario, three of the four hub aviation lights would be visible from this location, albeit with the glow from the fourth one also visible despite the light itself not being visible. The Proposed Development lights would be seen as an introduction of lights to a part of the coastal hills to the east at 4.5 km where there is very little existing lighting apart from low level domestic lighting associated with properties on the west-facing slope of Kirbuster Hill which sits below the ridge.

The hub lights would be seen in a part of the panorama that has relatively high levels of darkness, although with low level point sources of light associated with settlement across this hill. The hub aviation lights would be seen set above the ridgeline and against the open sky, although set low in the sky and contained within one sector of the much wider night sky view. Whilst the lights would be visible as points of light in the view and increase the influence of human elements, the lights are not expected to result in obtrusive light that impedes the view of the night sky, nor result in brightening of the night sky (skyglow) that might be of detriment to the overall experience of the dark skies in this view.

Taking all of this into account, the magnitude of change on residents is assessed as **medium** resulting in a **moderate** and **significant** effect, while on road-users it would be **medium-low** resulting in a moderate and **not significant effect**. The effect on residents is significant due to the intensity of light experienced within an otherwise relatively dark part of the horizon combined with the openness and orientation eastwards towards the lights, when viewed from this lochside location. Importantly, the visual effect of the aviation lights will not result in obtrusive light that impedes the view of the night sky.

200 cd Light Intensity

The description of lights visible for 2,000 cd also applies to the 200 cd reduced intensity scenario. The photomontage in Figure 6.19j shows the reduced intensity of the 200 cd hub aviation lights, which is notably less than the 2,000 cd hub aviation lights shown in Figure 6.19i. The 200 cd lights would have less of an effect on local residents and road-users, especially as seen in a sector of the view where domestic lighting below the ridgeline forms a baseline feature. On balance, the magnitude of change is predicted to be **medium-low** for this scenario which results in a **moderate** and **not significant** effect.

Reduced Effects

As the model of hub aviation light has not yet been determined, the reduced lighting intensity below the horizontal and above the 3+ degrees, which is a feature of some models, has not been considered within the main assessment but is considered here as a potential measure to further reduce the effects of the aviation lighting.

Viewpoint 2: A966 Hundland Road junction

The intensity of the hub lights in the 2,000 cd scenario, allowing for the vertical angle between Viewpoint 2 and the closest hub is calculated to be between 750 and 80 cd, while the intensity of the hub lights in the 200 cd scenario, allowing for the vertical angle between this viewpoint and the closest hub is calculated to be between 75 and 8 cd.

The reduced intensity of the 750 to 80 cd lighting would give rise to a **medium** magnitude of change on residents resulting in a **moderate** and **significant** effect, while it would give rise to a **medium-low** magnitude of change on road-users resulting in a **moderate / minor** and **not significant** effect. In respect of the reduced intensity of the 75 to 8 cd lighting this would be insufficient to give rise to effects on residents and road-users.

Viewpoint 3: Vinquin Hill

The intensity of the hub lights in the 2,000 cd scenario, allowing for the vertical angle between Viewpoint 3 and the proposed turbines is calculated to be 80 to 40 cd, while the intensity of the hub lights in the 200 cd scenario, allowing for the vertical angle between this viewpoint and the closest hub is calculated to be between 8 and 4 cd. The reduced intensity of the 80 to 40 cd lighting and 8 to 4 cd lighting would be insufficient to give rise to significant effects on residents and road-users.

Viewpoint 7: A967 Birsay Community Hall

The intensity of the hub lights in the 2,000 cd scenario, allowing for the vertical angle between Viewpoint 7 and the closest hub is calculated to be 750 to 80 cd, while the intensity of the hub lights in the 200 cd scenario, allowing for the vertical angle between this viewpoint and the closest hub is calculated to be 75 to 8 cd.

The reduced intensity of the 750 to 80 cd lighting would give rise to a **medium** magnitude of change on residents resulting in a **moderate** and **significant** effect, while it would give rise to a **medium-low** magnitude of change on road-users resulting in a **moderate / minor** and **not significant** effect. In respect of the reduced intensity of the 75 to 8 cd lighting this would be insufficient to give rise to significant effects on residents and road-users.

