TECHNICAL APPENDIX 4.9: LIGHTING ASSESSMENT

Turbine Lighting

The lighting of wind turbines is an emerging issue, related to the recent trend towards taller turbine proposals and the requirement for turbines of 150 m or above to be visibly lit in relation to aviation safety. As a consequence, there is potential for significant landscape and visual effects, especially where developments are located in remote rural locations where there are few artificial light sources and where darkness is an integral and valued aspect of the night landscape.

Regulatory Requirements

Article 222 (1) of the Civil Aviation Authority's (CAA) Air Navigation Order 2016 and Regulations (ANO 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."

Article 222 (8) defines an 'en route obstacle' as follows:

"an 'en-route obstacle' means any building, structure or erection, the height of which is 150 metres or more above ground level, but it does not include a building, structure or erection:

a) which is in the vicinity of a licensed aerodrome; and

b) to which section 47 of the Civil Aviation Act 1982 (warning of presence of obstructions near licensed aerodromes) applies."

These provisions mean that structures of 150m or more in the UK are routinely lit with medium intensity (2,000 candela) steady red lights.

ANO Article 222 also contains provisions allowing for exemptions from its lighting requirements. Article 222 (6) provides that:

"A permission may be granted for the purposes of this article for a particular case or class of cases or generally."

While Article 222 (7) 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 fi t and display lights in accordance with this article."

The proposed developments turbines would be up to 175 m above ground level to blade tip. They would not qualify for the exceptions listed in ANO Article 222 (8) (a) and (b). Therefore, they would normally be subject to the lighting requirements set out in Article 222(1). However, the provisions in the CAA Policy Statement[1]that the intermediate-level lights are only required to be low intensity

[1] DAP Policy: Lighting of Onshore Wind Turbine Generators in the United Kingdom with a maximum blade tip height at or in excess of 150m Above Ground Level, 1st June 2017

(32 candela) and that the intensity of the 2,000 candela light may be reduced to 10% of its peak intensity *"if the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5 km."*

The technical specifications for medium intensity obstacle lights are set out in International Civil Aviation Organisation (ICAO) Code - Annex 14 Table 6-3 and, for European Union Aviation Safety Agency (EASA) member states such as the UK, in Table Q-3 of CS-ADR-DSN. The ICAO and EASA specifications are identical.

The ICAO and EASA specifications for lighting do not use the term "minimum peak intensity" set out in paragraph 4.g. of the CAA Policy Statement. The required and recommended intensity settings for 2,000 candela lights are illustrated in Figure 4.9.1 and summarised as follows:

- Minimum average intensity between 0 and 3 degrees is 2,000 candela;
- between 0- and -1-degrees intensity would reduce from 2,000 to 750 candela;
- between -1- and -2-degrees intensity would reduce to from 750 to 80 candela;
- between -2 and -3 degrees intensity would reduce from 80 to 40 candela; and
- between -3- and -4-degrees intensity would reduce from 40 to 0 candela.

The implications of this for visibility of the lights from key viewpoints is that, depending upon the angle of receptors relative to the turbine lights, the intensity of light will vary, along with its perceived brightness. For example, for a light with a maximum intensity of 2,000 candela, views from below -3 degrees would see the light source as below 40 candela, a considerable reduction in brightness from the maximum intensity, and if receptors view the light from below -4 degrees there would, theoretically be no direct view of the light. However, depending upon the specification and design of the light, some light reflection off the back of turbine blades may be discernible.

In conditions where horizontal meteorological visibility exceeds a 5 km radius from the position of the light significant reductions in light intensity would be experienced, as lighting intensity would be reduced to 10% of the maximum intensity, as summarised below.

- Minimum average intensity at 10% between 0 and 3 degrees would be 200 candela;
- between 0- and -1-degrees intensity would reduce from 200 to 75 candela;
- between -1- and -2-degrees intensity would reduce to from 75 to 8 candela;
- between -2 and -3 degrees intensity would reduce from 8 to 4 candela; and
- between -3- and -4-degrees intensity would reduce from 4 to 0 candela.

