

15 Shadow Flicker

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15 Shadow Flicker

15.1 Executive Summary

- 15.1.1 This chapter presents an assessment of the potential shadow flicker effects from the Proposed Development on residential receptors. 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 three identified receptors with potential to experience flicker effects. Calculations have shown that the maximum occurrence of shadow flicker at all three receptors is anticipated to be well within the accepted limits for shadow flicker, of either 30 minutes per day or less than 30 hours per year.
- 15.1.2 The Applicant proposes the submission of a Shadow Flicker Protocol to be agreed with SLC prior to construction. The residual effect of shadow flicker is expected to be of no significance for all receptors during the operational phase of the Proposed Development.

15.2 Introduction

- 15.2.1 This chapter describes and assesses potential 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.
- 15.2.2 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, 2014, Onshore Wind Turbines).
- 15.2.3 Any receptors which may potentially be affected have been identified and the risk of shadow flicker calculated.
- 15.2.4 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.
- 15.2.5 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 in less than 3 flashes per second and are therefore unlikely to cause epileptic seizures (Harding *et al.*, 2008:

Smedley *et al.*, 2010). Therefore, there are not considered to be any health effects associated with the Proposed Development and this assessment will address the effects of shadow flicker related to local amenity.

15.2.6 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.

15.2.7 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.

15.3 Legislation, Policy and Guidance

Legislation

15.3.1 There is no applicable legislation to this assessment.

Policy

15.3.2 Chapter 5 of the ES sets out the planning policy framework that is relevant to the EIA. The policies set out include those from the adopted South Lanarkshire Local Plan (SLC, 29 June 2015), those relevant aspects of Scottish Planning Policy (SPP), National Planning Framework 3 (NPF3), Planning Advice Notes and other relevant guidance. Of relevance to the shadow flicker assessment presented within this chapter, regard has been had to the following policies:

- Local Plan Policy 19: Renewable Energy; and
- Paragraph 169 of SPP.

15.3.3 SLC Supplementary Planning Guidance on Renewable Energy (2015) sets out policies and other advice in support of wind developments in South Lanarkshire. Paragraph 6.76 states that the SLC would expect a shadow flicker assessment to be undertaken for residential development within 10 rotor diameters of the proposed turbine locations.

Guidance

15.3.4 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.

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

15.4 Consultation

15.4.1 The intent to undertake a shadow flicker assessment for this project was outlined to the Scottish Government in November 2018 as part of a request for a scoping opinion. The Scottish Government's Scoping Opinion (refer to Appendix 4.1) does not refer to shadow flicker specifically but does state that, "*Scottish Ministers are satisfied with the scope of the EIA set out at Section 1.4 of the scoping report*".

- 15.4.2 The SLC Environmental Health Officer (EHO) was re-consulted in February 2019 to confirm the proposed shadow flicker assessment methodology (refer to Appendix 4.3). The EHO responded, email dated 12 February 2019, to confirm the proposed approach and methodology and noted that a shadow flicker protocol would need to be submitted to SLC, and approved, prior to the operation of the Proposed Development.
- 15.4.3 Given that there are existing residential properties identified within the study area (refer to Section 15.5 below) that could potentially be affected by shadow flicker from the Proposed Development, a shadow flicker assessment was carried out as part of the EIA process to assess the likely impacts.

15.5 Assessment Methodology and Significance Criteria

Study Area

- 15.5.1 The shadow flicker assessment has been carried out for the proposed 13 turbines at the locations identified in Chapter 3. As no specific turbine model has been identified by the Applicant, this assessment has chosen the worst-case scenario model from a short list of candidate turbines 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 15.1.

Table 15.1 - Details of the Turbine Model Used for the Shadow Flicker Assessment (Siemens 6MW)

Hub height	122.5 m
Rotor diameter	155 m
Swept Area	18,869 m ²

- 15.5.2 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 Update of UK Shadow Flicker Evidence Base report (DECC, 2011) and agreed with the EHO (Appendix 4.3). In this assessment the study area extends to 1.55 km from each turbine. Figure 15.1 shows the extent of this area and those receptors that could potentially be affected by shadow flicker.

Desk Study

- 15.5.3 The desk-based assessment, using OS address data and mapping, identified two residential receptors within the study area. These are the only existing properties within the study area. The consented Hargreaves Land Limited housing development (planning permission in principle), on land at Gunsgreen to the south-west of Coalburn, has also been considered within the shadow flicker assessment. Receptor 3 within Table 15.2 provides a representative location on the edge of the development for the purposes of the model.
- 15.5.4 Table 15.2 summarises the locations of the receptors and the distance from each property/location to the nearest turbine.

