14 Shadow Flicker

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14 Shadow Flicker

14.1 Executive Summary

14.1.1 Within this chapter, the potential shadow flicker effects from the wind turbine generators of the Proposed Development on neighbouring residential receptors are described and assessed. Legislation, policy and relevant guidelines are discussed alongside the consultation undertaken regarding shadow flicker effects.

14.1.2 Shadow flicker effects are modelled for eight identified receptors using WindPro software for both theoretical worst-case and realistic scenarios. The theoretical duration of shadow flicker calculated exceeded guideline thresholds for all receptors. However, the theoretical scenario represents many unrealistic conditions such as a clear sky for 365 days a year and permanently occupied receptors. The realistic duration of shadow flicker calculated exceeded guideline thresholds for three receptors.

14.1.3 Mitigation through the implementation of a 'Wind Farm Shadow Flicker Protocol', to be agreed through consultation with NAC, is deemed to be an effective measure to reduce the impact of shadow flicker effects. Following this mitigation, the residual effect of shadow flicker is deemed to be insignificant at all identified receptors.

14.1.4 Cumulative effects are non-existent due to the absence of existing, proposed or consented turbines within the study area other than the Proposed Development.

14.2 Introduction

14.2.1 This chapter describes and assesses potential shadow flicker effects from turbines of the Proposed Development on neighbouring residential and commercial receptors. This chapter (and its associated figure 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 the EIA in Chapter 4.

14.2.2 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).

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

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

- time of day and year;
- wind speed and direction;
- height of 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.

14.2.5 At between 3 and 30Hz (Hertz or Flasfes per second) the flickering effect caused by shadow flicker could 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 (1 in 2620) (NSE, 2011). 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.

14.2.6 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 considered within this assessment as well as the cumulative effect with other operational wind farms in the local area.

14.3 Legislation, Policy and Guidelines

Legislation

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

Planning Policy

14.3.2 The chapter and assessment have taken into consideration the policies set out in the North Ayrshire Council (NAC) Local Development Plan 2 (LDP2) (North Ayrshire Council, 2019); relevant aspects of the Scottish Planning Policy (SPP) (Scottish Government, 2014b); 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:

- LDP2 Policy 29;
- Paragraph 169 of SPP.

Guidance

14.3.3 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 ten 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 effects have been identified, these have been resolved using standard mitigation.

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

14.3.5 National and local guidance is consistent with the findings of the DECC study. In particular, Scottish Government Onshore Wind Turbines planning advice (Scottish Government, 2014a) stipulates that, in most cases, where separation is provided between wind turbines and nearby dwellings (as a general rule, ten rotor diameters), shadow flicker should not be a problem.

14.4 Consultation

14.4.1 Consultation on the methodology of the shadow flicker assessment was undertaken with North Ayrshire Council and the Loch Lomond & the Trossachs National Park Authority through the EIA Scoping process, as summarised in Table 14.1.

Table 14.1 – Consultation

Consultee	Comment	Applicant Response
North Ayrshire Council (Scoping Opinion)	The Council has requested an assessment of the potential impact from shading or shadow flicker on the nearest properties, other than to the south.	This chapter contains an assessment of shadow flicker.
Loch Lomond & the Trossachs National Park Authority (Scoping Opinion)	The National Park Authority has stated that it will support renewable energy developments adjacent to the Park where they do not result in significant adverse impacts by virtue of shadow flicker.	This chapter contains an assessment of shadow flicker to quantify the impact of shadow flicker.
North Ayrshire Council (Methodology consultation)	The Council has confirmed that the methodology as outlined in this chapter is acceptable, though highlight that should further receptors come to light, further studies may be requested.	The methodology as outlined in this chapter has been used.

14.5 Assessment Methodology and Significance Criteria

Consultation

14.5.1 North Ayrshire Council was contacted to confirm the proposed methodology and requirement to undertake a shadow flicker assessment in respect to the Proposed Development (refer to Section 14.4).

Study Area

14.5.2 The shadow flicker assessment has been carried out for the proposed ten turbines at the locations identified in Chapter 3. An indicative turbine model has been identified by the Applicant and dimensions of the chosen model used for the purposes of 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	91.4 m
Rotor diameter	117 m
Swept Area	10,751.32 m^2

14.5.3 The study area within which a receptor could potentially be affected by shadow flicker has been set at a distance of ten 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). In this assessment the study area therefore extends to 1,170 m from each of the proposed turbine locations. Figure 14.1 shows the extent of this area and those receptors that could potentially be affected by shadow flicker.