Consequently, receptors located over 5 km from the turbines would only ever experience clear visibility to lights at these reduced intensities. In conditions of meteorological visibility less than 5 km the perceived brightness of turbine lights, whilst possibly still visible, are likely to be reduced by such conditions. Additionally, when combined with local sources of light (including internal and /or external lighting and car lights) such as those present along the A835 corridor and in the settled landscape to the east, approaching the coast, the impact of the turbine lighting on such distant receptor locations may decrease to slight or even negligible magnitude.

Potential Effects

There is a distinction between light pollution or nuisance and the effect of lighting on the character and amenity of the landscape at night.

The Guidance Notes for the Reduction of Obtrusive Light GN01:2011 identifies three principle forms of obtrusive lighting or 'light pollution':

- Skyglow - the brightening of the night sky, usually occurring above settlements or other concentrations of artificial light and exacerbated by the presence of dust particles or water droplets;
- Glare - the 'uncomfortable' brightness of a light source when viewed against a darker background; and
- Light Intrusion ("Trespass") - the spilling of light beyond the boundary of the property or area being lit.

Aviation lighting of the type proposed are designed to focus light horizontally (i.e. between 0 and 3 degrees) and incorporate both opaque caps and collars to avoid up-lighting and reduce downlighting. Outwith these angles there would be a reduced in light intensity.

This has been verified during field observations undertaken by the assessor throughout 2017 and 2018 in respect of existing 2,000 candela aviation lights on the established:

- Queensferry Crossing, Edinburgh – which unlike the lighting that would be utilised on the proposed turbines, is not constant, but illustrates the effect of flashing effects caused by rotor movement;
- Craigkelly Tower – located on the Binn' that overlooks the coastal town of Burntisland, near Kirkcaldy, Fife and comprising a series of constant red lights at 2000 candela;
- Levenmouth Demonstration Turbine – Fife Energy Park, Methil, Fife, which is a constant red 2000 candela light that is nacelle mounted;
- Hunterston Test Centre (Onshore) – Nr Fairlie, North Ayrshire, which is a constant red 2000 candela light that is nacelle mounted; and
- Windy Standard III Wind Farm test light in Dumfries and Galloway, which is a constant red 2000 candela light.

Field reconnaissance was undertaken:

- from varying distances of up to 15 km from each development to verify the effect of distance on the perception of the lighting;
- during differing weather conditions including periods of rain, low cloud and clear skies;
- at different times of day to reflect the variation in perceived brightness and prominence of lights at dusk and during hours of darkness; and
- from different directions and elevations.

It is apparent to the assessor from this field reconnaissance that whilst skyglow and diffuse light domes can be present from any light source, especially those that emit upwards, aviation lights of the type proposed do not form visible light domes or skyglow. Additionally, no dazzling, glare or light spill intrusion into neighbouring properties or receptor locations was witnessed. The lights were, however, bright and prominent points of light in views, especially where there was a high degree contrast (i.e. the lights were seen against a dark sky or backclothed by a dark landmass, or where there were little, or no, existing artificial light sources present at the viewpoint, in the intervening landscape, or behind the aviation lights. During periods of greater ambient light, (e.g. before dusk) the prominence of lights was observed to be considerably less. It is also the case that the size of the lights reduced according to distance and the perceived brightness of the lights diminished with distance also.

Observations during period of low cloud cover (i.e. that enveloped the lights) indicate that there is a noticeable reduction in aviation light intensity. During such conditions localised halo effects were observed in the immediate vicinity of the lights. Halo effects had a low light intensity and did not extend vertically. Other effects witnessed during field reconnaissance include illumination of the base of turbine blades and a 'blinking' effect caused by the screening effect of blades as they pass

the light. These effects are dependent upon the direction of wind and the location of the receptor, however. Where a number of lit turbines are present such 'blinking' is likely to be uncoordinated.