Viewpoint Lighting Visibility and Intensity

Table 6.3.1 below provides a summary of the potential visibility of hub lights for each of the LVIA viewpoints, this is based on the Hub Lighting ZTV in **Figure 6.18b**, and details how many lit turbines would be theoretically visible from each of the viewpoints included in the LVIA. It also provides a summary of the reduced intensity for the hub lights based on the Lighting Intensity ZTV **in Figure 6.18c**.

Table 6.3.1 - Viewpoint Lighting Visibility and Intensity Summary

VP No	Viewpoint	Distance to nearest turbine (km)	No of hub lights visible	Vertical Angle from Horizontal plane of light location to viewpoint location (degrees)	Light intensity at each viewpoint allowing for vertical angle (cd)	
					2000cd Scenario	200cd Scenario
1	A966, Loch of Swannay	2.2 km	4	-1 to -2 degrees	750 to 80 cd	75 to 8 cd
2	A966, Hundland Road junction	1.4 km	4	-3 to -4 degrees	40 to 10 cd	4 to 1 cd
3	Vinquin Hill, Costa	1.5 km	4	-2 to -3 degrees	80 to 40 cd	8 to 4 cd
4	Mid Hill	3.2 km	4	0 to 3 degrees	2,000 cd	200 cd

VP No	Viewpoint	Distance to nearest turbine (km)	No of hub lights visible	Vertical Angle from Horizontal plane of light location to viewpoint location (degrees)	Light intensity at each viewpoint allowing for vertical angle (cd)	
					2000cd Scenario	200cd Scenario
5	Kirbuster, Loch of Hundland	1.5 km	4	-2 to -3 degrees	80 to 40 cd	8 to 4 cd
6	Brough of Birsay	6.0 km	2	0 to -1 degree	2,000 to 750 cd	200 to 75 cd
7	A967, Birsay Community Hall	4.5 km	3	-1 to -2 degrees	750 to 80 cd	75 to 8 cd
8	A967, Twatt	4.0 km	4	-1 to -2 degrees	750 to 80 cd	75 to 8 cd
9	A967, near Rosemire	6.3 km	4	-1 to -2 degrees	750 to 80 cd	75 to 8 cd
10	A967, near Queena	10.9 km	3	0 to -1 degree	2,000 to 750 cd	200 to 75 cd
11	Ring of Brodgar	13.6 km	3	0 to -1 degree	2,000 to 750 cd	200 to 75 cd
12	Vishall Hill	7.9 km	No visibility			
13	B9057 north-west of Dounby	5.4 km	3		750 to 80 cd	75 to 8 cd
14	Skara Brae	10.9 km	No visibility			
15	Vestra Fiold	7.6 km	4	0 to -1 degree	2,000 to 750 cd	200 to 75 cd
16	A966 west of Abune the Hill	2.7 km	4	0 to -1 degree	2,000 to 750 cd	200 to 75 cd
17	Westside, Rousay	7.0 km	4	0 to -1 degree	2,000 to 750 cd	200 to 75 cd
18	Hillock Road, Shapinsay	23.3 km	No visibility			
19	Ward Hill, Hoy	25.8 km	4	0 to 3 degrees	2,000 cd	200 cd

Viewpoint Lighting Visibility

From the majority of the viewpoints, four of the hub aviation lights would be visible, albeit with some reduction from certain viewpoints owing to the screening effect of intervening landform. These would typically

occupy a limited horizontal extent amidst wider panoramic views and be contained at a relatively low level within the wider night sky.

Whilst it is noted that the actual intensity of light experienced at the representative viewpoints and across the wider study area is likely to be less intense than the maximum intensity of the light (2,000 cd in visibility <5 km and 200 cd in visibility >5 km), this appendix assesses the maximum possible intensity of light observed at each of the viewpoints considered and represents this maximum intensity in corresponding visualisations.

In reality, it is extremely unlikely that 2,000 cd will ever be experienced at its full intensity as it will only operate when visibility is reduced by climatic conditions. Reduced visibility will also affect someone's perception of the intensity of the light fitting. More than half of the viewpoints are beyond 5 km from the Proposed Development, therefore, the worst-case intensity experienced at these viewpoints would likely be represented by the 200 cd scenario. This is because the 2,000 cd intensity lights would only be in operation when visibility is less than 5 km and, in this situation, they would appear far less intense due to the poor visibility surrounding the Proposed Development.

