14 Shadow Flicker

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14 Shadow Flicker

14.1 Introduction

14.1.1 This chapter describes and assesses potential shadow flicker effects resulting from turbines of 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** and the summary of the approach to carrying out EIA in **Chapter 4**.

14.1.2 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).

14.1.3 Any receptors which may potentially be affected have been identified and the risk of shadow flicker calculated.

14.1.4 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 speed and 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;
- type and frequency of use of the affected space; and
- distance and direction of the wind turbine from the receptor.

14.1.5 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 less than 3 flashes per second and are therefore unlikely to cause epileptic seizures (Harding *et al.,* 2008: Smedley *et al*., 2010). Therefore, photo-sensitive epilepsy is scoped out and is not considered further in this assessment as there is no likelihood of any significant effect. This assessment will focus solely on the effects of shadow flicker related to local amenity.

14.1.6 Turbines can also cause flashes of reflected light, which can be visible for some distance. It is possible to ameliorate the flashing but it is not possible to eliminate it. Careful choice of blade colour and surface finish can help reduce the effect and all modern turbine manufacturers use light grey semi-matt finishes to reduce this effect.

14.1.7 A wind development of more than one turbine can also result in more than one turbine affecting a specific receptor at any time, potentially increasing the overall shadow flicker intensity or frequency. This potential effect has been taken into account within this assessment as well as the cumulative effect with other operational wind farms in the local area.

14.2 Legislation, Policy and Guidelines

Legislation

14.2.1 There is no applicable legislation setting out any relevant rules or requirements for the assessment or control of shadow flicker.

Planning Policy

14.2.2 This chapter and assessment has taken into consideration the policies contained in the Scottish Planning Policy (Scottish Government, 2014b).

Guidance

14.2.3 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. The DECC study also concluded that there have not been extensive issues with shadow flicker in the UK and, in circumstances where the potential for significant shadow flicker issues effects have been identified, these have been resolved using standard mitigation.

14.2.4 This assessment also takes into consideration the Scottish Government Online Renewables Planning Advice: Onshore Wind Turbines (Scottish Government, 2014a) and Shetland Islands Onshore Wind Energy Supplementary Guidance (Shetland Islands Council, 2018).

14.2.5 National and local guidance is consistent with the findings of the DECC study. In particular, Scottish Government Onshore Wind Turbines planning advice stipulates that, in most cases, where separation is provided between wind turbines and nearby dwellings (as a general rule, 10 rotor diameters), shadow flicker should not be a problem.

14.3 Consultation

14.3.1 Consultation on the methodology of the shadow flicker assessment was undertaken with Shetland Islands Council through the EIA Scoping process.

Table 14.1 - Consultation

Consultee	Comment	Applicant Response
Shetland Islands Council Environmental Health (Scoping Opinion)	The Service has however advised that it can only make comment on the proposed development once a detailed assessment of the main stressors, Noise and vibration, traffic, transportation and quarrying activities, shadow flicker and air quality, has been completed and submitted for review	This chapter contains an assessment of shadow flicker.
Shetland Islands Council Planning Service (Scoping Opinion)	The Planning Service is content with the approach intended to assess shadow flicker that is set down in the Scoping Report.	This chapter contains an assessment of shadow flicker as outlined in the Scoping Report.

14.4 Assessment Methodology and Significance Criteria

Consultation

14.4.1 Following a design freeze in December 2018 of the final 29 turbine locations, the Shetland Islands Council EHO was contacted to confirm the proposed methodology and requirement to undertake a shadow flicker assessment in respect to the Proposed Development (refer to Section 14.3).

Study Area

14.4.2 The shadow flicker assessment has been carried out for the proposed 29 turbines at the locations identified in Chapter 3. As no specific turbine model has been identified by the Applicant, this assessment is based on the worst-case scenario model (i.e. that with the largest proposed rotor area) that could be installed at the site. Dimensions of the chosen model used for the purposes of the shadow flicker assessment can be found in **Table 14.2**.

Table 14.2 - Details of the Turbine Model Used for the Shadow Flicker Assessment

Hub height	120 m
Rotor diameter	160 m
Swept Area	20,106.19 m²

14.4.3 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 and 130 degrees either side of north (relative to each turbine), as noted within Update of UK Shadow Flicker Evidence Base report (DECC, 2011) and agreed with Shetland Islands Council through the EIA Scoping process. In this assessment the study area extends to 1.6 km from each turbine. **Figure 14.1** shows the extent of this area and those receptors that could potentially be affected by shadow flicker.

Desk Study

14.4.4 The desk-based assessment identified seven residential receptors and no commercial receptors within the study area (shown in **Figure 14.1**). These are the only existing properties within the study area. **Table 14.3** summarises the locations of the receptors and the distance from each property/location to the nearest turbine.

Table 14.3 – Receptor Locations

Shadow Flicker ID	Easting	Northing	Approx. Distance to Nearest Turbine (Km)	Turbine
A	450621	1204904	1.60	T29
B	450588	1204841	1.55	T29
C	450693	1204623	1.32	T29
D	450683	1204590	1.29	T29
E	450723	1204520	1.21	T29
F	450915	1204530	1.21	T29
G	451025	1204540	1.23	T29

Assessment of Potential Effect Significance

14.4.5 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.