The key effect of interest in landscape and visual terms is therefore less concerned with light pollution, and more the introduction of new artificial lighting within a largely unlit landscape context, with consequent effects on the night character and visual amenity of the area. In this context, effects on landscape character are almost exclusively concerned with perceptions of darkness and remoteness as the key characteristic constituent elements of landscapes are generally obscured after dark.

Mitigation

There are principally five current sources of potential mitigation in respect of aviation lighting on turbines, comprising four technological (in addition to one inherent) which have been introduced and accepted to varying degrees by aviation authorities in countries around the world (including by the United States Federal Aviation Authority ('FAA'), German Federal Aviation Office ('LBA'), and the Netherlands Aerospace Centre ('NAC'):

- the reduction in lighting intensity during periods of meteorological visibility in excess of 5 km (as discussed previously);
- The inherent reduction in apparent light intensity from source and size of light when viewed over distance;
- The reduction in lighting intensity for receptors at different elevations relative to source, as a result of design of the lights;
- the design of the lights to avoid illumination of turbine nacelles, towers and blades;
- the lighting of only certain turbines along the perimeter of the wind farm, thereby limiting the number of lights visible at any given location;
- use of a radar activated lighting solution. Such a system would mean that lights would only be activated by 'nearby' aircraft and could therefore only be on for a small proportion of time.

Reduced Lighting Intensity Over Distance

As observed during field reconnaissance, the perceived brightness and size of the light source, as experienced at different locations, will vary according to distance and atmospheric conditions. The intensity and brightness of of the visible light, whilst constant in actuality, reduces as distance increases, due primarily to a reduction in the size of the lights surface and light energy reaching receptors. Clearly, any water droplets or air borne particles compounds this effect, partially or entirely obscuring the light source.

Reduced Lighting Intensity by Relative Elevation

Figure 4.9.1 illustrates the intensity of turbine lights at different locations across the LVIA study area (assuming lighting of all turbines), taking account of the angle at which they are seen from receptor locations. It is apparent from this figure that the greatest intensity and brightness experienced would occur at elevated locations which are infrequently visited after dark, whilst considerable reductions in intensity and brightness would be witnessed from low lying locations close by to the turbines, at primary receptor locations.

Lighting Design

The degree of mitigation achieved through careful design of lights is crucial. Lights on the side of towers can be designed to minimise illumination of the tower. Similarly, the incorporation of light

caps and collars can restrict up-lighting effects and the degree of downlighting and illumination of the nacelle of the turbine. In the case of the proposed development, this could reduce the visibility and perceived brightness of turbine lights, especially where receptors are situated close by and at low elevations relative to the lights (e.g. sections of the A835).

Cardinal Lighting

Current ICAO Annex 14 (8th Edition) guidance for lighting of wind turbines states (at paragraph 6.2.4.3) that lights should be installed to identify the perimeters of the wind farm, respecting the maximum spacing between lights ("not exceeding 900m" per paragraph 6.2.3.15) "unless a dedicated assessment shows that a greater spacing can be used", and also that any wind turbines of significantly higher elevation are also identified.

Figure 12.1 demonstrates what is considered to be an efficient and safe cardinal lighting scheme for the proposed development, comprising lighting of turbines T01, T03, T07, T10, T16 and T17. The figure illustrates that spacing of lighting between certain turbines would exceed the 900m recommendation, but not significantly. Other arrangements would necessitate a greater number of turbines to be lit.

Were a scheme such as this agreed by MoD and CAA, then it would consequently lead to markedly reduced impacts to receptors. For avoidance of doubt however, the current assessment has assumed lighting of all turbines.

It is noted, in this regard, that both of the neighbouring Lochluichart and Corriemoillie wind farms have ultimately agreed cardinal lighting schemes with the MoD and THC for discharge of their relevant planning conditions.