Taking into account the assessment of the three representative viewpoints, all of which are located within 5 km of the Proposed Development, the levels of visibility that would be experienced from the other viewpoints and the reduced intensity that would be experienced from viewpoints beyond 5 km, the broad conclusion that can be drawn is that there is potential for significant visual effects to arise as a result of the hub aviation lighting within the first 5 km of the Proposed Development.

Viewpoint Lighting Intensity

Figure 6.18c shows the Lighting Intensity ZTV, illustrating where the different intensities would be visible within the surrounding landscape as determined by the differentiation between the angle of the hub mounted aviation light in relation to the elevation of the different visual receptors in the surrounding landscape. **Figure 6.18c** also indicates the corresponding intensity reductions for each of the 2,000 cd and 200 cd situations. The light intensity ZTV analysis is run for each turbine however for ease of illustration it shows the light intensity based on the highest cd level that may occur in a particular location as a worst case. This additional reduction is considered in terms of reduced effects, as the extent of the reduction would be determined by the candidate light selected.

Figure 6.18c presents a pattern of lighting intensity in which the lowest lighting intensities would occur closest to the proposed turbines, with intensities broadly increasing with distance from the proposed turbines, although the ZTV does not take into account the reduction in light intensity that would also occur with distance. It is notable that the analysis shows the intensity of the light emitted at the angle viewed, however, it also does not take account of the distance over which the light is viewed and the deterioration of the intensity due to distance and atmospheric conditions that may occur. The patch below the turbines and out to an approximate 1 km radius would be below 10 cd at the 2,000 cd setting, and 1 cd at the 200 cd setting, which would be experienced as low intensity. This is because the hub lights would be at 102.5 m while the receptors on the ground would be at a considerably lower level, albeit within close-range. The intensity of the lighting then would increase to 40 to 10 cd at the 2,000 cd setting, and 4 to 1 cd at the 200 cd setting, out to an approximate 2 km radius and to 80 to 40 cd at the 2,000 cd setting and 8 to 4 cd at the 200 cd setting, out to an approximate 3 km radius. The combination of distance from the proposed turbines and the slight rise in elevation to the north-west and south-east would mean that the lighting intensities would rise again between the 3 to 4 km radius with 750 cd to 80 cd at the 2,000 cd setting, and 75 cd to 8 cd at the 200 cd setting, shown in yellow on the ZTV, and 2,000 to 750 cd at the 2,000 cd setting and 200 to 75 cd at the 200 cd setting, shown in orange on the ZTV. There would also be a patch of the full 2,000cd or 200 cd across the northern edge of the moorland hills to the south-east at 3 km to 4 km, this owing to the height being commensurate with or higher than the height of the hub lighting.

Beyond this initial 4 km of fairly concentrated visibility, the extents to which the hub lighting would be visible would reduce, with large patches of the wider study area showing no visibility. There would, however, also be large patches of hub lighting visibility, most notably extending across the lower-lying loch basin landscapes to the south-west and south between approximately 4 km and 17 km. In these patches, the intensity of the hub lights is shown as 750 cd to 80 cd at the 2,000 cd setting, and 75 to 8 cd at the 200 cd setting, shown in yellow on the ZTV, and 2,000 to 750 cd at the 2,000 cd setting and 200 to 75 cd at the 200 cd setting, shown in orange on the ZTV.

Many of the representative viewpoints within the areas closest to the Proposed Development, including those found within the loch basin and coastal hill landscapes, could have reduced intensity as a result of the negative vertical angle in which the hub lights would be viewed. Subject to the final choice of candidate light then the lighting intensity may be reduced from 2000cd or 200cd due to the vertical angle and this reduction may correspond with the intensities shown in the last 2 columns of Table 6.3.1 above.

The majority of residential properties within the RVAA 2 km study area would have a vertical angle of below -2 degrees, resulting in an approximate range of lighting intensities of below 80 to 40 cd - when visibility is less than 5 km and 8 to 4 cd when visibility is greater than 5 km – these findings based on the candidate light used in the analysis used to prepare **Figure 6.18c** and Table 6.3.1. These low levels of lighting intensity may further reduce the potential for significant effects to arise in respect of the closest range properties.

From areas between 5 km and 10 km there tends to be theoretical visibility of three or four hub lights, however, due to the distance of these viewpoints, the worst case intensity of the aviation lights will likely be 200 cd in 'clear' visibility because in the 2000 cd scenario, reduced visibility will reduce the perception of the intensity of the light fitting. In long distance views over 20 km, such as Viewpoint 19 on Ward Hill on Hoy, the aviation lights are still likely to be visible, based on experience of other operational wind farm aviation lights viewed in the field, however the distance and reduced intensity are mitigating factors with increasing distance.

