15 Shadow Flicker

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15 Shadow Flicker

15.1 Introduction

15.1.1 This chapter describes and assesses likely shadow flicker effects resulting from the Proposed Development on neighbouring residential and commercial receptors. This chapter (and its associated figures and appendices) is not intended to be read as a standalone assessment and reference should be made to the description of the Proposed Development in Chapter 3.

15.1.2 Shadow flicker occurs when, "[In] *certain combinations of geographical position, time of day and time of year, the sun may pass behind the rotor and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening*" (Scottish Government, 2014a, Onshore Wind Turbines).

15.1.3 The magnitude of shadow flicker effects varies both spatially and temporally, and depends on a number of environmental conditions coinciding at a particular point in time, which include:

- time of day and year;
- wind direction;
- height of wind turbine and blade length;
- position of the sun in the sky;
- weather conditions;
- proportion of daylight hours in which the turbines operate; and
- distance and direction of the wind turbine from the receptor.

15.1.4 The flickering effect caused by shadow flicker also has the potential to induce epileptic seizures in patients with photosensitive epilepsy. The National Society for Epilepsy (NSE) advises that around 1 in 131 people have epilepsy and up to 5 % of these have photosensitive epilepsy (NSE, 2011). The common rate or frequency at which photosensitive epilepsy might be triggered is between 3 and 30 hertz (Hz, flashes per second). Large commercial turbines rotate at low speeds resulting in less than 3 flashes per second and are therefore unlikely to cause epileptic seizures (Harding *et al*., 2008: Smedley *et al.,* 2010). Therefore, there are not considered to be any health effects associated with the Proposed Development and this assessment will address the effects of shadow flicker related to local amenity.

15.1.5 This assessment has been undertaken by Rebecca Todd (BSc (Hons), PIEMA) who has 7 years' experience undertaken shadow flicker assessments for wind farms.

15.2 Legislation, Policy and Guidelines

Legislation

15.2.1 There is no legislation that directly deals with the matter of shadow flicker.

Policy

15.2.2 Chapter 5 of the EIA Report sets out the planning policy framework that is relevant to the EIA. The policies set out within this chapter include those from the Orkney Islands Council (OIC) Local Development Plan (LDP) and relevant supplementary guidance, those relevant aspects of Scottish Planning Policy (SPP), PANs and other relevant guidance. Of relevance to the shadow flicker assessment presented within this chapter, regard has been had to the following policies and guidance:

- The Orkney Local Development Plan (OIC, 2017a);
- The Orkney Local Development Plan. Supplementary Guidance: Energy (OIC, 2017b);
- Development Criterion 1 – Communities and Amenity, Part 4: Wind Energy: The Orkney Local Development Plan. Supplementary Guidance: Energy (OIC, 2017b); and
- Paragraph 169 of SPP (Scottish Government, 2014b).

Guidance

15.2.3 The Update of UK Shadow Flicker Evidence Base (DECC, 2011) reviews international legislation relating to the assessment of shadow flicker for wind turbine development and concludes that the area within 130 degrees either side of north from the turbine, and out to 10 rotor diameters, is considered acceptable for shadow flicker assessment. This supports the policy detailed above (refer to paragraph 15.2.2).

15.2.4 This report draws on the conclusions of the Nordrhein-Westfalen (2002) on the identification and evaluation of shadow flicker, which are further referenced below.

15.2.5 This assessment also takes into consideration the Scottish Government Online Renewables Planning Advice: Onshore Wind Turbines (Scottish Government, 2014a).

15.3 Consultation

15.3.1 Consultation on the methodology of the shadow flicker assessment was undertaken with OIC. A summary of this consultation is shown in Table 15.1 below.