14.4.6 Within this assessment the sensitivity of the receptor is assumed to be high in all cases.

Assessment Modelling

14.4.7 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.

14.4.8 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 20 m resolution.

14.4.9 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.

14.4.10 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).

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

- in reality, many 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.

14.4.12 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

14.4.13 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 14.4.9.

Realistic Scenario

14.4.14 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. Other factors such as the potential for screening by vegetation or structures will also reduce or prevent flicker incidence in practice. 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.

14.4.15 In order to estimate the impact of cloud cover, information available from the Met Office (2019) was used to consider the likelihood of sunshine at different times of the year, and therefore allow calculations of the 'expected' values for shadow flicker occurrence. As part of the WindPro calculation it is possible to upload data from the nearest climatic station to the site. In the case of the Proposed Development this is the Lerwick Met Office, situated approximately 61 km to the south (summarised data from the Met office website can be found in **Appendix 14.1**, Table 1).

14.4.16 No vegetative screening was incorporated into the model.

14.4.17 The realistic scenario represents a long-term average as it is based on long-term historic metrological data. The variation between individual years can be significant and may lead to future observations differing from the predicted results.

14.4.18 A 16 degree sector wind rose was calculated for 7,446 hours of wind (assumes the Proposed Development is operational for 85 % of the year) based on representative UK wind data (refer to **Appendix 14.1**, 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

14.4.19 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 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 within 10 rotor diameters of the proposed turbines.

- The realistic scenario results represent a long-term average as they are based on long-term historic metrological data (87 years, from 1931 to 2017). The variation between individual years can be significant and may lead to future observations differing from the predicted results.

14.5 Baseline Conditions

14.5.1 As per the methodology set out in the Scoping Report and agreed by Shetland Islands Council in their Scoping Opinion no site visit was undertaken. Seven receptors have been identified within the study area with the potential to experience shadow flicker and they are all located to the north of the Proposed Development (around Gloup) (shown in **Figure 14.1**).

14.5.2 For the purposes of the assessment it is assumed that all properties face south, onto the Proposed Development and no local screening (vegetation and blinds/curtains) are considered.

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

14.6 Potential Effects

Construction

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

14.6.2 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

14.6.3 The modelling results presented below represent the theoretical worst-case scenario discussed in Section 14.4. The results of the modelling are shown in **Table 14.4**. The theoretical duration of shadow flicker calculated is indicated to be significant at all receptors (A to F) (greater than 30 hours per year). 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 14.4.

Table 14.4 – Worst-Case Scenario Shadow Flicker Occurrence at each Receptor (hrs/yr)

Shadow Flicker ID	Easting	Northing	Shadow Hours per Year	Max Shadow Hours per Day
A	450621	1204904	36:59	00:35
B	450588	1204841	39:35	00:38
C	450693	1204623	46:37	00:30
D	450683	1204590	48:10	00:31
E	450723	1204520	63:21	00:51
F	450915	1204530	48:36	00:33
G	451025	1204540	57:56	00:50

Realistic Modelling of Shadow Flicker Occurrence

14.6.4 The modelling results presented in **Table 14.5** represent the realistic scenario discussed in paragraph 14.4.15-19. 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. The results indicate that all the receptors are likely to experience shadow flicker substantially less than 8 hours per year (refer to **Figure 14.1** and Appendix 14.2) and therefore no significant effects are anticipated to the receptors from shadow flicker.

Table 14.5 - Realistic Scenario Shadow Flicker Occurrence for each Receptor (hrs/yr)

Shadow Flicker ID	Easting	Northing	Shadow Hours per Year	Max Shadow Hours per Day
A	450621	1204904	02:34	00:02
B	450588	1204841	02:46	00:03
C	450693	1204623	03:30	00:02
D	450683	1204590	03:39	00:02
E	450723	1204520	04:56	00:04
F	450915	1204530	03:49	00:02
G	451025	1204540	04:15	00:04

Decommissioning

14.6.5 No shadow flicker impact can occur post-decommissioning of the Proposed Development.

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

14.7 Mitigation

Construction

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

Operation

14.7.2 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 these locations it is possible that flicker will not be 'experienced' at all locations due to the time of day during which it may potentially occur.

14.7.3 Nevertheless, there are a number of forms of mitigation available to developers to mitigate the effects of shadow flicker further, with one of the most effective means being selective automatic turbine shutdown during certain times of year and during certain weather conditions. This level of mitigation is, however, not always required.

14.7.4 In order to ensure that potential shadow flicker effects do not exceed acceptable limits at any property, the Applicant proposes that prior to the erection of the first turbine a written scheme (known as the 'Wind Farm Shadow Flicker Protocol') shall be submitted to and approved in writing by Shetland Islands Council. This would set out mitigation measures to alleviate shadow flicker attributable to the Proposed Development as well as a protocol for addressing a complaint received from a receptor within the study area. 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 require to be implemented as appropriate. This matter could be secured by way of an appropriately worded condition of consent.

