16 Shadow Flicker

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16 Shadow Flicker

16.1 Executive Summary

16.1.1 This chapter presents an assessment of the potential shadow flicker effects from the Proposed Development on residual receptors.

16.1.2 Within the study area for shadow flicker effects (within 130 degrees either side of north from each turbine and out to 10 rotor diameters), there are two identified receptors with potential to experience shadow flicker effects.

16.1.3 Calculations have shown that the realistic scenario modelling of shadow flicker at both of these receptors is found to be within the accepted guidelines and therefore not significant.

16.1.4 A cumulative assessment shows there is no overlap with Dersalloch and Craiginmoddie wind farm study areas. Whereas there is an area of overlap between the Proposed Development Study Area and the Carrick wind farm study area. The two shadow flicker receptors do not fall within the area of overlap and therefore there will be no cumulative shadow flicker impact.

16.1.5 Shadow flicker is expected to be not significant for all receptors during the operational phase of the Proposed Development.

16.2 Introduction

16.2.1 This chapter describes and assess potential shadow flicker effects resulting from the Proposed Development on neighbouring residential properties. 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.

16.2.2 The Scottish Government Onshore wind turbines: planning advice (2014) states Shadow flicker occurs when, *"Under 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".*

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

16.2.4 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 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.

16.2.5 The flickering effect caused by shadow flicker also has the potential to induce epileptic seizures in people 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 only to local amenity.

16.2.6 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.

16.2.7 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.

16.2.8 This chapter is supported by the following figures and technical appendices:

- Figure 16.1 Shadow Flicker Study Area
- Figure 16.2 Shadow Flicker Results (Realistic Scenario)
- Figure 16.3 Cumulative Shadow Flicker Study Area
- Appendix 16.1 Shadow Flicker Meteorological Data
- Appendix 16.2 Potential Shadow Periods

16.3 Legislation, Policy and Guidelines

Legislation

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

Policy

16.3.2 This assessment has taken into consideration the policies contained in the Scottish Planning Policy (Scottish Government, 2014b). Chapter 5 of the EIA Report sets out the planning policy framework that is relevant to the EIA.

Guidance

16.3.3 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 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.

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

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

16.4 Consultation

16.4.1 The intent to undertake a shadow flicker assessment for this project was outlined to Scottish Ministers within the Scoping Report in December 2020 (refer to Appendix 4.1). The Energy Consents

Unit's Scoping Opinion received March 2021 (refer to Appendix 4.2) made no reference to shadow flicker specifically.

16.4.2 The relevant stakeholders were consulted regarding the potential effects of the Proposed Development as part of the scoping process. A summary of consultation is provided in Table 16.4.

Table 16.1 - Consultation Responses

Consultee	Summary of Consultation	Applicant Response
South Ayrshire Council (SAC)	State that a suitably qualified person should undertake the investigation into the incidence of shadow flicker at the compliant location and where shadow flicker is confirmed to result in loss of amenity, then mitigation measures require to be implemented, to the satisfaction of the Local Authority.	The shadow flicker assessment has been completed to the required standard and in accordance with Scottish Government Advice and good practice.
Crosshill, Straiton and Kirkmichael Community Council	Request the full extent of shadow flicker on all properties in the upper Girvan valley should be assessed. In previous local wind farm responses it has been shown that shadow flicker is a real issue for residents within a certain proximity to the site area. There is considerable local expertise in this field and I would recommend the proposers contact Save Straiton for Scotland to access the most up to date evidence on this issue.	The shadow flicker study area for assessment will be ten rotor diameters from each turbine, in accordance with Scottish Government advice. No significant impacts from shadow flicker would be anticipated to occur outwith this area. Potential impacts from shadow flicker on residents within the study area have been minimised by design where possible, and the shadow flicker assessment has been undertaken in line with Scottish Government advice and relevant good practice. The Applicant has actively engaged with local residents and interested parties via the ongoing stakeholder engagement process.
Dailly Community Council	State that for potential shadow flicker a 1m x 1m ground floor window at each identified sensitive receptor location is not appropriate.	The shadow flicker assessment has been undertaken in accordance with good practice. The assumption of a 1m x 1m ground floor window facing directly at the proposed wind farm for all receptors is a worst-case assumption.

16.5 Assessment Methodology and Significance Criteria

Study Area

16.5.1 The Study Area is shown in Figure 16.1 and the shadow flicker assessment has been carried out for the proposed nine turbines at the locations identified in Chapter 3. The final model has not been selected and this will be based on the most advanced technology available at the time. Therefore, as a precaution 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 16.2.