Table 15.1 - Consultation

Consultee	Comment	Applicant Response
OIC (Scoping Opinion)	With reference to shadow flicker it is noted that the 10 times rotor blade diameter separation distance is cited. Notwithstanding development criterion within Supplementary Guidance quoting this separation distance, as a general point the onus should be on avoiding harm and nuisance, which should be established by exposure thresholds, and not necessarily on limiting the area of assessment. The mitigation hierarchy of prevent, reduce and offset should be followed and detailed within the EIA Report given inhabited properties within 2km of the site.	A shadow flicker assessment has been conducted with an initial study area consisting of 10 times rotor blade diameter separation with an additional 50 m buffered (to account for micro-siting), resulting in a study area of 1,410 m from each turbine location. Properties out with the 1,410 m study area and up to 2km from the nearest turbine were included for avoidance of doubt to ensure that none could breach the significance threshold (i.e. greater than 30 hours of flicker a year or more than 30 minutes per day on the worst affected day (see Paragraph 15.4.6).

15.4 Assessment Methodology and Significance Criteria

Consultation

15.4.1 Consultation has been undertaken with OIC through EIA Scoping to confirm the proposed methodology and requirement to undertake a shadow flicker assessment in respect to the Proposed Development (refer to Section 15.3).

Study Area

15.4.2 The shadow flicker assessment has been carried out for the proposed six turbines at the locations identified in Chapter 3. Dimensions of the chosen model, based on the largest rotor diameter, used for the purposes of the shadow flicker assessment can be found in Table 15.2.

Table 15.2 – Details of the Turbine Model Used for the Shadow Flicker Assessment

Hub height	81.9m
Rotor diameter	136m
Swept area	14,526.72m^2

15.4.3 The study area within which receptors could potentially be affected by shadow flicker has been set at a distance of 10 rotor diameters with an extra 50 m added in order to account for micro-siting purposes and each turbine and 130 degrees either side of north (relative to each turbine), as noted within Update of UK Shadow Flicker Evidence Base report (DECC, 2011). In this assessment the study area extends to 1.14 km from each turbine. Figure 15.1 shows the extent of this area and those receptors that could potentially be affected by shadow flicker.

Desk Study

15.4.4 The desk-based assessment identified no residential receptors within the study area. However, four receptors were identified within 2 km of the nearest turbine and as such, the shadow flicker assessment was undertaken for these properties as requested by OIC. For the avoidance of doubt, a fifth receptor on the island of Westray was also included, even though it is located further than 2 km from the nearest turbine to determine whether impacts are anticipated on properties on Westray.

15.4.5 Table 15.3 summarises the locations of the receptors and the distance from each property/location to the nearest turbine.

Table 15.3 – Receptor Locations

Property	Ownership	Shadow Flicker ID	Easting	Northing	Approx. Distance to Nearest Turbine (m)	Turbine which may cause shadow
Crowbar (Eday)	Residential	A	355221	1037391	2,002	T4
Lesshamar (Eday)	Residential	B	355164	1037058	1,843	T4
North Guith (Eday)	Residential	C	355015	1036577	1,637	T4

Property	Ownership	Shadow Flicker ID	Easting	Northing	Approx. Distance to Nearest Turbine (m)	Turbine which may cause shadow
Mid Guith (Eday)	Residential	D	355271	1036559	1,892	T4
Ness (Westray)	Residential	E	349958	1039055	3,348	T1

Assessment of Likely Effect Significance

15.4.6 There are no UK statutory provisions setting out acceptable levels of shadow flicker. The DECC 2011 report identifies best practice guidelines across Europe and this assessment will adopt German quantitative guidance (Nordhein-Westfalen, 2002) which adopts two maximum limits to determine significant effects:

- an astronomic worst-case scenario limit of 30 hours per year or 30 minutes on the worst affect day; and
- a realistic scenario taking account of meteorological parameters limited to 8 hours per year.

15.4.7 Within this assessment effects are determined to be significant if they exceed the two limits identified above, or non-significant if they are below the limits.