Radar Activated Lights

There is some degree of uncertainty as to the availability and practicality of using radar activation at the proposed development site. This may be a matter that can be dealt with as a suspensive condition, but depending on design further examination of potential landscape and visual effects for such as system may not be necessary, and a clearer indication of the potential frequency of the triggering of lights would be important. Depending upon the frequency and regularity of light activation in some parts of the UK, this could prove more intrusive than lights that are on constantly during the hours of darkness. For avoidance of doubt, the current assessment has assumed no radar activation.

Assessment of Landscape and Visual Effects

Baseline Context

The main sources of artificial light in the vicinity of the proposed development are concentrated in the south-eastern quarter of the study area and are associated with the settlements approaching the Cromarty Firth and Beauly Firth, including Muir of Ord, Beauly, Kirkhill, Inverness, Dingwall and Strathpeffer, and which are relatively distant from the proposed development. Lighting at these settlements is associated with internal lights in properties/buildings as well as street lighting and vehicle lights on roads, both within and approaching the settlements. The number and concentrated nature of light can substantially reduce the sense of remoteness and darkness in their vicinity.

Elsewhere, the landscape within the study area is largely confined to settled straths and glens, and the edges of lochs, including:

- Strath Glass;
- Strath Bran;
- Strathconon;
- Strathgarve;
- Loch Broom;
- Loch Maree;
- Loch Glascarnoch; and
- Loch Ness.

Lighting within these incised landscapes generally comprises internal and external lighting at farmsteads and scattered dwellings, as well as the internal dash-lights and external headlights of vehicles. Existing light sources in the immediate vicinity of the proposed development include vehicle headlights on the A835, internal and external lighting (including vehicles) at the Aultguish Inn, as well as aviation lights on Corriemoillie and Lochluichart Wind Farm turbines.

The prominence of such lighting can be exacerbated by its contrast with the otherwise essentially dark context in which they are viewed, especially where they are backclothed by darkened landforms. It is also the case that the often unfocused or wide dispersal of lights and associated glare increases the prominence and intrusive qualities of lights, as does movement in the case of vehicle headlights.

The principal receptors present within straths and glens include residents of dwellings as well road users within vehicles, both receptor locations themselves representing sources of artificial light sources, however. The perception of both receptor types in respect of the darkness of the landscape is conditioned, in part, by whether the property has blinds or curtains (effectively screening views out from the property) or internal lights that can obscure or lessen the degree of perceived darkness outwith the property. Views from within road vehicles will also be affected by dashboard lights and headlight beams, thereby lessening the perceived darkness of the adjacent landscape. The perception of road users is also transitory, and of limited duration in comparison to that of residents of dwellings.

Much of the remainder of the study area comprises remote uplands which are typically devoid of artificial lighting, but from where there may be views into settled straths and glens (e.g. the A835 and Strath Bran) and/or towards the coast where existing lights clearly evident and conspicuous. The number and frequency of receptors present on elevated summits is likely to be relatively low and generally restricted to small number of wild campers.

Residual Effects

Visibility and Intensity of Lights

According to the analysis presented in Figure 4.9.1 the pattern of visibility of the lights would be broadly consistent with the hub-height viewshed of the proposed development, as depicted in Figure 4.5b. The greatest theoretical light intensity and brightness would be experienced at elevated locations, including:

- Sgurr Marcasaidh (Viewpoint 5), which is 8.3 km south of the proposed development;
- Ben Wyvis (Viewpoint 6), which is located around 10 km to the east of the proposed development;
- Sgurr a'Muillin (Viewpoint 8), which is 15.4 km to the south-west of the proposed development;
- Beinn a'Bha'ach Ard (Viewpoint 9), which is 24 km south of the proposed development;