Table 16.2 - Details of the Turbine Model Used for the Shadow Flicker Assessment

	Turbines 1, 2, 3, 7, 8 and 9	Turbines 4, 5 and 6
Hub Height	122.5 m	102.5 m
Rotor Diameter	155 m	

16.5.2 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 the DECC report (DECC, 2011). In this assessment, the Study Area extends to 1.55 km from each turbine. Figure 16.1 shows the extent of this area and those receptors that could potentially be affected by shadow flicker.

Desk Study

16.5.3 The desk study assessment identified two residential receptors, Linfairn Farm and Knockskae, within the Study Area (shown in Figure 16.1). Table 16.2 summarises the locations of the receptor and the distance from the property to the nearest turbine.

Table 16.3 - Receptor Locations

Receptor ID	X-coordinate	Y-coordinate	Distance (km)	Closest Turbine
Linfairn Farm	238134	601211	1.3	T4
Knockskae	237281	601390	1.3	T2 and T4

16.6 Assessment of Potential Effect Significance

16.6.1 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 considering meteorological parameters limited to 8 hours per year.

16.6.2 Within this assessment the sensitivity of the receptors is assumed to be high in all cases as all receptors are residential dwellings.

16.7 Assessment Modelling

16.7.1 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.

16.7.2 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 5 m resolution.

16.7.3 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 is 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 is present.

16.7.4 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 (Nordhein-Westfalen, 2002).

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

- the receptor 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 the receptor;
- it is unlikely that there will be clear skies 365 days a year;
- the receptor may not be occupied at the time that the shadow flicker impact is experienced; and
- screening, such as vegetation including the surrounding forestry, 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.

16.7.6 In addition, the distance between the turbine and a window has an impact on the intensity of any shadow flicker that is experienced. The study area has been set at 10 rotor diameters as the effects of shadow flicker are shown to be greatly reduced outside this distance.

16.7.7 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.

16.8 Theoretical Scenario

16.8.1 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 above.

16.9 Realistic Scenario

16.9.1 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 receptor and the turbines.

16.9.2 In order to estimate the impact of cloud cover, information available from the Met Office (2020) 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 Proposed Development. In the case of the Proposed Development this is the Prestwick Gannet station located approximately 28 km to the north.

16.9.3 Given the largely dynamic status of the plantation forestry over the lifetime of the Proposed Development and between seasons, no vegetative screening was incorporated into the model.

16.9.4 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.

16.9.5 A 16-degree sector wind rose was calculated for 7,446 hours of wind (assuming the Proposed Development is operational for 85 % of the year) based on Open Source World Meteorological Organisation Synoptic data. The Open Source data was from Prestwick Gannet over the period between 2014 and 2020., as no meteorological mast data was available at the site for a long-term period. 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 slighting higher results; as there is a degree of correlation between bright and sunny weather conditions and low wind speeds.

16.10 Limitations to Assessment

16.10.1 All assumptions made by the WindPro 3.2 model are noted above.

16.10.2 Given the absence of UK guidance on shadow flicker, the assessment has adopted the generally accepted industry practised limit of 30 hours per year or 30 minutes per day (worst case scenario) for permanent dwellings within 10 rotor diameters of the proposed turbines.

16.10.3 The realistic scenario results represent an average as they are based on historic metrological data (7 years, from 2014 to 2020 for wind and 28 years, from 1981 to 2010 for sunshine). The variation between individual years can be significant and may lead to future observations differing from the predicted results.

16.11 Baseline Conditions

16.11.1 Two receptors have been identified within the Study Area with the potential to experience shadow flicker (refer to Figure 16.1 and Table 16.2) and are located from the north and north-east of the Proposed Development turbine locations.

16.11.2 There are small areas of forestry located between the receptor and the proposed turbine locations which may act as visual screening. However, for the purpose of the assessment it is assumed that the properties face the Proposed Development and no local screening (vegetation and blinds/curtains) are considered.

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

16.12 Potential Effects

Construction

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

16.12.2 Given that any occurrence of shadow flicker during the short commissioning period would replicate itself during operation of the Proposed Development, albeit more frequently, 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

16.12.3 The modelling results presented below represent the theoretical worst-case scenario discussed in Section 16.5 above. The results of the modelling are shown in Table 16.4. The theoretical duration of shadow flicker calculated is indicated to be more than 30 hours per year and more than 30 minutes per day on the worst affected day at receptor A, and less than 30 hours per year and less than 30 minutes per day on the worst affected day at receptor B. The potential shadow flicker effects are therefore assessed as **significant** at receptor A. Whereas, effects are **not significant** at receptor B for the astronomical worst-case scenario. However, in reality, the duration of shadow flicker at each location is likely to be considerably less than that indicated above for the reasons outlined in Sections 16.7.5 and 16.7.6.

