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 Flickering effects caused by shadow flicker have 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 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 Eliot Weir (MEarthSci) and overseen by Rebecca Todd (BSc (Hons), PIEMA) who has 7 years' experience undertaking 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.

Table 15.1 - Consultation

Consultee	Comment	Applicant Response
OIC (Scoping Opinion)	In consideration of shadow flicker, it is noted that the 10 x rotor blade diameter separation distance is cited. Notwithstanding OIC development criterion quoting this separation distance, the onus should be on avoiding harm and nuisance, which should be established by exposure thresholds, and not on limiting the area of assessment.	A shadow flicker assessment has been conducted with a study area consisting of 10 x rotor blade diameter separation with an additional 50 m buffered (to account for micro-siting), resulting in a buffer of 1410 m. If there had been any properties outwith the 1,410 m study area that were predicted to 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), they would have been included. This was not the case.
OIC (May, 2020)	An email detailing the scope of the shadow flicker assessment was sent to OIC for comment in May 2020. No response was received.	The scope as detailed in this correspondence has been followed.

15.4 Assessment Methodology and Significance Criteria

Consultation

15.4.1 Consultation has been undertaken with OIC 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	81.9 m
Rotor diameter	136 m
Swept area	14,526.72 m^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 from each turbine with an extra 50 m added in order to account for micro-siting purposes 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 1.41 km from each turbine. Figure 15.1 shows the extent of this area and those receptors that could potentially be significantly affected by shadow flicker.

Desk Study

15.4.4 The desk-based assessment identified 11 residential receptors, including a range of farmhouses and isolated properties. Two commercial receptors were identified within the study area, Hoy Hotel and Burnhouse Fish Farm (shown in Figure 15.1).

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	Property Type	Shadow Flicker ID	Easting	Northing	Approx. Distance to Nearest Turbine (m)	Turbine which may cause shadow
Rysa Mill	Residential	A	329,970	995,448	1368	T1
2 Chalet	Residential	B	330,423	994,320	1330	T1
Summer Cleary	Residential	C	330,333	994,894	1335	T1
Little Scews	Residential	D	330,045	994,879	1066	T1
1 Chalet	Residential	E	330,416	994,290	1325	T1

Property	Property Type	Shadow Flicker ID	Easting	Northing	Approx. Distance to Nearest Turbine (m)	Turbine which may cause shadow
Moorlands	Residential	F	330,076	994,491	986	T1
Thurvoe	Residential	G	330,039	994,439	950	T1 & T2
Haybrake Farm	Residential	H	330,482	994,495	1391	T1
Scews	Residential	I	330,022	995,111	1171	T1
The Noddle	Residential	J	330,004	995,375	1336	T1
Hoy Hotel	Commercial	K	330,406	994,462	1313	T1
Burnhouse Fish Farm	Commercial	L	329,597	995,425	1145	T1
Treetops Bungalow	Residential	M	330,408	994,509	1315	T1

15.4.6 In line with advice received from the Environmental Health Officer (when consulted for the noise assessment), Ore Burn Cottage has been scoped out of the shadow flicker assessment. This is because it has been vacant and derelict since at least 2005 and on that basis in planning terms it has lost its status as a dwelling.

Assessment of Likely Effect Significance

15.4.7 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.

Receptor Sensitivity

15.4.8 The sensitivity towards shadow flicker of an affected receptor depends on its usage, type, normal hours of occupancy, and the likelihood of shadow flicker instances coinciding with occupancy. Additionally, the affected party's stance relating to the wind turbines may also influence sensitivity to some degree.

15.4.9 A conservative approach has been taken and the sensitivity of all receptors within the assessment is assumed to be high.

Assessment Modelling

15.4.10 In assessing the effect of shadow flicker, the commercial software model WindPro 3.2. was used to calculate the expected number of hours of 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.

15.4.11 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.

15.4.12 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.

15.4.13 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).

15.4.14 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 that could prevent shadow flicker effects is not accounted for within the DTM and model.

15.4.15 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, in line with the guidance, shadow flicker effects outdoors have been scoped out of further assessment.