Assessment Modelling

15.4.8 In assessing the effect of shadow flicker, the commercial software model WindPro 3.2. was used to calculate the expected number of hours shadow flicker that could occur at each receptor. The model takes into account the movement of the sun relative to the time of day and time of year and predicts the time and duration of expected shadow flicker at a window of an affected receptor. The input parameters used in the model are as follows:

- the turbine locations;
- the turbine dimensions;
- the location of the receptors to be assessed; and
- the size of windows on each receptor and the direction that the windows face.

15.4.9 The WindPro model is based upon a Zone of Theoretical Visibility (ZTV) analysis, which in this case was based upon a Digital Terrain Model (DTM) of 50 m resolution.

15.4.10 Calculations were undertaken for predicted shadow hours at each of the receptors for two scenarios: a theoretical (worst-case) and a realistic scenario. For the worst-case scenario the following assumptions were made:

- all receptors have a 1 m x 1 m window facing directly towards the turbine;
- the turbine blades were assumed to be rotating for 365 days per year;
- there is a clear sky 365 days per year;
- the turbine blades were assumed to always be positioned towards each receptor;
- more than 20 % of the sun was covered by the blade; (in practice, at a distance, the blades do not cover the sun but only partly mask it, substantially weakening the shadow);
- the receptor is occupied at all times; and

- no screening was present.

15.4.11 The effect of shadow flicker was not calculated where the sun lies less than 3 degrees above the horizon due to atmospheric diffusion, low radiation (intensity of the sun's rays is reduced) and high probability of natural screening. It is generally accepted that below 3 degrees shadow flicker is unlikely to occur to any significant extent (Nordrhein-Westfalen, 2002).

15.4.12 These assumptions result in a highly conservative assessment for the following reasons:

- in reality, some of the houses within the study area may not directly face the turbines;
- the turbine blades will not turn for 365 days of the year, and will turn to face into the direction of the wind, in order to maximise the energy generating potential from the wind, and therefore will not always face one or more receptors;
- it is unlikely that there will be clear skies 365 days a year;
- receptors may not be occupied at the time that the shadow flicker impact is experienced; and
- screening, such as vegetation or curtains between the window and the turbine is not accounted for within the DTM and model and will prevent any shadows from being cast onto the window and therefore prevent any flickering effect.

15.4.13 The assessment carried out is limited to the effects of shadows within buildings. Moving shadows will also be apparent out of doors; however, these do not result in flicker in the same manner or to the same extent, as the light entering windows. Therefore, shadow flicker effects outdoors have been scoped out of further assessment.

Theoretical Scenario

15.4.14 The modelling results for the theoretical scenario are typically considered to be a theoretical worst-case estimation of the actual impacts experienced, which would not arise in practice given the assumptions listed in paragraph 15.4.10.

Realistic Scenario

15.4.15 In actuality, for much of the year weather conditions will be such that shadows will not be cast, or will be weak and would therefore not give rise to shadow flicker effects. WindPro calculations most likely overestimate the duration of effects as outlined in the theoretical scenario. To create a more realistic scenario for the potential impact of shadow flicker on receptors, it was necessary to identify the expected meteorological conditions at the site and take into account any significant shielding of receptors by buildings and vegetation between the receptors and the turbines.

15.4.16 A 16 degree sector wind rose was calculated for 7,475 hours of wind (assumes the Proposed Development is operational for 85 % of the year) based on representative UK wind data (refer to Appendix 15.1, Table 2). The WindPro model also employs a slightly simplistic assumption that sunshine probability and turbine operational probability are independent parameters. The model is therefore expected to yield conservative results; as bright and sunny weather conditions and low wind speeds generally tend to show some degree of correlation.

Limitations to Assessment

15.4.17 All assumptions made by the WindPro 3.2 are outlined above. There are no limitations to the assessment although the following must be noted:

- Given the absence of UK guidance towards the assessment of significant effects of shadow flicker, the assessment has adopted the generally accepted industry practise maximum figure of 30 hours per year or 30 minutes per day for permanent dwellings and commercial properties.