Table 16.4 – Worst-Case Scenario Shadow Flicker Occurrence at each Receptor

Shadow Flicker ID	Address	Shadow Hours per Year	Max Shadow Hours per Day	Significance
A	Linfairn Farm	51:02	1:01	**Significant**
B	Knockskae	13:50	0:23	**Not Significant**

16.12.4 Graphs 16.2.1 to 16.2.2 within Technical Appendix 16.2 summarise the occurrence of shadow flicker at the receptors and illustrate the times of year and times of day when shadow flicker could theoretically occur. The graph shows that turbine four would contribute to the shadow flicker experienced at both receptors for the period of November to January. Turbine two would contribute to the shadow flicker experienced at receptor A for the period of November to January. Turbine three would contribute to the shadow flicker experienced at receptor A for the period of December to January.

Realistic Modelling of Shadow Flicker Occurrence

16.12.5 The modelling results presented in Table 16.5 represent the realistic scenario. 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 both of the receptors (refer to Figure 16.2).

Table 16.5 - Realistic Scenario Shadow Flicker Occurrence for each Receptor

Shadow Flicker ID	Address	Shadow Hours per Year	Max Shadow Hours per Day	Significance
A	Linfairn Farm	5:07	00:06	**Not Significant**
B	Knockskae	1:08	00:02	**Not Significant**

16.12.6 The results fall within the recommended limit of eight hours per year considering meteorological parameters. Therefore, the realistic duration of shadow flicker calculated is indicated to be **not significant** at both receptors, with a duration less than 8 hours per year.

16.12.7 The model still does not take into consideration any local screening from vegetation, blinds or curtains, or true window orientation relative to the turbines, which in reality will reduce further the potential time receptors are likely to experience shadow flicker over the course of the year.

Decommissioning

16.12.8 Given that any occurrence of shadow flicker during the short decommissioning period would replicate that which would occur 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.

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

16.13 Cumulative Assessment

16.13.1 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 turbine locations were reviewed. Shadow flicker impacts are considered to extend to 10 rotor diameters from turbine locations, therefore a 3 km search area for cumulative developments considers any potential for overlap between the Proposed Development Study Area (1.55 km) and a cumulative development with at least an equivalent rotor diameter.

16.13.2 There are three developments located within 3 km of the Proposed Development which have a shadow flicker study area that overlaps with, or is within very close proximity to, the Proposed Development shadow flicker Study Area, shown on Figure 16.3. Shadow flicker study areas were calculated for Dersalloch wind farm (operational), Craiginmoddie wind farm (in planning) and Carrick wind farm (Scoping) based on the dimensions and locations detailed within the planning applications and Scoping Report.

16.13.3 However, as the shadow flicker study area of Dersalloch, Craiginmoddie and Carrick wind farms does not overlap with either of the identified receptors, there is no requirement to undertake a cumulative shadow flicker assessment with this Proposed Development.

16.13.4 The cumulative shadow flicker residual effect across the Study Area is therefore expected to be **not significant.**

16.14 Mitigation

Construction

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

Operation

16.14.2 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 and internal screening from blinds, curtains or furniture that are not included in the model. Additionally, while shadow flicker may potentially occur at this location it is possible that flicker will not be 'experienced' at the location due to the time of day during which it may potentially occur. As potential effects are not significant no mitigation measures are proposed during operation.

Decommissioning

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

16.15 Residual Effects

16.15.1 No significant residual effects are predicted during the operational or construction phases of the proposed Development

16.16 Summary

16.16.1 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.

16.16.2 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 1.55 km from each turbine.

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

16.16.4 A shadow flicker assessment was undertaken at the two 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 at receptor A amounts to approximately 5:07 hours per year or a maximum of 6.1 minutes per day. Receptor B amounts to approximately 1:08 hours per year or a maximum of 1.8 minutes per day. Both well within the accepted limits for realistic shadow flicker of less than 8 hours per year.

16.16.5 A cumulative assessment shows there is no overlap with Dersalloch and Craiginmoddie wind farm study areas. Whereas there is an area of overlap between the Proposed Development Study Area and the Carrick wind farm study area. The two shadow flicker receptors do not fall within the area of overlap and therefore there will be no cumulative shadow flicker impact. 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.

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

Table 16.6 Summary Table

Description of Effect	Significance of Potential Effect		Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/ Adverse
During Construction & Decommissioning					
No shadow flicker effects during construction or decommissioning.					
During Operation					
Shadow flicker nuisance on residential receptors A and B	Not Significant	Adverse	None	Not Significant	Adverse
Cumulative Effects					
Shadow Flicker effects	Not Significant	Adverse	None	Not Significant	Adverse

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