Theoretical Scenario

15.4.16 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 15.4.14.

Realistic Scenario

15.4.17 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 (refer to Appendix 15.1).

15.4.18 The WindPro model 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.

15.4.19 In addition, screening (buildings, trees, vegetation, curtains, etc.), usage and normal hours of occupancy were not factored into the calculations. Therefore, whilst more realistic, the realistic scenario is still considered to be an overestimate of likely effects.

Limitations to Assessment

15.4.20 All assumptions made by the WindPro 3.2 are outlined above. There are no further 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 worst-case maximum figure of 30 hours per year or 30 minutes per day for permanent dwellings and commercial properties within 10 rotor diameters of the proposed turbines. And the realistic scenario taking into account meteorological parameters of 8 hours per year.

15.5 Baseline Conditions

15.5.1 Elevenresidential receptors have been identified within the study area with the potential to experience shadow flicker:

- Rysa Mill;
- 1 and 2 Chalet;
- Summer Cleary;
- Scews;
- Little Scews;
- Thurvoe;
- Moorlands;
- Treetops Bungalow;
- Haybrake Farm; and
- The Noddle.

15.5.2 Two commercial receptors have been included within this assessment; these are:

- Hoy Hotel; and
- Burnhouse Fish Farm.

15.5.3 Hoy Hotel has been closed as a Hotel for c.6 years. However, the bar is sometimes open, and it currently hosts the wartime exhibition whilst the museum is being renovated. Whilst Hoy Hotel is not currently utilised as a hotel, it is treated as residential for the purpose of this assessment.

15.5.4 Due to COVID 19 restrictions we were unable to ground-truth Burnhouse Fish Farm to assess its potential as a shadow flicker receptor (e.g. types of buildings, whether there are narrow openings in building façades facing the Proposed Development, etc.). Therefore, a conservative approach was taken, and the property was included in the assessment.

15.6 Potential 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 (worst-case) duration of shadow flicker calculated is indicated to be significant at five residential receptors (greater than 30 minutes per day on the worst affected day) and one commercial receptor (greater than 30 hours of flicker a year and more than 30 minutes per day on the worst affected day). 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
Rysa Mill	A	329,970	995,448	18:06	28
2 Chalet	B	330,423	994,320	15:23	24
Summer Cleary	C	330,333	994,894	9:06	24
Little Scews	D	330,045	994,879	28:23	48
1 Chalet	E	330,416	994,290	15:28	24
Moorlands	F	330,076	994,491	25:45	32
Thurvoe	G	330,039	994,439	28:48	33
Haybrake Farm	H	330,482	994,495	8:37	23
Scews	I	330,022	995,111	26:25	40
The Noddle	J	330,004	995,375	17:33	30
Hoy Hotel	K	330,406	994,462	15:06	24

Property Name	Shadow Flicker ID	Easting	Northing	Shadow Flicker Hours per Year	Max Shadow Flicker Minutes per Day
Burnhouse Fish Farm	L	329,597	995,425	47:20	38
Treetops	M	330, 408	994, 509	14:31	24

Realistic Modelling of Shadow Flicker Occurrence

15.6.4 The modelling results presented in Table 15.5, Appendix 15.2 and Figure 15.1 represent the realistic scenario discussed in paragraphs 15.4.17-19. The inclusion of 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 (hours: minutes)	Shadow Flicker hours per Year (% of total hours)	Shadow Flicker Minutes Per Day (minutes: seconds)
Rysa Mill	A	329,970	995,448	1:51	0.02%	1:16
2 Chalet	B	330,423	994,320	2:23	0.03%	3:34
Summer Cleary	C	330,333	994,894	1:14	0.01%	2:52
Little Scews	D	330,045	994,879	3:40	0.04%	5:43
1 Chalet	E	330,416	994,290	2:25	0.03%	3:35
Moorlands	F	330,076	994,491	3:49	0.04%	4:49
Thurvoe	G	330,039	994,439	4:23	0.05%	5:39
Haybrake Farm	H	330,482	994,495	1:20	0.02%	3:02
Scews	I	330,022	995,111	3:02	0.03%	4:47
The Noddle	J	330,004	995,375	1:55	0.02%	2:17
Hoy Hotel	K	330,406	994,462	2:15	0.03%	3:39
Burnhouse Fish Farm	L	329,597	995,425	3:58	0.05%	2:43
Treetops Bungalow	M	330,408	994,509	2:11	0.02%	3:17

15.6.5 The realistic model predicts less than 8 hours per year at all receptors and therefore **no significant effect** is anticipated (refer to Figure 15.1).