15.5 Baseline Conditions

15.5.1 The desk-based assessment identified no residential receptors within the study area. However, four receptors were identified within 2 km of the nearest turbine and as requested by OIC a shadow flicker assessment was undertaken of these. For the avoidance of doubt, a fifth receptor on the island of Westray was also included, even though it is located further than 2 km from the nearest turbine.

15.5.2 For the purposes of the assessment it is assumed that all properties face directly on to the Proposed Development. No local screening (vegetation and blinds/curtains) is considered.

15.5.3 Within this assessment the sensitivity of the receptors is assumed to be high in all cases.

15.6 Likely Effects

Construction

15.6.1 No shadow flicker will occur during construction of the Proposed Development.

15.6.2 Given that any occurrence of shadow flicker during the short commissioning period would replicate itself during operation of the Proposed Development, albeit more infrequently, it is considered appropriate to consider the commissioning activities as part of the operational stage of the Proposed Development.

Operation

Theoretical Modelling of Shadow Flicker Occurrence

15.6.3 The modelling results presented below represent the theoretical worst-case scenario discussed in Section 15.4. The results of the modelling are shown in Table 15.4. The theoretical duration of shadow flicker calculated shows no shadow flicker at all at receptors A, B, D and E. Shadow flicker at receptor C is shown to be below the limit of 30 hours per year or 30 minutes on the worst affected day, and therefore no significant effects are anticipated. It should be noted that this is the theoretical modelling and in reality the duration of shadow flicker at each location is likely to be considerably less than that indicated below for the reasons outlined in Section 15.4.

Table 15.4 – Worst-Case Scenario Shadow Flicker Occurrence at each Receptor

Property Name	Shadow Flicker ID	Easting	Northing	Shadow Flicker Hours per Year	Max Shadow Flicker Minutes per Day
Crowbar (Eday)	A	355221	1037391	0	0
Lesshamar (Eday)	B	355164	1037058	0	0
North Guith (Eday)	C	355015	1036577	8:59	11:40
Mid Guith (Eday)	D	355271	1036559	0	0
Ness (Westray)	E	349958	1039055	0	0

Realistic Modelling of Shadow Flicker Occurrence

The modelling results presented in Table 15.5, Appendix 15.2 and Figure 15.1 represent the realistic scenario discussed in paragraphs 15.4.15-16. The inclusion of indicative wind data and average

sunshine hours into the shadow flicker calculations has greatly reduced the potential of shadow flicker occurrence at all of the receptors.

Table 15.5 - Realistic Scenario Shadow Flicker Occurrence for each Receptor (hrs/yr)

Property Name	Shadow Flicker ID	Easting	Northing	Shadow Flicker Hours per Year	Max Shadow Flicker Minutes per Day
Crowbar (Eday)	A	355221	1037391	0	0
Lesshamar (Eday)	B	355164	1037058	0	0
North Guith (Eday)	C	355015	1036577	1:22	3:42
Mid Guith (Eday)	D	355271	1036559	0	0
Ness (Westray)	E	349958	1039055	0	0

15.6.4 No shadow flicker is predicted at receptors A, B, D and E. With a modelled shadow flicker occurrence of 1:22 hours per year, the anticipated shadow flicker at receptor C is below the 8 hours per year significance threshold, and therefore no significant effects are anticipated.

Decommissioning

15.6.5 The Applicant is seeking in-perpetuity consent for the Proposed Development. In the event of decommissioning, it is anticipated that the levels of effect would be similar but of a lesser level than those predicted during construction (i.e. no effects). Decommissioning would be undertaken in line with best practice processes and methods at that time and will be managed through an agreed Decommissioning Environmental Management Plan.