Table 15.2 – Receptor Locations

Shadow Flicker ID	Address	Easting	Northing	Elevation (m)	Approx. Distance to Nearest Turbine (km)	Turbine
1	Station House	282095	630960	271.0	1.38	T11
2	Blackwood Cottage	282134	631007	269.9	1.39	T11
3	Gunsgreen	281010	633962	269.0	1.30	T12

Assessment of Potential Effect Significance

- 15.5.5 There is no UK statutory guidance relating to the acceptable levels of shadow flicker. The DECC 2011 report identifies best practice guidelines across Europe and this assessment will adopt the generally accepted quantitative guidance which adopts the maximum limits of 30 hours per year or 30 minutes on the worst affect day.
- 15.5.6 Within this assessment the sensitivity of the receptors is assumed to be high in all cases.

Assessment Modelling

- 15.5.7 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.
- 15.5.8 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.
- 15.5.9 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.

- 15.5.10 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 (Nordhein-Westfalen, 2002).
- 15.5.11 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;
 - it is unlikely that there will be clear skies 365 days a year;
 - receptors may not be occupied at the time that the shadow flicker impact is experienced; and
 - screening, such as vegetation or curtains between the window and the turbine is not accounted for within the DTM and model and will prevent any shadows from being cast onto the window and therefore prevent any flickering effect.
- 15.5.12 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.
- 15.5.13 The assessment carried out is limited to the effects of shadows within buildings. Moving shadows will also be apparent out of doors; however, these do not result in flicker in the same manner or to the same extent, as the light entering windows. Therefore, shadow flicker effects outdoors have been scoped out of further assessment.

Theoretical Scenario

- 15.5.14 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 15.5.9.

Realistic Scenario

- 15.5.15 In actuality, for much of the year weather conditions will be such that shadows will not be cast or will be weak and would therefore not give rise to shadow flicker effects. WindPro calculations most likely overestimate the duration of effects as outlined 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 take into account any significant shielding of receptors by buildings and vegetation between the receptors and the turbines.
- 15.5.16 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 Eskdalemuir Met Office, situated approximately 50 km to the south-east (summarised data from the Met office website can be found in Appendix 15.1, Table A15.1).
- 15.5.17 Given the largely dynamic status of woodland over the life time of the Proposed Development and between seasons, no vegetative screening was incorporated into the model.
- 15.5.18 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.

- 15.5.19 A single 16 degree sector was calculated for 7,446 hours of wind (assumes the Proposed Development is operational for 85% of the year) based on meteorological mast data from the neighbouring Douglas West Wind Farm site (refer to Appendix 15.1, Table A15.2). The WindPro model also employs a slightly simplistic assumption that sunshine probability and turbine operational probability are independent parameters. The model is therefore expected to yield conservative results; as bright and sunny weather conditions and low wind speeds generally tend to show some degree of correlation.

Limitations to Assessment

- 15.5.20 All assumptions made by the WindPro 3.2 are outlined within Section 15.5.
- 15.5.21 Given the absence of UK guidance towards shadow flicker, the assessment has adopted the generally accepted industry practised 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.
- 15.5.22 The realistic scenario results represent a long-term average as they are based on long-term historic metrological data (90 years, from 1929 to 2018). The variation between individual years can be significant and may lead to future observations differing from the predicted results.

15.6 Baseline Conditions

- 15.6.1 As per the methodology set out in the Scoping Report and agreed with the EHO no site visit was undertaken. Three receptors have been identified within the study area with the potential to experience shadow flicker and they are located to the north (receptor 3) and south-east (receptors 1 and 2) of the Proposed Development.
- 15.6.2 There are small areas of tall vegetation between the Proposed Development and receptor 1 which act as a visual screen. Receptors 1 and 2 are also predominantly orientated in a north-east / south-west direction. No information on the layout and orientation of the proposed houses within the consented Gunsgreen development is available.
- 15.6.3 For the purposes of the assessment it is assumed that all properties face onto the Proposed Development and no local screening (vegetation and blinds/curtains) are considered.
- 15.6.4 Within this assessment the sensitivity of the receptors is assumed to be high in all cases.

15.7 Assessment of Potential Effects

Construction

- 15.7.1 No shadow flicker will occur during construction of the Proposed Development.
- 15.7.2 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

- 15.7.3 The modelling results presented below represent the theoretical worst-case scenario discussed in Section 15.5. The results of the modelling are shown in Table 15.3. The theoretical duration of shadow flicker calculated is indicated to **not be significant** at all receptors (1, 2 and 3) and show that all the

receptors are likely to experience shadow flicker significantly less than 30 hours per year or less than 30 mins per day.

Table 15.3 – Worst-Case Scenario Shadow Flicker Occurrence at each Receptor (hrs/yr)

Shadow Flicker ID	Address	Shadow Hours per Year	Max Shadow Hours per Day
1	Station House	22:21	00:22
2	Blackwood Cottage	19:50	00:27
3	Gunsgreen	18:02	00:27

15.7.4 Graphs A15.1 to A15.3 within Appendix 15.2 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. 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 15.5 and 15.6.

Realistic Modelling of Shadow Flicker Occurrence

15.7.5 The modelling results presented in Table 15.4 represent the realistic scenario discussed in paragraph 15.5.15. 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 (refer to Figure 15.1).