- Sgurr a' Choire Ghlais (Viewpoint 10), which is located over 26 km to the south-west of the proposed development;
- Moruisg (Viewpoint 11), which is situated over 37 km to the south-west of the proposed development;
- Beinn Eighe, which is located over 37 km to the west south-west of the proposed development;
- An Coileachan, Fannich range (Viewpoint 13), situated over 12 km to the west of the proposed development;
- Beinn Dearg (Viewpoint 14), situated over 17 km to the north-east of the proposed development;
- Beinn à Chaisteil (Viewpoint 15), situated over 10 km to the north of the proposed development;
- Meall Mor (Viewpoint 16), situated over 16.7 km to the north-east of the proposed development;
- An Teallach (Viewpoint 18), which is located over 33 km to the north-west of the proposed development; and
- Little Wyvis (Viewpoint 19), which is located around 7.3 km to the south-east of the proposed development.

However, as these locations are over 5 km from the proposed development, the maximum intensity of light that would be experienced in clear meteorological conditions would be 200 candela, as previously discussed. Moreover, the majority of summits are over 15 km from the proposed development and therefore subject to further mitigation due to distance. It is also the case that these receptor locations are infrequently visited after dark.

Of the large number of straths and glens in the study area, the visibility of turbine lights would be substantially constrained by a combination of intervening topography and vegetation. The principal location from where the lights would be visible would be from vehicles travelling along the A835 between Loch Droma and Black Bridge, equivalent to visibility from around 13 km of this part of the A835 (equating to approximately 8 minutes visibility at 60 mph, which is the national speed limit for an A road). Viewed from locations outwith 5 km within this glen, the lights would be experienced in clear meteorological conditions at between 200 and 8 candela. Within 5 km of the proposed development, the lights would be experienced at intensities of between 750 and 0 candela assuming lights are set at 2,000 candela, reducing to between 75 and 0 in periods where meteorological visibility exceeds 5 km.

Figures 4.8e and 4.24d illustrate the anticipated lighting at:

- Viewpoint 1: Aultguish Inn (around 2.3 km of the proposed lights) from where the light intensity viewed would be up to 40 candela during periods of visibility under 5 km, and up to 4 candela during periods of meteorological visibility of over 5 km; and
- Viewpoint 17: Layby, Loch Glascarnoch, around 7 km to the north-west of the proposed development from where the lights would be seen at an intensity of up to 200 candela during periods of clear meteorological visibility over 5 km. During period of reduced visibility (i.e. due to low cloud, fog and/or rain) lighting intensity at turbines would be 2000 candela, but would be perceived as considerably less at this viewpoint.

Both images were produced at dusk, whilst there was some ambient light and some of the landscape context was still evident.

Effects on Landscape Character

The greatest degree of perceived remoteness is associated within elevated locations, from where receptors would experience lighting intensities of no more than 200 candela and would generally be seen distantly and experience as points of light within a largely dark context.

The proposed turbine lights are considered to represent moderate impacts and **major/moderate** effects on the sense of remoteness at a number of key summits in the upland landscapes such as:

- the Rounded Hills landscape (LCT RCY7) at Ben Wyvis, Little Wyvis and Beinn à Chaisteil, from where the lights would be seen to the west of these summit and constitute a notable addition to the effect of existing lights on the Corriemoillie and Lochluichart turbines and along the A835 corridor;
- Rocky Moorland landscape (LCT RCY4) at Sgurr Marcasaidh, where the proposed turbine lights would add a series of new lights to the east of the existing turbine lights of Corriemoillie and Lochluichart; and

Effects on other, more distant uplands, would be more sporadic and partially mitigated by distance and as a result are not predicted to be significant.

The turbine lights would be screened from the majority of low-lying smaller scale enclosed landscapes such as the Narrow Farmed Straths (LCT RCY8) and Wide Farmed Straths (LCT RCY9) but views of some lights would be provided from the A835 corridor between Loch Droma and Black Bridge, which lies within the Rolling Hill landscape type (LCT RCY7). However, the degree of perceived remoteness in this part of LCT is reduced due to the presence of existing light sources, including internal and external light sources associated with scattered farmsteads and dwellings, and vehicle headlights.