Assessment of Potential Effect Significance

14.5.4 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 the German quantitative guidance (Nordhein-Westfalen, 2002) which adopts two maximum limits to define 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.

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

Assessment Modelling

14.5.6 In assessing the effect of shadow flicker, the commercial software model WindPro 3.2.744 was used to calculate the expected number of hours of shadow flicker that could occur at each receptor. The model considers 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:

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

14.5.7 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 30 m resolution.

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

- all receptors have a 1 m x 1 m window at ground floor 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.

14.5.9 The effect of shadow flicker was not calculated when and 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).

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

- 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 will prevent any shadows from being cast onto the window of a receptor and therefore prevent any flickering effect.

14.5.11 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

14.5.12 The modelling results for the theoretical scenario are typically considered to be a worst-case estimation of the actual impacts experienced, and use the assumptions listed in paragraph 14.5.8.

Realistic Scenario

14.5.13 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 above. 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 consider any significant shielding of receptors by buildings and vegetation between the receptors and the turbines.

14.5.14 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 of 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 Largs Met Office Climate Station, situated approximately 6 km to the south of the Proposed Development (summarised data from the Met Office website can be found in Appendix 14.1, Table 1).

14.5.15 No vegetative screening was incorporated into the model.

14.5.16 The realistic scenario represents a long-term average as it is based on long-term historic meteorological data (1981-2010). The variation between individual years can be significant and may lead to future observations differing from the predicted results.

14.5.17 A 16-degree sector was calculated for 7,446 hours of wind (assuming that 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

14.5.18 All assumptions made by the WindPro 3.2.744 are outlined above. There are no limitations to the assessment although the following must be noted:

- Given the absence of UK guidance regarding 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 ten rotor diameters of the proposed turbines.
- The realistic scenario results represent a long-term average as they are based on long-term historic meteorological data (29 years, from 1981 to 2010). The variation between individual years can be significant and may lead to future observations differing from the predicted results.

14.6 Baseline Conditions

14.6.1 As per the methodology set out in the Scoping Report no site visit was undertaken. Eight receptors have been identified within the study area with the potential to experience shadow flicker. With respect to the Proposed Development, all receptors are located to the south-west (shown in Figure 14.1).

14.6.2 For the purpose of the assessment it is assumed that all properties face towards the Proposed Development and no local screening (vegetation and blinds or curtains) are considered.

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

14.7 Receptors Brought Forward for Assessment

14.7.1 The desk-based assessment identified eight residential receptors, inclusive of the holiday park caravans, as shown in Figure 14.1. The holiday park caravans were represented as three receptors, showing the worst-case scenario as the structures are in proximity. These are the only existing properties within the study area. Table 14.3 summarises the locations of the receptors and the distance from each receptor to the nearest turbine.

Table 14.3 – Receptor Locations

Receptor ID	Building Name	Easting	Northing	Approx. Distance to Nearest Turbine (km)	Nearest Turbine ID
SF1	Dykes Cottage	220584	665105	0.93	T3
SF2	Barr Farm	220560	665600	0.64	T3
SF3	Unknown Dougliehill Road	220330	665292	1.00	T3
SF4	Holiday Park 1	220260	665648	0.92	T3
SF5	Holiday Park 2	220201	665377	1.06	T3
SF6	Holiday Park 3	220151	665583	1.04	T3
SF7	Unknown Kaimes Grove	220201	665305	1.10	T3
SF8	Dykes Farm	220592	665036	0.99	T3

14.8 Standard Mitigation

14.8.1 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 North Ayrshire Council.

14.8.2 This would set out mitigation measures to alleviate shadow flicker attributable to the Proposed Development, for example shut-down periods during dates and meteorological conditions when shadow flicker is predicted, 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 Wind Farm Shadow Flicker Protocol and any mitigation measures that have been agreed through the protocol would be required to be implemented as appropriate. This matter could be secured by way of an appropriately worded condition of consent.

14.9 Potential Effects

Construction

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

14.9.2 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

14.9.3 The modelling results presented below represent the theoretical worst-case scenario discussed in Section 14.5. 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 (greater than 30 hours per year). It should be noted that this is the theoretical scenario and in reality the duration of shadow flicker at each location is not likely to be as indicated below for the reasons outlined in Section 14.5.