Table 15.4 - Realistic Scenario Shadow Flicker Occurrence for each Receptor (hrs/yr)

Shadow Flicker ID	Address	Shadow Hours per Year	Shadow Hours per Day
1	Station House	3:05	00:03
2	Blackwood Cottage	02:39	00:04
3	Gunsgreen	01:53	00:03

15.7.6 The results from the model show that all receptors fall well below the recommended limit of 30 hours per year or 30 minutes per day (on the worst affected day).

15.7.7 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.

15.7.8 Graph A15.3 within Appendix 15.2 shows that the expected periods of shadow flicker at the receptor 3 is predicted from the end of November through to mid-January, winter months, when there is typically less sunshine due to cloud cover.

15.7.9 The results for the realistic scenario show a significant reduction in the potential shadow flicker effects on surrounding receptor locations. The reduction has shown that for all receptors the effect is expected to be of **no significance**.

Decommissioning

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

15.7.11 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.

15.8 Cumulative Assessment

15.8.1 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 site were reviewed. 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 (1,550 m) and a cumulative development with a blade length up to 76 m.

15.8.2 Shadow flicker study areas were calculated for the above developments based on the dimensions and locations detailed within the planning applications. There are two developments located within 3 km of the proposed turbine locations, which have a shadow flicker study area that overlaps with the Proposed Development study area and the 3 identified receptors. These are as follows:

- Dalquhandy Wind Farm, consented (and application), and located directly to the north-west of the Proposed Development site; and
- Douglas West Wind Farm, consented, and located directly to the east and north of the Proposed Development site.

15.8.3 Receptors 1 and 2 lie within the within the area of overlap between the study area of the Proposed Development and Douglas West Wind Farm. Receptor 3 (Gunsgreen) lies within the area of overlap between the study area of the Proposed Development, Dalquhandy Wind Farm and Douglas West Wind Farm. As such, a cumulative shadow flicker assessment was undertaken. Table 15.5 details the expected total realistic hours of shadow flicker per year on all receptors as a result of the three development being operational.

Table 15.5 – Cumulative Shadow Hours (Realistic Scenario) at Receptors

Shadow Flicker ID	Address	Shadow Hours per Year
1	Station House	03:05
2	Blackwood Cottage	02:39
3	Gunsgreen	10:59

15.8.4 The total number of shadow hours per year at all three of the receptor locations remains within the recommended limit of 30 hours per year. This total figure is likely to be conservative for the reasons noted in paragraph 15.7.7 and given the final orientation and any landscape planting proposals for the proposed houses in the Gunsgreen area is unknown.

15.8.5 In conclusion, the predicted cumulative shadow flicker residual effect across the Proposed Development study area is **not significant**.

15.9 Mitigation

Construction

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

Operation

- 15.9.2 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.
- 15.9.3 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.
- 15.9.4 While no significant effects are anticipated as a result of the operation of the Proposed Development and therefore no requirement within the EIA Regulations (2017) to outline mitigation, 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 SLC. 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

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

15.10 Residual Effects

- 14.1.1 On the basis that any 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.

15.11 Summary

- 15.11.1 This assessment considers whether the effect known as 'shadow flicker' is likely to be caused by the Proposed Development and assesses the potential for impact on sensitive receptors. Shadow flicker is the effect of the sun passing behind the moving rotors of the turbines casting a flickering shadow through the windows and doors of neighbouring properties. This occurs in certain combinations of geographical position, time of day, time of year and specific weather conditions.
- 15.11.2 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 1,550 m from each turbine.
- 15.11.3 No shadow flicker impact can occur during the construction or the decommissioning of the turbines.
- 15.11.4 A shadow flicker assessment was undertaken at the three identified receptors within the study area with potential to experience flicker effects. Realistic scenario calculations have shown that the

maximum occurrence of shadow flicker was at receptor 1 (Station House) where the effect amounts to approximately 3 hours per year, well within the accepted limits for shadow flicker, of either 30 minutes per day or less than 30 hours per year.

- 15.11.5 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.
- 15.11.6 Proposed mitigation measures in this case relate to the imposition of a Shadow Flicker Protocol to be agreed with SLC which could include a programme of selective automatic shutdown of certain turbine(s) under certain conditions, if required.
- 15.11.7 The residual effect of shadow flicker is, therefore, expected to be of **no significance** for all receptors during the operational phase of the Proposed Development.
- 15.11.8 Turbine components will be covered in industry standard non-reflective paint to reduce the occurrence of glinting.
- 15.11.9 Table 15.6 below provides a summary of effects with regards to the shadow flicker effects resulting from the Proposed Development.

Table 15.6 – Summary Table

Description of Effect	Significance of Potential Effect		Mitigation Measure	Significance of Residual Effect	
	Significance	Beneficial/ Adverse		Significance	Beneficial/ Adverse
Shadow Flicker effects on 3 nearby residential receptors	Negligible	Adverse	Installation of a Shadow Flicker Protocol to be agreed with South Lanarkshire Council.	Negligible	Adverse

15.12 References

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