On the basis of the preceding analysis, significant effects on landscape character, specifically the remoteness of the landscapes within the study area, would be confined to elevated summits within 10 km of the proposed development, including summits within LCTS RCY4 and RCY7, but would affect a limited and infrequent number of receptors.

Effects on Visual Amenity

In a similar vein to the effects of the lights on landscape character, effects on the visual amenity of the study area would occur at elevated summits in the vicinity of the proposed development, However, **major/moderate** (significant) effects are also predicted along the A835 between Loch Droma and Black Bridge, where they would form prominent new features in views from eastbound vehicles (Ref. Figure 4.24d). Viewed from the Aultguish Inn, which is oriented towards the south and towards the proposed development, the lights on the proposed turbines would form a considerable addition to the existing lights on the Corriemoillie turbines and constitute a potentially **major/moderate** (significant) visual effect on the external amenity of the Inn (Ref. Figure 4.8e). However, such effects would primarily affect patrons leaving the Inn or utilising its car parking and external spaces. Such an effect would not occur within the interior of the Inn due to the effect of internal light sources in the Inn and where external lamps and headlights in the car park interrupt the otherwise dark outlook of the Inn, and would not be significant.

Conclusions on Lighting Effects without Further Mitigation

The issue of lighting effects is complex and highly nuanced. How the lights are experienced will depend upon the elevation and distance of receptors from them, the perceived brightness varying

considerably, reducing substantially in low lying positions in close proximity to the proposed development and at elevated locations that are distant from the light sources.

Lighting effects on landscape character and visual amenity are primarily concerned with effects on the darkness and remoteness of landscapes. The visibility of the lights at the proposed development would primarily affect elevated upland landscapes locations, which are substantially unpopulated after dark. Consequently, the predicted significant effects within the Rounded Hills and Rocky Moorland landscapes would be experienced infrequently and by a small number of receptors.

Views of the lights from low lying incised landscapes such as straths and glens would be substantially restricted. Such landscapes also have a lesser degree of perceived remoteness, often containing existing light sources associated with scattered farmsteads and dwellings as well as the headlights and interiors of vehicles. Significant effects in these landscapes would be confined mainly to eastbound road users in vehicles on the A835 between Loch Droma and Black Bridge and at the Aultguish Inn where the lights would form prominent elevated points of light and pronounced focal points in views. However, car dash-lights and headlights coupled with the transient nature of views from vehicles would lessen the magnitude of impacts arising from the turbine lights. Similarly, interior lights and external lamps and car lights would result in a lessening of the prominence of turbine lights when experienced at the Aultguish Inn.

Residual Effects Following Further Mitigation

The effects presented above represent a reasonable worst-case but could be reduced through the application of a cardinal lighting on selected turbines (e.g. Turbines 1, 7 and 17 on the southern side of the scheme, and turbines 3, 10 and 16 on the northern side of the schemes. In such a scenario only two lights would be seen from Loch Glascarnoch rather than the six indicated in Figure 4.24d). Similarly, viewed from Aultguish Inn only three lights would be seen rather than the ten indicated in 4.8e.

The frequency and duration of radar activation of lighting would depend on the design of the three-dimensional volume of airspace within which aircraft detection would trigger lighting, as well as the agreed duration criteria for lighting once activated. At present there are no CAA guidance, however following the FAA's approach of a 5.5 km horizontal by 304 m vertical volume area, it is apparent firstly that in the vertical component no regular commercial traffic (such as that passing daily between Inverness and Stornoway) would be expected to be found so low as to trigger lighting. Secondly, that the horizontal component would represent a relatively small proportion of the overall Highlands low-flying Area 14T (approx. 11,500 ha out of 1.03m ha being around 1%), and that in particular noting the existing presence of Lochluichart and Corriemoillie wind turbines, along with the MoD's responses to these proposals as well as the Kirkan EIA Scoping exercise, that frequency and importance of use of the area is likely to be so low enough as to lead to a substantial reduction in effects as considered above.