Decommissioning

14.7.5 No mitigation measures are required during the decommissioning phase of the Proposed Development.

14.8 Residual Effects

14.8.1 On the basis that potential shadow flicker effects can be mitigated through matters secured through the agreement of the Wind Farm Shadow Flicker Protocol, no significant residual effects are predicted during the operational, construction or decommissioning phases of the Proposed Development.

14.9 Cumulative Assessment

14.9.1 In order to assess the potential for cumulative impact from other wind developments in the surrounding area or from turbines within the Proposed Development, 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, 2013) from turbine locations, a 3 km study for cumulative developments considers any potential for study area overlap between the Proposed Development (1.6 km) and a cumulative development with a blade length up to 70 m.

14.9.2 There are six developments located within 3 km of the proposed turbine locations (refer to Figure 14.2), which are as follows:

- Tulac (Kingspan6KW), operational, and located approximately 2.75 km to the southwest of Turbine 20;
- Uphouse (Kingspan6KW), operational, and located approximately 1.75 km to the west of Turbine 20;
- SW Cullivoe Hall (Kingspan6KW), constructed, and located approximately 2.33 km to the southwest of Turbine 26;
- Niaroo (Kingspan6KW), consented, and located approximately 1.06 km to the south of Turbine 29;
- Dalsetter (3 turbines, Kingspan6KW), EIA screening request (2014), and located approximately 1.00 km from Turbine 20;
- Innhouse (Kingspan6KW), consented, and located approximately 2.06 km from Turbine 20; and
- Garth (5 turbines, Enercon E44), operational, and located approximately 1.92 km from Turbine 24.

14.9.3 Shadow flicker study areas were calculated for the above developments based on the dimensions and locations detailed within the planning applications (refer to Appendix 14.3). There are no receptors within the area of overlap between the study area of the Proposed Development and the above cumulative development, as such, there is no potential for cumulative shadow flicker effects.

14.10 Summary

14.10.1 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.

14.10.2 The study area within which properties could potentially be affected by shadow flicker covers a distance of 10 rotor diameters from each turbine and lies 130 degrees either side of north (relative to each turbine). In the case of the Proposed Development, this area extends to 1,600 m from each turbine.

14.10.3 No shadow flicker impact can occur during the construction or the decommissioning of the turbines.

14.10.4 A shadow flicker assessment was undertaken at the seven identified receptors within the study area with potential to experience flicker effects. Calculations have shown that the maximum occurrence of shadow flicker within the realistic scenario was at receptor E where the effect amounts to just under five hours per year, well within the accepted limits for realistic shadow flicker, of less than 8 hours per year.

14.10.5 It is important, however, to note that these results do not take into account existing screening features (structures and vegetation), dwelling orientation and local mitigation measures such as 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.

14.10.6 Proposed mitigation measures in this case relate to the implementation of a Shadow Flicker Protocol to be agreed with Shetland Islands Council which could include a programme of selective automatic shutdown of certain turbine(s) under certain conditions, if required.

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

14.10.8 Turbine components will be covered in industry standard non-reflective paint to reduce the occurrence of glinting.

14.10.9 **Table 14.6** below provides a summary of effects with regards to the shadow flicker effects resulting from the Proposed Development.

Table 14.6 – Summary Table

Description of Effect	Significance of Potential Effect		Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/ Adverse
Operation					
Shadow Flicker effects on 7 nearby residential receptors	No significant	N/A	Implementation of a Shadow Flicker Protocol to be agreed with SIC.	No significant	N/A

Table 14.7 – Summary of Cumulative Effects

Receptor	Effect	Cumulative Developments	Significance of Cumulative Effect	
			Significance	Beneficial/ Adverse
Receptors 1-7	Shadow flicker	Tulac, Uphouse, SW Cullivoe Hall, Niaroo, Dalsetter, Innhouse and Garth	No effect	N/A

14.11 References

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

Harding G, Harding P & Wilkins A (2008). *Wind turbines, Flicker and photosensitive epilepsy: Characterising the flashing that may precipitate seizures and optimising guidelines to prevent them*. Epilepsia. Vol. 19 (6): 1095-1098.

Nordrhein-Westfalen (2002). *Notes on the identification and Evaluation of the Optical Emissions of Wind Turbines*. States Committee for Pollution Control. Germany

NSE- The National Society for Epilepsy (2011). Available at: http://www.epilepsysociety.org.uk/AboutEpilepsy/Whatisepilepsy/Triggers/Photosensitiveepilepsy/windturbines.

Scottish Government (2014a). *Onshore Wind Turbines*. Available at: https://www.gov.scot/publications/onshore-wind-turbines-planning-advice/

Scottish Government (2014b). *Scottish Planning Policy*. Available at: https://www.gov.scot/publications/scottish-planning-policy/

Shetland Islands Council (2018). Lo*cal Development Plan Onshore Wind Energy Supplementary Guidance.* Available at: http://www.shetland.gov.uk/planning/documents/SIC_Onshore_wind_Energy_SG_Feb_2018_Adopted.pdf

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