15.6.6 The shadow flicker hours per year as a percentage of the total hours per year further illustrates the low levels of shadow flicker predicted by the realistic scenario.

Decommissioning

15.6.7 The Applicant is seeking in-perpetuity consent for the Proposed Development. In the event of decommissioning, or replacement of turbines, it is anticipated that the levels of effect would be similar but of a lesser level than those during construction. Any replacement of turbines that could increase the incidence of shadow flicker would be subject to an additional approval process. 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 Based on the modelling results from the realistic scenario, which for the reasons outlined above are still likely to be conservative, no mitigation is considered to be required.

15.7.3 To ensure that any unanticipated adverse effects on amenity are appropriately managed, the Applicant is willing to provide a written Shadow Flicker Protocol document for agreement with OIC prior to operation of the Proposed Development. This would set out a protocol for addressing any complaint received from a receptor within the study area, including directly contacting and gaining responses from those affected by shadow flicker. The protocol would set out mitigation and management options, which could include programmed/automated switch off of one or more turbines for specified time periods and in particular climatic conditions. Operation of the turbines would be required to take place in accordance with the approved Shadow Flicker Protocol and any mitigation measures that have been agreed through the protocol would be implemented as appropriate.

15.8 Residual Effects

15.8.1 Based on the modelling results from the realistic scenario and committed mitigation measures, for all receptors the effect is expected to be not significant.

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.

15.9.2 The only cumulative development within the study area is Ore Brae (08/249/PPF). However, there are no residential properties within 10 rotor diameters (440m) of the Ore Brae turbine and as such the turbine has been scoped out of the assessment.

15.9.3 Therefore, in the absence of any relevant developments, a cumulative assessment has been scoped out.

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 likelihood of significant effects 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 from each turbine, with an additional 50 m applied for micro-siting purposes 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.

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

15.10.4 A shadow flicker assessment was undertaken at the 13 identified receptors within the study area. The worst-case modelling identified the potential for significant effects at a small number of properties, however the realistic (but still conservative) modelling shows that once wind data and average sunshine hours are applied, all receptors experience shadow flicker well below the accepted limits of less than 8 hours per year.

15.10.5 Furthermore, 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 significantly less than what has been predicted.

15.10.6 No mitigation is considered to be required. However, the Applicant will provide a written Shadow Flicker Protocol document, setting out a protocol for addressing any complaint received from a receptor within the study area, and mitigation options available to address any such complaint. The Shadow Flicker Protocol will be agreed with OIC prior to operation of the Proposed Development.

15.10.7 The residual effect of shadow flicker is, therefore, expected to be not significant for all receptors during all phases of the Proposed Development.

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	Not significant	Neutral	None required.	Not significant	Neutral
Operation					
Shadow flicker nuisance on residential receptor	Not significant	Adverse	Wind Farm Shadow Flicker Protocol.	Not significant	Adverse
Decommissioning					
Shadow flicker nuisance on residential receptor	Not significant	Neutral	None required.	Not significant	Neutral

Table 15.7 – Summary of Cumulative Effects

Receptor	Effect	Cumulative Developments	Significance of Cumulative Effect	
			Significance	Beneficial/ Adverse
Residential Property	Shadow flicker nuisance.	No relevant cumulative developments identified.	None	Neutral

15.11 References

DECC- Department of Energy and Climate Change (16 Mar 2011). *Update of UK Shadow Flicker Evidence Base*. Prepared by Parsons Brinckerhoff.

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