Table 14.4 – Theoretical Scenario Shadow Flicker Occurrence at each Receptor

Receptor ID	Easting	Northing	Shadow Hours per Year	Max Shadow Hours per Day
SF1	220584	665105	32:59	0:28
SF2	220560	665600	96:27	0:49
SF3	220330	665292	42:01	0:26
SF4	220260	665648	47:49	0:48
SF5	220201	665377	47:32	0:28
SF6	220151	665583	40:31	0:41
SF7	220201	665305	43:08	0:27
SF8	220592	665036	34:06	0:34

Realistic Modelling of Shadow Flicker Occurrence

14.9.4 The modelling results presented in Table 14.5, Figure 14.1 and Appendix 14.2 represent the realistic scenario discussed in paragraph 14.5.13 - 14.5.17. The inclusion of indicative wind data and average sunshine hours into the shadow flicker calculations has greatly reduced he potential of shadow flicker occurrence at all of the receptors.

14.9.5 The realistic duration of shadow flicker calculated is indicated to be at significant levels at receptors SF2, SF4 and SF5 (Barr Farm, Holiday Park 1 and Holiday Park 2), with a duration greater than 8 hours per year.

Table 14.5 – Realistic Scenario Shadow Flicker Occurrence for each Receptor

Receptor ID	Easting	Northing	Shadow Hours per Year	Max Shadow Hours per day
SF1	220584	665105	6:08	0:06

Receptor ID	Easting	Northing	Shadow Hours per Year	Max Shadow Hours per day
SF2	220560	665600	16:58	0:11
SF3	220330	665292	7:42	0:05
SF4	220260	665648	8:07	0:08
SF5	220201	665377	8:38	0:06
SF6	220151	665583	7:04	0:09
SF7	220201	665305	7:53	0:05
SF8	220592	665036	6:20	0:07

Decommissioning

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

14.9.7 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.

14.10 Additional Mitigation

Construction

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

Operation

14.10.2 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. Furthermore, the affected receptors may not be occupied during times of shadow flicker. 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.

14.10.3 Nevertheless, the Shadow Flicker Protocol, will ensure that shadow flicker impacts will not occur.

Decommissioning

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

14.11 Residual Effects

14.11.1 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 construction, operational or decommissioning phases of the Proposed Development.

14.12 Cumulative Assessment

14.12.1 In order to assess the potential for cumulative impact from other wind developments in the surrounding area or from turbines within the Proposed Development, the closest wind farm developments were identified. The closest turbines are two turbines at Kellybank, measuring up to 35 m tip, with a rotor diameter of 24 m. This gives a shadow flicker study area 240 m around the turbines. There is no overlap between the study areas of the Proposed Development and of the Kellybank turbines, and therefore no cumulative effects will arise between the Proposed Development and Kellybank (refer to Figure 14.2.)

14.13 Summary

14.13.1 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 moving rotors of the turbine passing in front of the sun, 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 weather conditions.

14.13.2 The study area within which properties could potentially be affected by shadow flicker covers a distance of ten 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 1,170 m from each turbine.

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

14.13.4 A shadow flicker assessment was undertaken for the eight identified receptors within the study area which demonstrated the potential to experience shadow flicker effects. WindPro modelling has shown that receptors SF2, SF4 and SF5 experience shadow flicker for a duration exceeding the significance criteria of 8 hours per year. Therefore, the effect of shadow flicker is significant at these receptors.

14.13.5 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 occupied 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.

14.13.6 Proposed mitigation measures in this case relate to the implementation of a Wind Farm Shadow Flicker Protocol to be agreed with North Ayrshire Council, which could include a programme of selective automatic shutdown of certain turbine(s) under certain conditions.

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

14.13.8 There is no overlap between the shadow flicker study areas of the Proposed Development and the closest turbines at Kellybank and therefore no cumulative shadow flicker effects are anticipated.

14.13.9 Table 14.6 and Table 14.7 below provides a summary of effects and cumulative effects, respectively, with regard to the shadow flicker effects resulting from the Proposed Development.

Table 14.6 – 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 receptors	Not significant	N/A	None required.	Not significant	N/A
Operation					
Shadow flicker nuisance on residential receptor	Significant	Adverse	Implementation of a Wind Farm Shadow Flicker Protocol to be agreed with North Ayrshire Council	Not significant	N/A
Decommissioning					
Shadow flicker nuisance on residential receptor	Not significant	N/A	None required.	Not significant	N/A

Table 14.7 – Summary of Cumulative Effects

Receptor	Effect	Cumulative Developments	Significance of Cumulative Effect	
			Significance	Beneficial/ Adverse
Receptors SF1-SF8	Shadow Flicker	Kellybank	No effect	N/A

14.14 References

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