15.7 Mitigation

Construction

15.7.1 No mitigation measures are required during the construction phase of the Proposed Development.

Operation

15.7.2 Although the realistic scenario takes into consideration expected operational time for the turbines and average sunshine hours for the region, the results are likely to still be conservative due to local vegetation, dwelling orientation and internal screening from blinds, curtains or furniture that are not included in the model. Additionally, while shadow flicker may potentially occur at North Guith, it is possible that flicker will not be 'experienced' at all locations due to the time of day during which it may potentially occur.

15.7.3 Due to the above and as no significant effects are anticipated no mitigation is required during operation.

15.8 Residual Effects

15.8.1 No shadow flicker effects are anticipated during construction or decommissioning phases of the Proposed Development and no significant residual effects are anticipated during operation.

15.9 Cumulative Assessment

15.9.1 In order to assess the potential for cumulative impact from other wind developments in the surrounding area, any turbines within 3 km of the proposed turbine locations were noted. Shadow flicker impacts are considered to extend to 10 rotor diameters (Scottish Government, 2014a) from turbine locations, therefore a 10 rotor diameter study area has been placed around all turbines in the vicinity of the Proposed Development. Two turbines were identified within the 3 km study area of the Proposed Development. These include Newark Wind Turbine and Bredakirk Wind Turbine, both operational Evance R9000 turbines with rotor diameters of 5.5 m. This would give a shadow flicker study area of 55 m (refer to Figure 15.2). No receptors were identified within any overlap between the shadow flicker study areas for the Newark and Bredakirk turbines and the Proposed Development (refer to Figure 15.2), and as such there is no potential for cumulative shadow flicker effects.

15.10 Summary

15.10.1 This assessment considers whether the effect known as 'shadow flicker' is likely to be caused by the Proposed Development and assesses the potential for impact on sensitive receptors. Shadow flicker is the effect of the sun passing behind the moving rotors of the turbines casting a flickering shadow through the windows and doors of neighbouring properties. This occurs in certain combinations of geographical position, time of day, time of year and specific weather conditions.

15.10.2 The study area within which properties could potentially be affected by shadow flicker covers a distance of 10 rotor diameters plus an additional 50 m from each turbine and lies 130 degrees either side of north (relative to each turbine). In the case of the Proposed Development, this area extends to 1,410 m from each turbine. At OIC's request the study area has been extended beyond this to include properties within 2 km of the turbines.

15.10.3 No shadow flicker impact can occur during the construction of the turbines.

15.10.4 Shadow flicker modelling was undertaken for five receptors. Both the worst-case and realistic modelling identified no effects at four of the receptors. No significant effects were identified at the fifth receptor as the shadow flicker anticipated in a realistic scenario would equal 1:22 hours per year, which is significantly below the eight hours per year threshold considered to be a significant effect.

15.10.5 It is important to note that these results do not take into account any existing features which would limit the incidences of shadow flicker such as screening features (structures and vegetation), dwelling orientation, blinds or curtains which will reduce potential effects further. Receptors may also be in rooms that are not generally used at the affected times, therefore, the amount of time when shadow flicker is actually 'experienced' will likely be substantially less than what has been predicted.

15.10.6 No significant residual effects are anticipated from shadow flicker.

Table 15.6 – Summary of Effects

Description of Effect	Significance of Potential Effect		Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/ Adverse
Construction					
Shadow flicker nuisance on residential receptor	None	N/A	None required.	None	N/A
Operation					
Shadow flicker nuisance on residential receptor	Not significant	Adverse	None required.	None	N/A
Decommissioning					
The Applicant is seeking in-perpetuity consent for the Proposed Development. In the event of decommissioning it is anticipated that the levels of effect would be similar but of a lesser level than those during construction (i.e. no effects). Decommissioning would be undertaken in line with best practice processes and methods at that time and will be managed through an agreed Decommissioning Environmental Management Plan.					

Table 15.7 – Summary of Cumulative Effects

Receptor	Effect	Cumulative Developments	Significance of Cumulative Effect	
			Significance	Beneficial/ Adverse
No receptors found	No effect	**None**	None	N/A

15.11 References

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