It is clear from **Figure 6.18c** that the full intensity of the lights would only theoretically be experienced from very localised parts of the study area, where similar or more elevated terrain occurs, while the majority of the lower-lying parts would experience reduced intensity. As described in the LVIA baseline, the ZTV itself is contained to some extent by the coastal hills to the east and the moorland hills to the south. While the coastal hills are too low to create an extensive screen, the terrain on the northern edge of the moorland hills is at a similar elevation to the hub aviation lighting and **Figure 6.18c** illustrates a vertical angle of between 0 and 3 degrees, which would result in an approximate range of lighting intensity of between 2,000 cd when visibility is less than 5 km, and 200 cd when visibility is greater than 5 km.

Conclusion

At night, the turbines would not in themselves be conspicuous during the hours of darkness. Nevertheless, the assessment of night-time effects for the Proposed Development has predicted significant effects for all three of the three agreed representative night-time viewpoints, in respect of hub aviation lighting on all four turbines. These effects are summarised as follows:

Viewpoint 2 – A966 Hundland Road junction is predicted to experience a major and significant effect on residents and a moderate and significant effect on road-users for the 2,000 cd scenario and a major / moderate and significant effect for residents and moderate / minor and not significant effect for the 200 cd scenario. This is due to the introduction of the aviation lights at close proximity to residents and road-users which would affect the sense of seclusion experienced at this location and within the coastal hill along the north coast of West Mainland.

Viewpoint 3 – Vinquin Hill is predicted to experience a major / moderate and significant effect on residents for the 2,000 cd scenario and a moderate and significant effect for the 200 cd scenario. This is due to the introduction of the aviation lights at close proximity to residents, especially as many of these properties face west towards Hundland Hill where the hub aviation lighting would be seen.

Viewpoint 7 – Birsay Community Hall is predicted to experience a moderate and significant effect on residents and moderate and not significant effect on road-users for the 2,000 cd scenario and a moderate and not significant effect on residents and road-users for the 200 cd scenario. Whilst the higher intensity lighting would form a notable feature for residents and road-users in this area, the separation distance combined with the extent of settlement across Kirbuster Hill seen in the view to the east ensures that the lower intensity lighting would not form a notable feature.

The duration of the effect of the lights on receptors is likely to be over a relatively short period, more commonly experienced during evening and morning hours of darkness, around dusk and sunrise. The ICAO standard requires the lights to be switched on 30 minutes after sunset, and 30 minutes before sunrise, removing the likelihood of visible lighting during twilight. The visual effects of the Proposed Development at night would also be limited by the activity of receptors at night. Receptors that experience views at night are

generally limited to residents of settlements, rural properties and road-users using the road network. Views from within properties are likely to be restricted by the use of window coverings, particularly in winter.

Views from remote rural locations such as the coastline, loch shores, or coastal hills, are visited infrequently at night, therefore, numbers of receptors affected will be low. There are also no Dark Sky Parks on West Mainland which would otherwise denote a special sensitivity and settlement and roads are fairly dispersed such that there is some baseline lighting in most parts, albeit typically at a low level.

In considering the maximum intensity of 2,000 cd and based on information presented in Table 6.3.1 and the assessment of the three representative viewpoints, it can be concluded that there would be the potential for significant effects associated with the hub aviation lighting to extend over an approximate 5 km radius of the Proposed Development, although, as previously stated, the maximum intensity of 2,000cd would be infrequently experienced. In considering the reduced intensity of 200 cd, this might give rise to significant effects on residents within an approximate 5 km radius but less likely to significantly affect road-users within this area. In considering the mitigation measures that would be introduced by the use of certain candidate lights that would have controlled directional beams, as illustrated in the Lighting Intensity ZTV in **Figure 6.18.c**, the extent of significant effects would be reduced further, such that it would only be specific locations with potential for residents to undergo significant effects.

The assessment of night-time effects is based on clear night time viewing conditions. At dusk and sunrise, it may be possible to identify the formation of the turbines with the lighting switched on, but only in conditions of good and excellent visibility. At sunrise it may also be possible, in views from the west, to see the turbines with lights switched on whilst backlit by the rising sun.

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